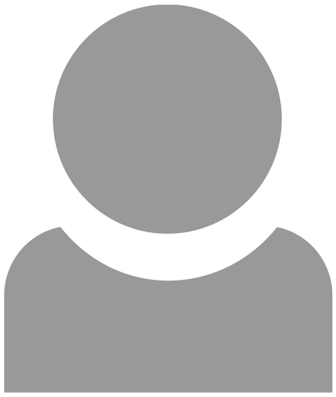

Dr. Gerardo Rodríguez Hernández

1 [redacted]

2 [redacted]

Doctor en Ciencia de Materiales por la Universidad de Oxford, Reino Unido, Maestro en Inteligencia Artificial Aplicada por la Universidad de Exeter, en el Reino Unido, Ingeniero en Comunicaciones y Electrónica por la Universidad de Guadalajara. 7 años de experiencia en el desarrollo de software, empezando como programador y posteriormente como Líder técnico y Liaison, para proyectos internaciones con Hamilton Sundstrand en Rockford Illinois EUA. He participado en múltiples conferencias internacionales de divulgación científica en Europa y Estados Unidos, así como eventos de divulgación científica en México. Poseo un interés por el uso de la tecnología para el desarrollo y solución de problemas sociales. Cofundador de la Iniciativa Materiom. He realizado proyectos de desarrollo sustentable para el Royal College of Arts en el Reino Unido y actualmente participante en el concurso CAPSTONE para el desarrollo de proyectos con impacto ambiental como representante regional con el proyecto EcoCity, una plataforma para el desarrollo de ciudades inteligentes.

Perfil de puesto **Dirección de Inteligencia de Datos**	**Perfil profesional y experiencia**
Escolaridad: Doctorado Nivel de estudios mínimo requerido, maestría.	Formación académica: • Licenciatura en Ingeniería en Comunicaciones y Electrónica, Universidad de Guadalajara, CUCEI, 2005. • Maestría en Inteligencia Artificial Aplicada, Universidad de Exeter, Exeter Reino Unido, 2011. • Doctorado en Ciencias de Materiales, Universidad de Oxford, Oxford Reino Unido, 2017.

Campos de formación académica: Licenciatura en: • Ciencias de la información • Tecnologías de información • Ciencias de la comunicación • Gestión documental • Inteligencia artificial • Ingeniería industrial • Mercadotecnia digital • Administración Maestría en alguna de las áreas mencionadas en los puntos anteriores	• Maestría en Inteligencia Artificial Aplicada, Universidad de Exeter, Exeter, Reino Unido, 2011.
Formación adicional deseable: • Archivo y gestión documental (físico y digital) • Data Ware House, fundamentos • Minería de datos, fundamentos • Tableros de control • Redes sociales, posicionamiento y marcas • Inteligencia artificial, fundamentos • I+D • Mercadotecnia digital	• Maestría en Inteligencia Artificial Aplicada • Tesis de Maestría: "Procesamiento de textos para el llenado automático de ontologías". • Ingeniero de Investigación y Desarrollo, Bodle Techonolgies, Oxford, Reino Unido. • Curso "HPC: From cluster deploying to user applications" Impartido por el Barcelona Supercomputing Centre • Curso "Capacitación para Usuarios y Administradores de sistema HPC implementado por FIJITSU" Impartido por FUJITZU.
Experiencia requerida: Tres años en puestos directivos o de mando medio superior en el sector público • Áreas de inteligencia de datos o institucional • Creación de nuevo conocimiento e informes estratégicos • Gestión de documentos y archivos para la mejora en la toma de decisiones en la organización	Experiencia laboral: Octubre 2017 – Mayo 2019 Institución: Universidad de Guadalajara Adscripción: Centro de Análisis de Datos y Supercómputo. Posición: Asesor Mi tarea principal consistió en colaborar en el desarrollo de las políticas, procesos y metodologías de operación del Centro de Análisis de Datos y Super cómputo de la Universidad de Guadalajara Diciembre 2016 – Enero 2019 Bodle Technologies

• Creación, posicionamiento de marcas, estrategias de posicionamiento en redes sociales y marketing digital Cinco años en áreas de estrategias, toma de decisiones o inteligencia institucional.	Posición: Ingeniero de Investigación y Desarrollo / Consultor Mi tarea principal consistió en la elaboración de modelos físicos de los dispositivos electrónicos que produce la compañía y el análisis de los datos producidos por dichos modelos, con el propósito de proporcionar información sobre la eficiencia de distintos diseños, que permitía tomar decisiones estratégicas en el proceso de desarrollo. Mayo 2016 - Diciembre 2018 Materiom Posición: Socio fundador Materiom es un start-up de base tecnológica, que busca impulsar a la comunidad internacional interesada en el desarrollo de materiales open-source mediante la creación de una plataforma web. Mi rol consistió en coordinar el desarrollo de la plataforma web y diseñar la estrategia de administración de datos, así como planear, diseñar y fabricar un roadmap de instrumentos de código abierto para la caracterización de materiales. https://materiom.org/ Enero 2008 – Septiembre 2010 Global Vantage Engineering Services Trabajé como Liaison y líder técnico, gestionando distintos proyectos de ingeniería de software para la industria aero-espacial, en colaboración con diferentes compañías integradoras en México y Estados Unidos: - Hamilton-Sundstrand 787-Dreamliner CMSC (Common Motor Starter/Controller) Etapa de Integración Hardware-Software Posición: Líder Técnico /Liaison on site, en la planta de Hamilton-Sundstrand en Rockford Illinois, EUA. En este proyecto, estuve a cargo de un equipo de 15 ingenieros de software como líder técnico; como liaison on site, estuve a cargo de las negociaciones y presentación de informes estratégicos hacia el cliente y la compañía durante

	el desarrollo del proyecto. El objetivo era desarrollar una serie de scripts en TCL/TK para un test-bench que simula la operación del 787, a fin de verificar el código del CMSC, la computadora a cargo del control de lo motores eléctricos del 787. El CMSC se clasifica como nivel A y B (dispositivos de misión crítica) de acuerdo al modo de operación requerido, según la norma RTCA DO-178B. - Honeywell 747-8 FMS (Flight Management System), Capa de Servicios de la plataforma,Timer Services. Posición: Desarrollador en C/C++ embebido / Líder técnico. La capa de Servicios de la plataforma FMS es la interface entre el Sistema Operativo y las capas superiores del FMS, el cual es un sistema embebido a cargo de controlar el plan de vuelo del Boeing 747-8. El componente Timer Services es un scheduler encargado de la adquisición de mediciones periódicas de los distintos sensores de la aeronave. El software del sistema FMS se clasifica como nivel B de acuerdo a la norma RTCA DO-178B 2005 – 2008: IBM Guadalajara, Mexico IFS (Integrated File System)GUI. Posición: Desarrollador Java / Visual C++ Este proyecto consistía en el desarrollo de la interfaz gráfica de usuario, del componente IFS, a cargo de la administración de los distintos sistemas de archivos soportados por el Sistema Operativo i5Os. El desarrollo de esta aplicación en Java permitió el soporte multiplataforma para los entornos Web y PC. En este proyecto, estaba a cargo de todo el ciclo de vida del producto, incluyendo la migración de la versión anterior (desarrollada en Visual C++), el desarrollo del nuevo componente en Java, pruebas unitarias, mantenimiento y soporte al cliente Nivel 3 (desarrollador).

Competencias técnicas indispensables: • Dominio del inglés, nivel alto • Gestión de proyectos • Gestión documental • Habilidades de I+D • Marketing digital • Redes sociales, uso experto • Alta capacidad de comunicación presencial y escrita en formatos diversos (papers, notas, reportes, estudios a profundidad, etc). • Nivel avanzado en ofimática • Edición e impresión de materiales	• Co-Fundador de Materiom, plataforma web para el desarrollo de comunidades interesadas en la creación de Materiales Open Source, para la impresión digital tridimensional. • Ingeniero de Investigación y Desarrollo para Bodle Technologies, Oxford, Reino Unido • Doctor en Materiales, Universidad de Oxford, Reino Unido • Asesor e Investigador Invitado, para el Centro de Análisis de Datos y Super Cómputo (CADS) de la Universidad de Guadalajara. • Paper: G. Rodriguez-Hernandez, P.Hosseini, C.Rios, C.D. Wright, and H.Bhaskaran "Mixed-mode electro-optical operation of Ge2Sb2Te5 nanoscale crossbar devices." Advanced Electronic Materials 2017, 1700079. • Paper: Syed Ghazi Sarwat, Pascal Gehring, Gerardo Rodriguez Hernandez, Jamie H. Warner, G. Andrew D. Briggs, Jan A. Mol, and Harish Bhaskaran. "Scaling Limits of Graphene Nanoelectrodes" Nano Letters, 2017, 17, 3688-3693. • Paper: Lokeshwar Bandhu, Gerardo Rodriguez Hernandez, Clement Talagrand, Graham Triggs, Sergio Garcia-Castillo, Ben Broughton, Harish Bhaskaran and Peiman Hosseini. "A novel ultra-thin switchable OVD for fully personalisable active and passive security features" Optical Document Security, 2018. • Operador de equipo de impresión digital de Alto Volumen Xerox Docutech 135. • Conferencia Magistral: "Nuevos Paradigmas de diseño de Ingeniería usando Metodologías de Modelado de Elemento Finito", 4º Congreso Internacional de Sistemas Embebidos

	• Conferencia de Divulgación:" Supercómputo y sus posibilidades" Jalisco TalentLand 2019.
Competencias de gestión requeridas: • Visión estratégica • Orientación a resultados • Análisis y resolución de problemas • Trabajo en equipo • Organización • Comunicación efectiva • Dominio de estrés • Seguimiento normativo y procesos	• Liaison/Líder Técnico, para el proyecto de Integración Hardware/Software del CMSC (Common Motor Starter Controller) del 787-Dreamliner, en Rockford Illinois, EUA. • Desarrollador especializado en la Normatividad de la FAA DO178B para dispositivos de misión crítica. • Consultor para el Desarrollo de los planes de estudios de Licenciatura y Maestría en Computación del Centro Universitario de Tonalá, Universidad de Guadalajara. • Profesor de la Asignatura de Big Data, de la Maestría en Tecnologías de Información del CUCEA, Universidad de Guadalajara. • Profesor de la Asignatura de Arquitectura de Microcomputadoras, de la Maestría en Ciencias Computacionales de la Universidad Autónoma de Guadalajara.
Requisitos específicos • Disponibilidad de horario y para viajar • Dedicación laboral exclusiva en los días y horarios laborales	Si / No ___ / _X__ _X__ / ___
Otros:	

Instrucciones de llenado:

- Márgenes: No cambiar este formato
- Espacio de interlineado: No cambiar este formato
- Tipo de letra: Helvética

- Tamaño: 11
- Uso de negritas: Sólo en el nombre del colaborador y títulos de apartados del CV (perfil de puesto, perfil profesional y experiencia, así como en los datos laborales)
- No se usa texto en cursiva
- La fotografía deberá ser con fondo blanco o claro, vestimenta formal y de color obscuro, de tal forma que contraste con el fondo blanco.

Se eliminan los datos 1 (correo electrónico personal) 2 (teléfono personal) Por ser considerados un dato personal identificable.
Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

1 [redacted]

JALISCO
GOBIERNO DEL ESTADO
PODER EJECUTIVO

2 [redacted]

3 [redacted]

NACIMIENTO DE:

Gerardo
Rodriguez
Hernandez

1- 28-29

"

4 [redacted]

Se eliminan los datos 1 (oficialía, acta, libro, municipio, año, CURP) 2 (oficina, libro, acta) 3 (oficialía, nombre, edad, nacionalidad y domicilio de padres y abuelos) 4 (huella digital) Por ser considerados un dato personal identificable.

Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

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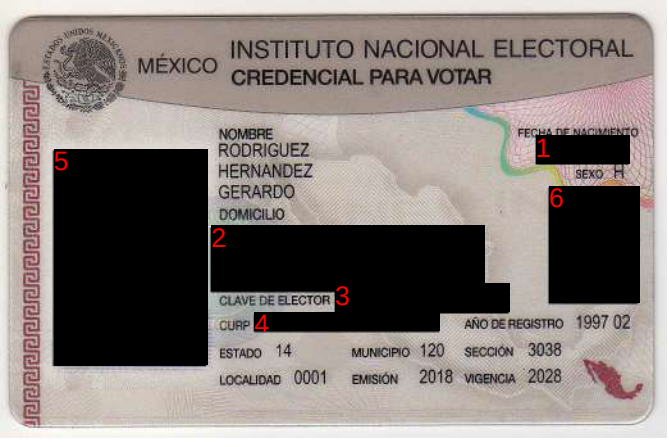
CON FUNDAMENTO EN LO DISPUESTO POR LOS ARTICULOS 6,121 Y APLICABLES DE LA LEY DE REGISTRO CIVIL DEL ESTADO, 4 FRACCION II, 6 Y RELATIVOS DEL REGLAMENTO DE DICHA LEY, CERTIFICA Y HACE CONSTAR QUE LA PRESENTE ES COPIA FIEL.

DIRECCIÓN DEL ARCHIVO GENERAL
PODER EJECUTIVO DEL ESTADO
ESTADOS UNIDOS MEXICANOS
JALISCO

Firma electrónica certificada : cccfa7b558869bbe79dea42fceac4999

GUADALAJARA, JALISCO, jueves, 6 de diciembre, de 2018

Gobierno de


MÉXICO
INSTITUTO NACIONAL ELECTORAL
CREDENCIAL PARA VOTAR
NOMBRE
RODRIGUEZ
HERNANDEZ
GERARDO
DOMICILIO
FECHA DE NACIMIENTO
1
SEXO H
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2
6
CLAVE DE ELECTOR
3
CURP
4
AÑO DE REGISTRO 1997 02
ESTADO 14
MUNICIPIO 120
SECCIÓN 3038
LOCALIDAD 0001
EMISIÓN 2018
VIGENCIA 2028

Se eliminan los datos 1(fecha de nacimiento) 2(domicilio) 3(clave de elector) 4(CURP) 5, 6(fotografía) 7(firma) 8(huella) 9(folio). Por ser considerados un dato personal identificable. Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

Se eliminan los datos 1 (Foto) Por ser considerados un dato personal identificable.
Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

1

La Universidad de Guadalajara

Otorga a

Gerardo Rodríguez Hernández

El título de

Ingeniero en Comunicaciones y Electrónica

En virtud de que terminó en forma debida los estudios que la ley señala; que fue aprobado en la modalidad de titulación correspondiente, y de que cumplió con todos los demás requisitos legales, para que pueda ejercer libremente la citada profesión, sin más limitaciones que las establecidas por la ley.

"Piensa y Trabaja"

Guadalajara, Jal., México, a 09 de Enero de 2006.

El Rector General

Lic. José Trinidad Padilla López

El Secretario General

Mtro. Carlos Jorge Briseño Torres

015086

FECHA DE EXAMEN PROFESIONAL

DÍA 18 MES V AÑO 2005

SE TOMÓ RAZÓN DEL PRESENTE TÍTULO, A FOJAS 104

BAJO EL NÚM. 30543 DEL LIBRO NÚM. 219

GUADALAJARA, JAL. 09 DE Enero DE 2006

EL COORDINADOR DE CONTROL ESCOLAR
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15823428-365E4
ID Firmado

MXUDGL 11 01

395471196090106

Folio Número: A36868

UNIVERSITY OF OXFORD

This is to certify that

Gerardo Rodriguez Hernandez

Wolfson College

having submitted a thesis entitled

Study of Mixed Mode electro-optical operation of $Ge_2Sb_2Te_5$

and, having satisfied all the conditions prescribed by the Statutes of the University on 15 June 2017, was on 12 May 2018 admitted to the Degree of

DOCTOR OF PHILOSOPHY

University Offices,
Oxford.
12 May 2018

Registrar

673047/1

UNIVERSITY OF EXETER

We the undersigned hereby certify that

Gerardo Rodriguez Hernandez

having pursued an approved programme of study
and having fulfilled the requirements of the
Ordinances and Regulations of the University
was awarded the Degree of

Master of Science
in Applied Artificial Intelligence
with Merit

by the Senate of the University on

10 October 2011

Hoella Benjamin
CHANCELLOR

Steve Smith
VICE-CHANCELLOR

David Allen
REGISTRAR AND SECRETARY

[redacted]

Número de Cédula Profesional
11286229

Estados Unidos Mexicanos
Secretaría de Educación Pública
Dirección General de Profesiones
Cédula Profesional Electrónica

[redacted]

1 [redacted]

Entidad Federativa de Registro
CIUDAD DE MÉXICO

Libro	Foja	Número	Tipo
1128	347	2	C1

Se elimina los datos 1, 2 (CURP) Por ser considerados un Fundamento Municipio Estado Información Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

Se expide a: [redacted]

Datos del profesionista

Nombre(s)	Primer apellido	Segundo apellido
GERARDO	RODRIGUEZ	HERNANDEZ

Quien cumplió con los requisitos establecidos en la Ley Reglamentaria del Artículo 5o. Constitucional, relativo al ejercicio de las profesiones en la Ciudad de México y su Reglamento, la cédula con efectos de patente para ejercer profesionalmente en el nivel de:

LIC[redacted] EN INGENIERÍA EN COMUNICACIONES Y ELECTRÓNICA — [redacted] 505306

Nombre del programa — Clave

Datos de la institución educativa

Nombre o denominación	Clave
UNIVERSIDAD DE GUADALAJARA	140001

Datos de expedición y firma electrónica

Fecha	Hora
14/09/2018	14:04:02

[redacted] [redacted]

Se expide la presente cédula electrónica de conformidad con el artículo 32 del Reglamento de la Ley Reglamentaria del Artículo 5o. Constitucional, relativo al Ejercicio de las Profesiones en la Ciudad de México y demás relativos y aplicables.

El presente acto administrativo cuenta con la firma electrónica avanzada del servidor público competente, amparada por un certificado vigente a la fecha de su elaboración y es válido de conformidad con lo dispuesto en la Ley de Firma Electrónica Avanzada.

Firma electrónica

2 [redacted]

Firma electrónica avanzada del servidor público facultado

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Sello digital de tiempo SEP

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QR para validar la información

La presente cédula electrónica, su integridad y autoría se podrá comprobar en **www.gob.mx/cedulaprofesional**

Identificador electrónico - cédula
11286229

[redacted]

Número de Cédula Profesional
11522439

Estados Unidos Mexicanos
Secretaría de Educación Pública
Dirección General de Profesiones
Cédula Profesional Electrónica

1 [redacted]

Entidad Federativa de Registro
CIUDAD DE MÉXICO

Libro	Foja	Número	Tipo
1152	136	10	C1

Se eliminan los datos 1, 2 (CURP) Por ser considerados
Fundamento legal: Artículo 21.1 de la Ley de Transpare
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Se expide a: [redacted]

Datos del profesionista

GERARDO	RODRIGUEZ	HERNANDEZ
Nombre(s)	Primer apellido	Segundo apellido

Quien cumplió con los requisitos establecidos en la Ley Reglamentaria del Artículo 5o. Constitucional, relativo al ejercicio de las profesiones en la Ciudad de México y su Reglamento, la cédula con efectos de patente para ejercer profesionalmente en el nivel de:

[redacted]TRÍA EN CIENCIAS EN INTELIGENCIA ARTIFICIAL — [redacted]573511

Nombre del programa — Clave

Datos de la institución educativa

UNIVERSITY OF EXETER, LONDRES, INGLATERRA — 330081

Nombre o denominación — Clave

Datos de expedición y firma electrónica

08/04/2019 — 11:02:33

Fecha — Hora

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Se expide la presente cédula electrónica de conformidad con el artículo 32 del Reglamento de la Ley Reglamentaria del Artículo 5o. Constitucional, relativo al Ejercicio de las Profesiones en la Ciudad de México y demás relativos y aplicables.

El presente acto administrativo cuenta con la firma electrónica avanzada del servidor público competente, amparada por un certificado vigente a la fecha de su elaboración y es válido de conformidad con lo dispuesto en la Ley de Firma Electrónica Avanzada.

Firma electrónica

2 [redacted]

Firma electrónica avanzada del servidor público facultado

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SANCHEZ
SIONES

Sello digital de tiempo SEP

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QR para validar la información

La presente cédula electrónica, su integridad y autoría se podrá comprobar en **www.gob.mx/cedulaprofesional**

Identificador electrónico - cédula
11522439

[redacted]

Número de Cédula Profesional
11539187

Estados Unidos Mexicanos
Secretaría de Educación Pública
Dirección General de Profesiones
Cédula Profesional Electrónica

1 [redacted]

Entidad Federativa de Registro
CIUDAD DE MÉXICO

Libro	Foja	Número	Tipo
1153	511	8	C1

Se eliminan los datos 1, 2 (CURP) Por ser considerados [redacted]
Fundamento legal: Artículo 21.1 de la Ley de Transparen[redacted]alisco y sus
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Se expide a: [redacted]

Datos del profesionista

GERARDO	RODRIGUEZ	HERNANDEZ
Nombre(s)	Primer apellido	Segundo apellido

Quien cumplió con los requisitos establecidos en la Ley Reglamentaria del Artículo 5o. Constitucional, relativo al ejercicio de las profesiones en la Ciudad de México y su Reglamento, la cédula con efectos de patente para ejercer profesionalmente en el nivel de:

[redacted]

DOCTORADO EN CIENCIA DE MATERIALES	505609 [redacted]
Nombre del programa	Clave

Datos de la institución educativa

UNIVERSITY OF OXFORD, REINO UNIDO DE GRAN BRETAÑA E IRLANDA DEL NORTE	330377
Nombre o denominación	Clave

Datos de expedición y firma electrónica

24/04/2019	14:00:18
Fecha	Hora

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Se expide la presente cédula electrónica de conformidad con el artículo 32 del Reglamento de la Ley Reglamentaria del Artículo 5o. Constitucional, relativo al Ejercicio de las Profesiones en la Ciudad de México y demás relativos y aplicables.

El presente acto administrativo cuenta con la firma electrónica avanzada del servidor público competente, amparada por un certificado vigente a la fecha de su elaboración y es válido de conformidad con lo dispuesto en la Ley de Firma Electrónica Avanzada.

Firma electrónica

2 [redacted]

Firma electrónica avanzada del servidor público facultado

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Sello digital de tiempo SEP

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QR para validar la información

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Identificador electrónico - cédula
11539187

Contraloría del Estado
GOBIERNO DE JALISCO

Carta de no Sanción Administrativa

Fecha de expedición: 07 de Agosto del 2019 a las 11:43:23 horas.
Número de Folio: CEJ/DGJ/JZ1HENN8-TO9UYTBLMQF
Dirección General Jurídica.

Nombre(s): GERARDO
Primer Apellido: RODRIGUEZ
Segundo Apellido: HERNANDEZ

Con fundamento a lo establecido en los artículos 10 fracción XVII y 12 fracción VII del Reglamento Interior de la Contraloría del Estado, una vez revisado el registro de sanciones administrativas aplicadas por la Contraloría del Estado, se hace constar la inexistencia de sanción administrativa en su contra.

Esta constancia tiene validez oficial de una semana a partir del día de impresión.

Mtro. Fernando Radillo Martínez Sandoval
Director General Jurídico.

Av. Ignacio L. Vallarta Núm.1252, Colonia Americana.
Guadalajara, Jalisco, México. C.P: 44160.
Tel:(33) 4739-0104 y (33) 4739-0121.

Notas:
En el entendido que pueden existir otras sanciones administrativas aplicadas por Ente Público distinto a la Contraloría del Estado, en términos de la abrogada Ley de Responsabilidades de los Servidores Públicos del Estado de Jalisco, mediante decreto 26435/LXI/17, aprobado por el H. Congreso del Estado de Jalisco en sesión del 14 de Septiembre del 2017, publicada en el Periódico Oficial del "Estado de Jalisco", el 26 de Septiembre del 2017.

Se eliminan los datos 1 (foto) 2 (no. de identificación) 3 (huella) 4 (firma) Por ser considerados un dato personal identificable. Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

Jalisco
GOBIERNO DEL ESTADO

Instituto Jalisciense de Ciencias Forenses
SCIENTIA LUX IUSTITIAE

IJCF0300851

Folio No.
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Dirección General
Archivo de Identificación Criminalístico

1 [redacted]

Apellido paterno:
RODRIGUEZ

Apellido materno:
HERNANDEZ

Nombre(s):
GERARDO

Se identificó con:
Credencial Elector

No. de identificación:
2 [redacted]

3 [redacted]

Huella índice derecho

A QUIEN CORRESPONDA:

La persona cuya fotografía y huella dactilar aparecen en este documento, solicitó CONSTANCIA DE NO ANTECEDENTES, a nombre de:

GERARDO RODRIGUEZ HERNANDEZ.

Realizada la confrontación procedente, quien responde al nombre de referencia, no registra antecedentes en los archivos criminalísticos correspondientes a esta dependencia.

Se extiende la presente para los fines que convengan. Este documento no debe tomarse como medio de identificación de la persona a la que corresponde dicha fotografía.

Atentamente

Zapopan Sur, Jalisco a 02 AGOSTO 2019

ING. GUSTAVO QUEZADA ESPARZA
Director General del Instituto
Jalisciense de Ciencias Forenses

4 [redacted]

Firma del interesado

Área de Identificación y Control

GOBIERNO DE JALISCO
PODER EJECUTIVO
INSTITUTO JALISCIENSE DE CIENCIAS FORENSES
Constancia de no Antecedentes

Esta constancia ampara la ausencia de registro(s) de antecedentes penales en el Estado de Jalisco hasta la fecha de su expedición, y sólo de aquellos que hayan sido cancelados y/o solicitados por las autoridades competentes.

Se recomienda actualizar este documento cada 90 días a partir de la fecha de expedición.
** Costo del formato $ 65.00 (sesenta y cinco pesos 00/100 M.N) conforme a la ley
Ingresos del Gobierno del Estado para el ejercicio fiscal 2019
Dudas sobre la autenticidad de la presente constancia, comunicarse al tel.(33)30309491

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5 [redacted]

1st August 2019

To whom it might concern,

Bodle Technologies, an Oxford University spinout company, is pioneering the development of video-capable, vibrant colour reflective display technology, utilizing phase-changing materials. Reflective displays, which reflect rather than transmit or emit light, are particularly suited to situations where outdoor readability is a concern, such as public information displays, eReaders and wearables. The technology is bistable, requiring no energy to retain a static image, significantly extending battery life for portable applications.

Dr. Gerardo Rodriguez Hernandez joined our company in **December 2016** as an R&D Engineer specialized in electro-thermal finite element modelling of our solid-state semiconductor based devices. His work consisted in modelling and analyzing new design prototypes prior to the fabrication step. Identifying optimal designs with higher performance and reliability is a crucial development stage for Bodle and Dr. Rodriguez Hernandez is one of the most important engineers in that respect.

Dr. Rodriguez Hernandez relocated to Mexico in **August 2017** to fulfill his scholarship duty with the Mexican government. He has been working with us as a consultant since then.

Se eliminan los datos 1 (firma), 2 (nombre), 3 (correo electrónico personal) 4 (dirección institución), 5 (nombre de institución),6 (teléfono personal),7 (página de internet de institución) 8 (correo electrónico institución): Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

2 [redacted]
Chief Technology Officer
3
1 [redacted]

4 [redacted]
Tel. 6 [redacted] E-mail. 8 [redacted]
7 [redacted]

INSTITUTO POLITECNICO NACIONAL
CENTRO DE INVESTIGACION EN COMPUTACIÓN
LABORATORIO DE ROBÓTICA Y MECATRÓNICA
Av. Juan de Dios Bátiz esq. con M. Othón de Mendizábal
Unidad Profesional Adolfo López Mateos
México, D.F. 07738, México
Tel: (5) 729 6000 ext 56512
E-mail: hsossa@cic.ipn.mx 2 [redacted]

Ciudad de México a 02 de agosto de 2019
Asunto: Carta de recomendación

A quien corresponda
Presente:

Estimados señores,

El motivo de la presente es para recomendar ampliamente al Dr. Gerardo Rodríguez Hernández, quien actualmente me entero con agrado que está presentando una aplicación para la posición de Director de Inteligencia de Datos en la Secretaría Ejecutiva del Sistema Estatal Anticorrupción de Jalisco.

Conozco al Dr. Rodríguez Hernández desde hace un año, luego de su regreso del extranjero. Hemos coincidido en diferentes eventos académicos y de divulgación científica en México. Durante este tiempo he podido constatar el interés que presenta el Dr. Rodríguez Hernández hacia temas de impacto social, pues hemos participado en varios foros que se enfocan en la búsqueda de soluciones a problemas sociales, mediante el uso de la inteligencia artificial.

Durante este periodo de conocer al Dr. Rodríguez Hernández, me he dado cuenta de que es una persona de excelente calidad académica, así como gran calidad humana, por lo que no dudo en recomendarlo ampliamente y quedo a su disposición en caso de requerir cualquier información adicional.

Sin más por el momento, aprovecho la oportunidad para enviar a ustedes un cordial saludo.

Atentamente

1 [redacted]

Dr. Juan Humberto Sossa Azuela
Profesor Investigador
Miembro del Sistema Nacional de Investigadores nivel III
Miembro de la Acaemia Mexicana de Ciencias.
Miembro Senior de la IEEE.

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Guadalajara Jalisco, 02 de agosto de 2019.

A quien corresponda,

La presente es para recomendar al Dr. Gerardo Rodríguez Hernández, quien está aplicando al puesto de Director de Inteligencia de Datos de la Secretaria Ejecutiva del Sistema Estatal Anticorrupción de Jalisco.

Conocí al Dr. Rodríguez Hernández desde nuestros años de estudios en la carrera de Ingeniería en Comunicaciones y Electrónica hace 20 años. Desde entonces, pude constatar que el Dr. Gerardo Rodríguez Hernández es una persona brillante, dedicada plenamente a todas las actividades las que se compromete y siempre busca alternativas y oportunidades de crecimiento

En ese sentido, el interesado trabajó desde sus años universitarios en la Coordinación de Tecnologías para el Aprendizaje (CTA, CUCEA) de la Universidad de Guadalajara y cuenta además con una sólida carrera profesional en la industria. Por si esto fuera poco, el Dr. Gerardo Rodríguez Hernández cuenta con una muy solidad formación académica, habiéndose graduado de una de las mejores universidades del mundo. A nivel profesional, he podido colaborar en múltiples proyectos de investigación y desarrollo tecnológico con el interesado, y he podido corroborar que es un profesionista capaz, adaptable y con una gran capacidad analítica, sin demerito de su capacidad de resolver problemas de forma eficiente.

Desde un punto de vista personal, puedo decir que el Dr. Gerardo Rodríguez Hernández es una persona comprometida y motivada por sus actividades tanto de desarrollo tecnológico, como de investigación y docentes. Por otro lado, a través de los años he podado constatar que el interesado es una persona íntegra, que se conduce de forma profesional y con una ética intachable en todas las actividades en las que se involucra.

Por las razones citadas arriba no dudo en recomendar ampliamente al Dr. Gerardo Rodríguez Hernández, tanto por sus cualidades técnicas como humanas y quedo a sus órdenes para cualquier información suplementaria

1 [redacted]

Atentamente

2 [redacted]

Profesor Investigador

3 [redacted]

4 [redacted]

Se eliminan los datos 1 (firma), 2 (nombre), 3 (correo electrónico personal) 4 (teléfono personal), : Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas mitidos por el Consejo Nacional del Sistema Nacional de ransparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

DEPARTMENT OF ENGINEERING SCIENCE

Parks Road, Oxford OX1 3PJ
Tel: +44(0)1865 273094
Email: aidong.yang@eng.ox.ac.uk

Professor Aidong Yang
ASSOCIATE PROFESSOR OF ENGINEERING SCIENCE

12 April 2018

To Whom It May Concern

Re: Dr Gerardo Rodriguez Hernandez

I am writing to provide a supporting statement on Dr Gerardo Rodriguez Hernandez's role in the creation of a research proposal and in the subsequent development of the research project at the University of Oxford.

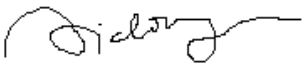
In early 2016, I led a small group to develop a research proposal for submission to a research network sponsored by UK's Engineering and Physical Sciences Research Council (EPSRC) on "Future Makespaces in Redistributed Manufacturing". The aim of the proposal was to develop and assess novel materials testing facilities to support the utilisation of low material flows in a makespace through technologies such as 3-D printing. A DPhil student at the time, Gerardo was a key member of the proposal group, and acted as the main contributor with respect to materials science and engineering, which was an essential aspect of the proposed research (along with other aspects such as digital platforms and knowledge sharing). In particular, he independently developed the scope and description of one of the four work packages entitled "build and test", in addition to making very useful input to other work packages.

The above proposal was successfully accepted in June 2016. In the subsequent development and execution of the project, Gerardo continued to be a core member of the team, being responsible for making detailed plans of the "build and test" work package and providing guidance to the required research work as well. In this project, he did not only make input through his own work, but also collaborate actively and smoothly with other team members and external parties, which was critical for the success of the whole project.

Overall, I would like to stress that Gerargo played an essential role in both the creation and the execution of the research project described above, and his contribution was undoubtedly substantial.

I hope you find the above statement useful. Should you need further information, please do not hesitate to contact me.

Yours sincerely



Aidong Yang
University of Oxford

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July 18, 2013

http://www.isom.jp/

Th-N: Media and Material Science

Presiders: R. Katayama (Fukuoka Inst. of Tech., Japan)
O. Matoba (Kobe Univ., Japan)

Th-N-01 *Invited*

(13:35) Mixed-Mode Electro optical Properties of $Ge_2Sb_2Te_5$

G. Rodriguez-Hernandez[1], P. Hosseini[1], C. D. Wright[2], W. H. P. Pernice[3], H. Bhaskaran[1]

[1]Univ. of Oxford, [2]Univ. of Exeter (U.K.), [3]Karlsruhe Inst. of Tech. (Germany)

In this talk, we present ongoing work on a novel alternative mode of operation of phase change materials, specifically $Ge_2Sb_2Te_5$: mixed-mode electro-optical operation, which offers a new set of potential applications for this material.

Th-N-02 *Invited*

(14:00) Crystallization Properties of Ge-Sb and (GeTe)-(Bi_2Te_3) Nanoparticles by Pulsed Laser Irradiation

Takashi Mihara[1], Akio Tsuchino[1], Shuji Sato[1], Kazuya Hisada[1],Rie Kojima[1], Noboru Yamada[2], Shigeru Furumiya[1]

[1]Panasonic, [2] Kyoto Univ. (Japan)

Crystallization time of nanoparticles, 50 nm in diameter, is roughly equivalent to that of blanket film for (GeTe)-(Bi_2Te_3) while it becomes 500-times longer for Ge-Sb, suggesting the significant influence of their different crystallization processes.

Th-N-03

(14:25) High Capacity, Inexpensive Optical Data Storage using Co-Extruded Multilayer Films

Cory W Christenson[1], Brent Valle[2], Anuj Saini[1], Chris Ryan[1], Joseph Lott[1], Jack Johnson[1], Christoph Weder[3], Eric Baer[1], Kenneth D Singer[2], Jie Shan[1]

[1]Case Western Reserve Univ., [2]Folio Photonics, [3]Univ. of Fribourg (U.S.A.)

An inexpensive, scalable, and high capacity medium for multilayer ODS is described, based on fabrication by co-extrusion of dye-doped polymers. Images are written in 23 layers by photobleaching. Aging and sub-μs exposures are also explored.

Mixed-Mode Electro Optical Properties of $Ge_2Sb_2Te_5$

G. Rodriguez-Hernandez[1], P. Hosseini[1,2], Yat-Yin Au[2], WHP Pernice[3], CD Wright[2] and H. Bhaskaran[1]

[1]Department of Materials, University of Oxford, Parks Road, Oxford, OX1 3PH United Kingdom
[2]College of Engineering Mathematics and Physical Sciences, University of Exeter, Exeter, EX4 4QF United Kingdom
[3]Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany

1. Introduction

$Ge_2Sb_2Te_5$ (GST), a phase change material, has been broadly used as rewritable optical data storage media [1]. Recently GST has also been commercially used for data storage in the electrical domain using the change in resistance that occurs as a consequence of the phase change [2]. Thus, it can be used in both optical and electrical domains; the combined use of optical and electrical properties of GST ("mixed-mode") opens a new set of potential applications ranging from optical modulators to electrical read-out of all-optical memories. In this talk we present some preliminary work on this "mixed-mode" read-out [3].

2. Experimental

For testing mixed-mode read-out of our devices, a test device was fabricated by creating of a pair of TiN/Pt electrodes in contact with a 50nm thin film of amorphous as deposited GST covered with SiO_2 as a capping layer, both the GST and the SiO_2 were deposited by RF magnetron sputtering on a thermally oxidized Si wafer substrate. The electrodes confine a region in the GST substrate as shown in Fig. 1.
Our experiment consists of iteratively applying a series of optical pulses at increasing power (0.5 - 5.5 mW), followed by measuring the changes in the device resistance. During each iteration a series of 20 identical high energy pulses of 1μs duration is applied at first to partially induce the crystallization of the material. The reflectivity is then measured as the amount of reflected power by applying a continuous wave low power laser beam (0.3mW). Finally the electrical resistance of the device is measured. Reflectivity maps shown in Fig. 3 and Fig. 4 were made by the reflected power measurements obtained by scanning an area around the PCM with a low power continuous wave laser beam. The same 405nm laser was used for the pulse and reflected power measurements.

3. Results & discussion

We studied the amorphous to crystalline transition of GST225; our observations are presented in Fig. 2. As the PCM is exposed to consecutive series of pulses, the reflected power increases which indicate an increment in reflectivity characteristic of the crystalline phase [4], at the same time the electrical resistance decreases. Correspondence between the behaviors of both curves can be observed, which confirms the feasibility of using GST in a electro-optical domain, optically inducing the phase change and performing the read out electrically. The change of reflectivity of the PCM can be observed in Fig. 3 and Fig. 4 before and after applying the set of optical pulses.

4. Conclusions

In the presented work we have experimentally demonstrated the operation of the phase change material GST in the Mixed-Mode electro-optical domain. These are very preliminary results and require further characterization; however this indicates the first such measurements on GST, and shows the potential for devices based on these materials in the combined optical and electrical domain, especially in photonic devices.

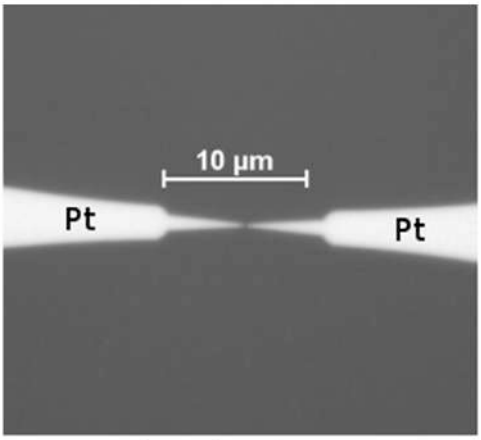

Fig. 1. Phase Change Memory Cell

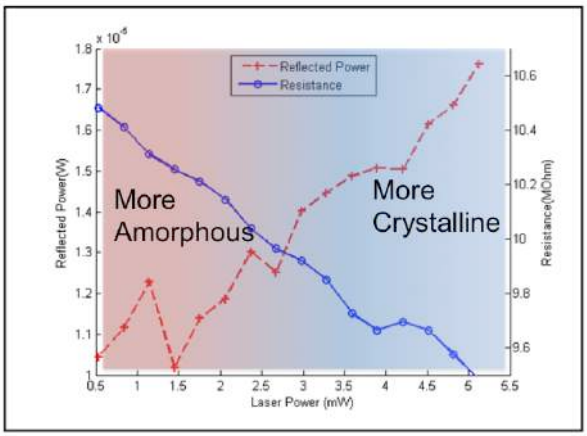

Fig. 2. Resistance and Reflectivity change

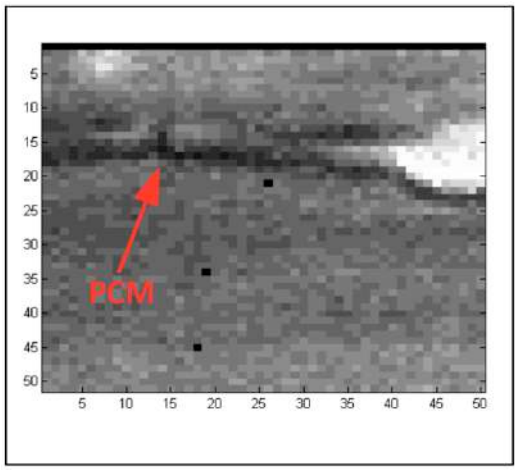

Fig. 3. Initial reflectivity map

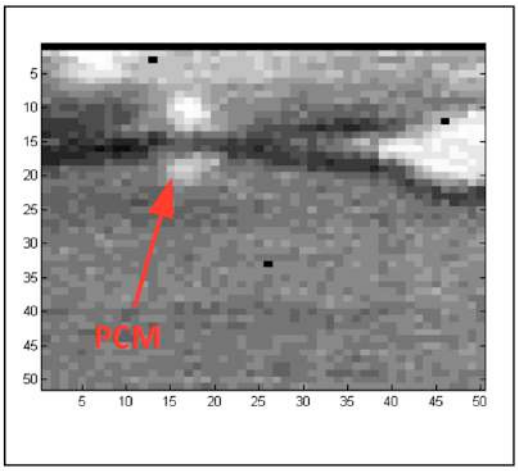

Fig. 4. Final reflectivity map

References

1. M. Wuttig and N. Yamada, Nature Mater. **6**, 824 (2007).
2. S. R. Ovshinsky, Phys. Rev. Lett. **21**, 1450‑1453 (1968).
3. C.D.Wright, L.Wang, M. Aziz, J.A.Vazquez Diosdado, P. Ashwin, Phys. Status Solidi B. **10**,249 (2012).
4. A Chabli, C Vergnaud, F Bertin, V Gehanno, B Valon, B Hyot, B Bechevet, M Burdin, D Muyard, Journal of Magnetism and Magnetic Materials, **3**, 249 (2002).

MATERIOM

We are Materiom

Materiom is a non-profit working at the intersection of design, digital fabrication, ecology, and material science.

We believe this multidisciplinary and collaborative approach is the key to unlocking a 21st century materials economy that is regenerative by design.

We are an international team of designers, material scientists and engineers based in Chile, Spain, the Netherlands, the United Kingdom, and Mexico.

We are passionate about developing, testing, and sharing materials that regenerate our local, regional, and global economy and ecology.

Meet the team

MATERIOM

Alysia Garmulewicz

Director, Professor of the Circular Economy

Liz Corbin

Director, Materials designer and researcher

Gerardo Rodriguez

Technical lead, Ph.D. Material Science

Andrew Luers

Organizational development, Ph.D. Physics

Anastasia Pistofidou

Materials designer, FabTextiles founder

Mariet Sauerwein

Materials designer, Ph.D. candidate

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Gerardo Rodriguez

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Location

Oxford, UK

Skills

Development of Web Platforms, Mainframe Software, Aerospace Systems and Finite Element Method simulations

About Gerardo Rodriguez

Technical lead for Materiom. I have a Ph.D. in Material Science from the University of Oxford, and am interested in the development of accessible instruments for material characterization, open source hardware as well as the creation of web based platforms for information sharing.

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2013 MRS Spring Meeting & Exhibit

April 1-5, 2013 | San Francisco
Meeting Chairs: Mark L. Brongersma, Vladimir Matias, Rachel Segalman, Lonnie D. Shea, Heiji Watanabe

Back to Symposium Sessions

Symposium EE : Phase-Change Materials for Memory, Reconfigurable Electronics, and Cognitive Applications

Apr 02 | Apr 03 | Apr 04 | Apr 05

2013-04-03 Show All Abstracts

Symposium Organizers

Raffaella Calarco, Paul Drude Institute for Solid State Electronics
Paul Fons, Advanced Institute of Industrial Science and Technology
Bart J. Kooi, M2i University of Groningen
Martin Salinga, RWTH Aachen University
Martha (Salinga's Asst) Shafer-Thyen,

EE6/DD6: Joint Session: Phase-change Memory

Session Chairs

Martin Salinga
Bart J. Kooi

Wednesday AM, April 03, 2013
Moscone West, Level 3, Room 3008

8:45 AM - *EE6.01/DD6.01
Phase Change Memory: The Beginning of a New Story

Andrea Redaelli [1]

[1]Micron Semiconductor Italia Agrate Brianza Italy

Show Abstract

Wednesday PM, April 03, 2013
Moscone West, Level 3, Room 3011

1:30 AM - *EE8.01
Programming Phase Change Synaptic Devices for Neuromorphic Computation

Duygu Kuzum [1,2] Rakesh G. D. Jeyasingh [1] Sukru B. Eryilmaz [1] Shimeng Yu [1] H.-S. Philip Wong [1]

[1]Stanford University Stanford USA[2]University of Pennsylvania Philadelphia USA

Show Abstract

2:00 AM - *EE8.02
Beyond von-Neumann Computing with Phase-change Materials and Devices

C. David Wright [1] Harish Bhaskaran [1] Gerardo Hernandez-Rodriguez [1] Peiman Hosseini [1] Jorge A. Vazquez Diosdado [1] Wolfram H P Pernice [2]

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Hide Abstract

To date the main applications of phase-change materials and devices have been limited to the provision of non-volatile memories. Recently however the potential has been demonstrated for using phase-change devices as the basis for new forms of computing, by exploiting their multi-level resistance capability to provide electronic mimics of biological synapses [1,2]. Here we exploit a different and previously under-explored property also intrinsic to phase-change materials and devices, namely accumulation, to demonstrate that phase-change devices can also be used to implement a simple form of integrate-and-fire neuron. Thus, we might imagine 'all phase-change' based neural networks or neuromorphic processors [3]. Furthermore, the accumulation regime can also be used to carry out arithmetic computing and perform Boolean logic, leading potentially to a new type of phase-change based arithmetic logic unit (ALU) for general purpose computing. A major difference between such a phase-change ALU and conventional silicon processors is that the phase-change system would be non-volatile; if the power were to be removed from the phase-change system it would remain in its pre-existing state, and processing could recommence from where it left off when power is re-supplied. Moreover, since the phase-change ALU both computes (processes) and stores the result of such computations simultaneously and at the same physical location, the detrimental von Neumann 'bottleneck' inherent to conventional computing systems is avoided [4]. Finally, we note that both the neuromorphic and ALU computing capabilities of phase-change materials and devices are accessible in both the optical (photonic) and the electrical (electronic) domains, or indeed via a 'mixed-mode' approach. This opens up the route towards various attractive non-von-Neumann phase-change computing possibilities. For example, we might implement 'all-photonic computing' that avoids the well-known high-frequency limitations of electrical buses [5]. Alternatively we could used a mixed optical-electrical approach, in which the ultra-fast optical switching capabilities of phase-change materials [6] is used to provide high-speed computing operation, but with data output (sensing) being in the electrical domain. In this paper we discuss such novel approaches to phase-change based neuromorphic and general purpose

computing and present experimental proof-of-principal of some of the underlying concepts.
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2:30 AM - EE8.03
Mixed Phase Ge2Sb2Te5 Thin Films with Temperature Independent Resistivity for Reconfigurable High Precision Resistors

Stefania Privitera $_1$ Cristina Garozzo $_1$ Alessandra Alberti $_1$ Giuseppe D'Arrigo $_1$ Luca Perniola $_2$ Barbara De Salvo $_2$ Emanuele Rimini $_1$

$_1$IMM-CNR Catania Italy$_2$CEA-LETI Grenoble-Cedex France

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2:45 AM - EE8.04
Reconfigurable Phase Change Switch

Nabila Adnane $_1$ Nadim Kanan $_1$ Ali Gokirmak $_1$ Helena Silva $_1$

$_1$University of Connecticut Storrs USA

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3:00 AM -
BREAK

EE9: Thermal Aspects and Fabrication

Session Chairs
Paul Fons

Wednesday PM, April 03, 2013
Moscone West, Level 3, Room 3011

3:30 AM - *EE9.01
Engineering PCRAM with Low Current from the Material and Carrier Transportation Aspects

2015 MRS Spring Meeting & Exhibit

April 6-10, 2015 | San Francisco
Meeting Chairs: Artur Braun, Hongyou Fan, Ken Haenen, Lia Stanciu, Jeremy A. Theil

Back to Symposium Sessions

Symposium Y : Phase-Change Materials for Data Storage, Cognitive Processing and Photonics Applications

Apr 07 | Apr 08 | Apr 09

2015-04-09 Show All Abstracts

Symposium Organizers

Ritesh Agarwal, Univ of Pennsylvania
Huai-Yu Cheng, Macronix International Co Ltd
Riccardo Mazzarello, RWTH Aachen
Robert Simpson, SUTD

Y8: Superlattice Material

Session Chairs

Robert Simpson
Raffaella Calarco

Thursday AM, April 09, 2015
Moscone West, Level 2, Room 2003

8:30 AM - *Y8.01
Role of Substrate Preparation in Order to Employ Molecular Beam Epitaxy Grown Phase Change Materials for Devices

Raffaella Calarco [1]

[1]Paul-Drude-Institut fuer Festkoerperelektronik Berlin Germany

2:15 AM - *Y10.03
New 'Mixed-Mode' Optoelectronic Applications Possibilities Using Phase-Change Materials and Device

C. David Wright [1] Yat-Yin Au [1] Harish Bhaskaran [2] Gerardo Rodriguez-Hernandez [2] Peiman Hosseini [2] Carlos Rios [2] Ritesh Agarwal [3] Wolfram HP Pernice [4]

[1]University of Exeter Exeter United Kingdom[2]University of Oxford Oxford United Kingdom[3]University of Pennsylvania Philadelphia United States[4]Karlsruhe Institut fuuml;r Technologie Eggenstein-Leopoldshafen Germany

Hide Abstract

To date the main applications of phase-change materials and devices have been limited to the provision of non-volatile memories. Recently, however, the potential has been demonstrated for using a phase-change approach for the provision of entirely new concepts in optoelectronics, including phase-change displays, integrated phase-change photonic memories, optical modulation and optical computing [1-3]. Such novel applications are enabled by the ability of phase-change devices to operate in a 'mixed-mode' configuration, where the excitation is provided electrically and the sensing is carried out optically, or vice-versa. Exploitation of this mixed-mode is made possible in phase-change materials due to the large and simultaneous changes that occur in both refractive index and electrical resistivity on transformation between amorphous and crystalline states. In this paper, based on studies part-funded by the NSF Materials World Network, we present recent results of the use of such mixed-mode operation to provide new applications, including a demonstration of phase-change optoelectronics devices that can be used to make ultrathin all-solid-state colour displays of ultrahigh resolution [1], and hybrid integrated phase-change photonic circuits that offer both a low-power, multi-level memory capability and a computing functionality [2,3]. As so often mentioned by the late (and sadly missed) Stanford Ovhinsky at previous MRS meetings [4], phase-change materials have the potential to provide us with so much more than simple digital memory - a potential that we are now beginning to realize and exploit.
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2:45 AM - Y10.04
A Phase-Change-Based Synaptronic Device with Weight-Dependent Plasticity

Tomas Tuma [1] Manuel Le Gallo [1] Angeliki Pantazi [1] Abu Sebastian [2] Evangelos Eleftheriou [1]

[1]IBM Research - Zurich Rueschlikon Switzerland[2]IBM Rueschlikon Switzerland

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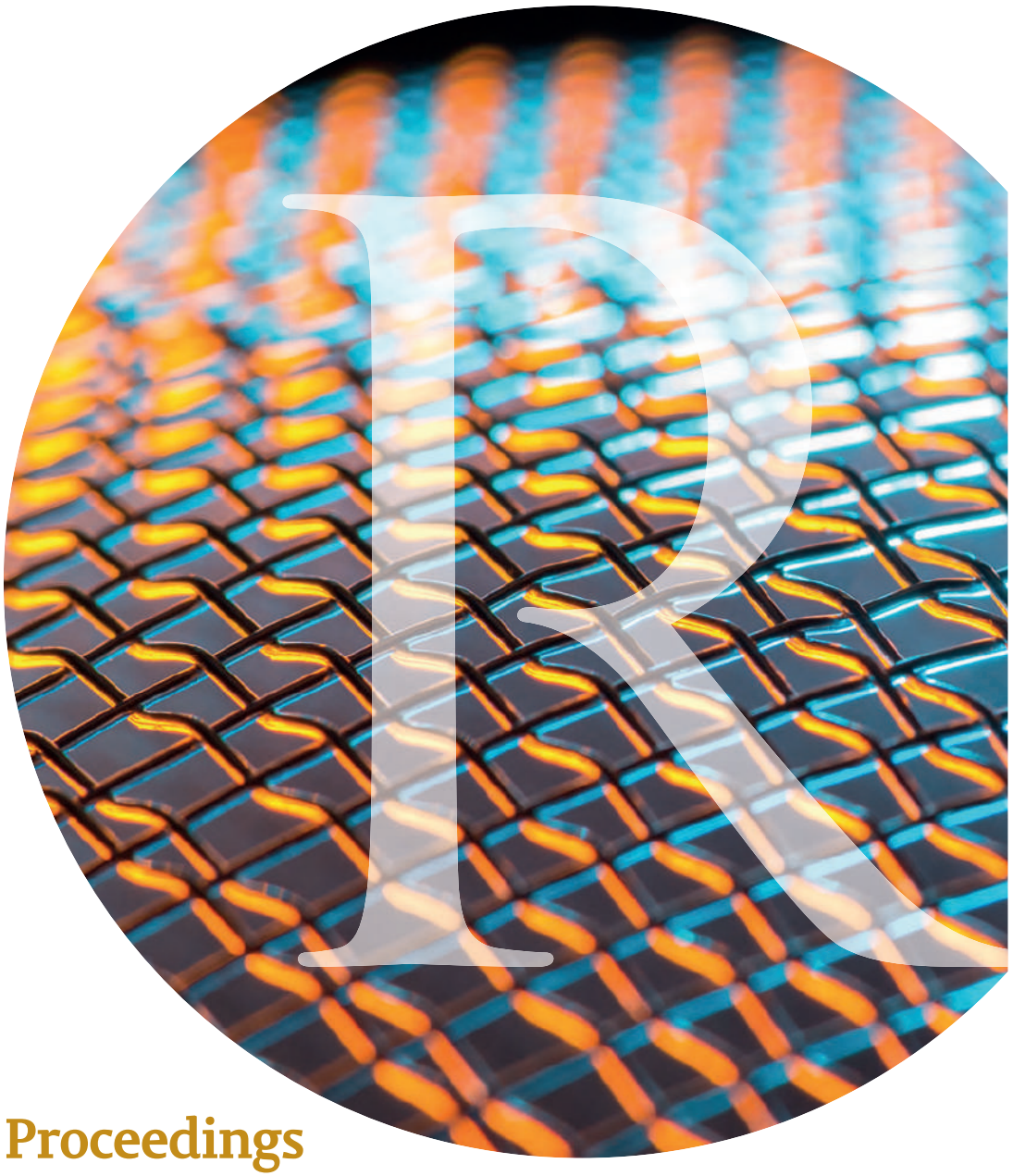
3:00 AM - Y10.05
Towards Artificial Electronic Neurons and Their Noises

RECONNAISSANCE

OPTICAL DOCUMENT SECURITY™



Conference Proceedings

A novel ultra-thin switchable OVD for fully personalisable active and passive security features

Lokeshwar Bandhu [a], Gerardo Rodriguez Hernandez [a], Clement Talagrand [a], Graham Triggs [a], Sergio Garcia-Castillo [a], Ben Broughton [a], Harish Bhaskaran [a,b] and Peiman Hosseini [a].

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ABSTRACT

Interference based OVDs are well-known security devices used in a variety of applications such as document, currency and high value goods protection. In this paper, we present a novel and extremely versatile type of switchable OVD (SOVD) coating capable of reversibly manipulating light using an optical, electrical or heat excitation. Light modulation is achieved by reversibly changing the physical phase of an ultra-thin (7 – 15 nm) continuous layer of chalcogenide based phase change material sandwiched between two transparent layers. The optical stack is designed to switch precisely between two states with tuneable colour and view angle variability, in a few microseconds, with high contrast, high reflectivity and without consuming any power once the switching is completed. The versatility of this novel non-printing, non-destructive technique is demonstrated by optically switching regions of a continuous film ranging from nanometres to millimetres using an inexpensive visible-light laser system. More importantly, the films are deposited using PVD manufacturing techniques that are available within the industry and are known to be up-scalable without aggressive capital requirements. Finally, all the materials that we use are well characterised in terms of reliability and already commercialised on different applications such as re-writeable DVDs and Blu Ray disks.

Keywords: phase change, OVD, SRD, ultra-thin personalization

1. INTRODUCTION

Chalcogenide based Phase Change materials (PCMs) are functional materials able to switch between two solid states when an appropriate thermal stimulus is supplied to the system(1). PCMs have already played a major part in the realisation of an optically accessed, re-writable, data storage media able to store considerable amount of information on a cheap, flexible, plastic substrate (i.e. CD, DVD, Blu-ray)(2). Recently, PCMs have also been demonstrated as promising candidates for the next generation electronic solid-state memories due to Flash Drive and Hard Disk Drive technologies reaching their respective storage density physical limits(3). Phase Change materials are indeed active in both in optical and electrical domains, a characteristic that makes them suitable candidates for future reflective-type ultra-high resolution, video capable, solid reflective displays (SRD)(4-6).

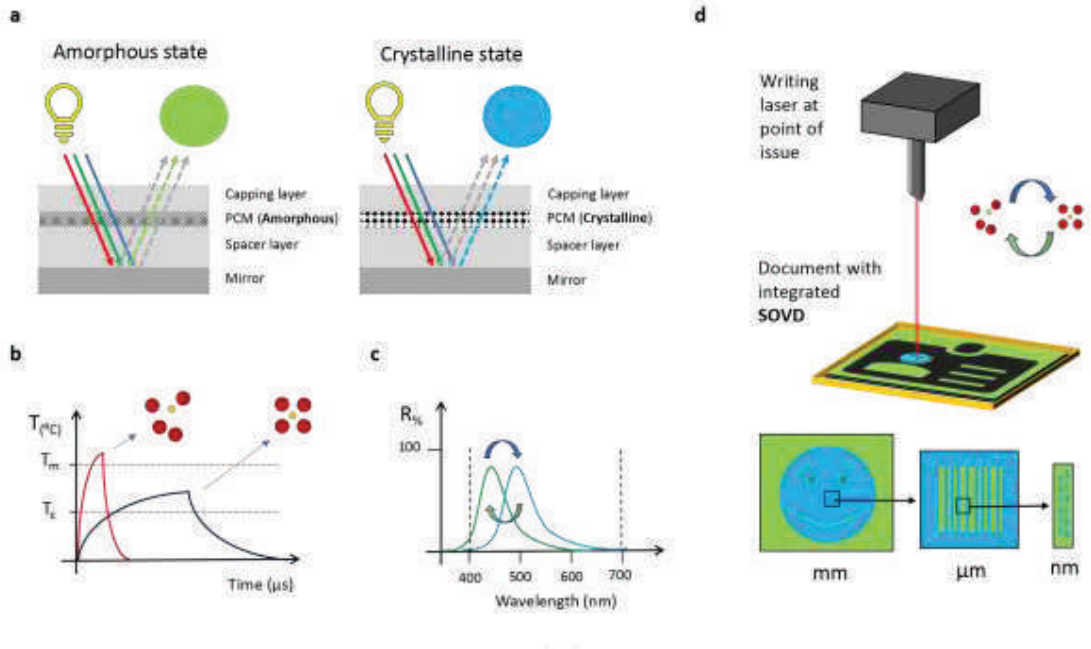

Figure 1 – Schematic representation of a phase change material based SOVD (switchable OVD). An ultra-thin layer of PCM is used to modulate the reflected colour generated by a strong inference optical cavity. ***a*** *The physical phase of the PCM (amorphous or crystalline) dictates the colour reflected from a thin optical cavity.* ***b*** *The stack can be switched between the amorphous and crystalline phase by heating up the PCM layer locally from millimeters to nanometers.*

In this paper, we demonstrate how PCMs can be applied to novel switchable OVD (SOVD) applications by creating a colour switchable, ultra-thin interference-based film with a tuneable degree of optical angle dependence. The fundamental physics governing the technology have already been discussed elsewhere(5); a schematic representation of the basic structure can be found in Figure 1**a** for convenience to the reader. Briefly, a 7 nm layer of solid PCM ($Ge_2Sb_2Te_5$) is sputtered between two adjacent layers of transparent materials (ITO) and on top of a thick metallic mirror (Ag). Chalcogenide based PCMs are engineered to be stable in two very optically distinct physical phases: amorphous and crystalline. The two states have very different refractive indexes in both the real and imaginary part of the refractive index. Changing the phase of the ultra-thin PCM generates a dramatic change in the reflected spectra of the entire optical stack (as shown in Figure 1**c**) created by what is known as strong interference effect(7). As for traditional interference stacks, the reflected colour appearance can be designed by simply adjusting the thickness and ordering sequence of each layer within the optical stack. Optical cavities based on strong interference effects have the advantage of being inherently thin (less than 400 nm in total) and showing close to zero angle dependence. It is important to note that the whole stack is deposited on one single run, without breaking vacuum, using standard sputter deposition from commercial solid targets(5). A localised pulse of heat of only a few µs can be used to switch between these two bistable, solid states, millions of times(3) as shown in Figure 1**b**. Once a heat cycle is concluded the phase change material will remain in its current state for roughly 10 years at 80^0 C temperature(1). Heat can be applied via optical, electrical or combined opto-electrical means(8). The diagram of Figure 1**d** shows an example of how a SOVD integrated film can be used to personalise a document at a point of issue. A pulsed scanning laser system is used to "write" crystalline regions of an amorphous PCM film designed to switch between to specific colours by the issuing body. The same laser could also be used to read, re-write and erase the SOVD of an existing document adding encrypted or hidden information such as last point of entry, biometric data, digital signature, etc. with feature sizes anywhere between millimetres to nanometres.

A collection of 8 different examples of PCM based SOVD with different colour can be found in Figure 2**a**. The samples were made with different cavity thicknesses and, since the deposition is done at room temperature, the PCM layers are always expected to be deposited in the amorphous phase. After the deposition step, each sample was cut in 2 pieces and one half placed on a hot plate at 200 ^{0}C for 1 minute to ensure full crystallisation of the PCM layer. The entire collection of 16 samples was divided into 8 pairs of optical stacks with one sample having the PCM in the amorphous state and one in the crystalline state and photographed at both a straight and a shallow angle. It is interesting to note how the majority of the samples show bright colours and high contrast with extremely low angle dependency. This is an inherent feature of the strong interference effect which is not commonly available in dielectric based interference filters.

Figure 2**b** shows an example of a laser addressed PCM based SOVD with a scale of millimetres. The stack was designed to show large contrast upon switching and low angle dependence. Figure 2**c** shows an example of the ultrahigh-resolution capabilities of this SOVD technology. A conductive atomic force microscope tip is employed as a moveable hot electrode used to crystallise nanometre size region of an otherwise continuous amorphous film similarly to(5). It is important to remember that this is not a destructive technique, the film topography remains the same (both in terms of roughness and flatness) before and after the crystallisation pulse. Remarkably, the combination of room temperature vacuum deposition and ultra-thin nature of the active film makes the SOVD inherently compatible with flexible substrate. Figure 2**d**,**e** show two examples of a thin BoPET (mylar) substrates coated with different stacks showing excellent uniformity and highly metallic appearance. Figure 2**d** was designed to show angle dependence upon tilting contrary to Figure 2**e** that was purposely designed to show near zero angle dependence.

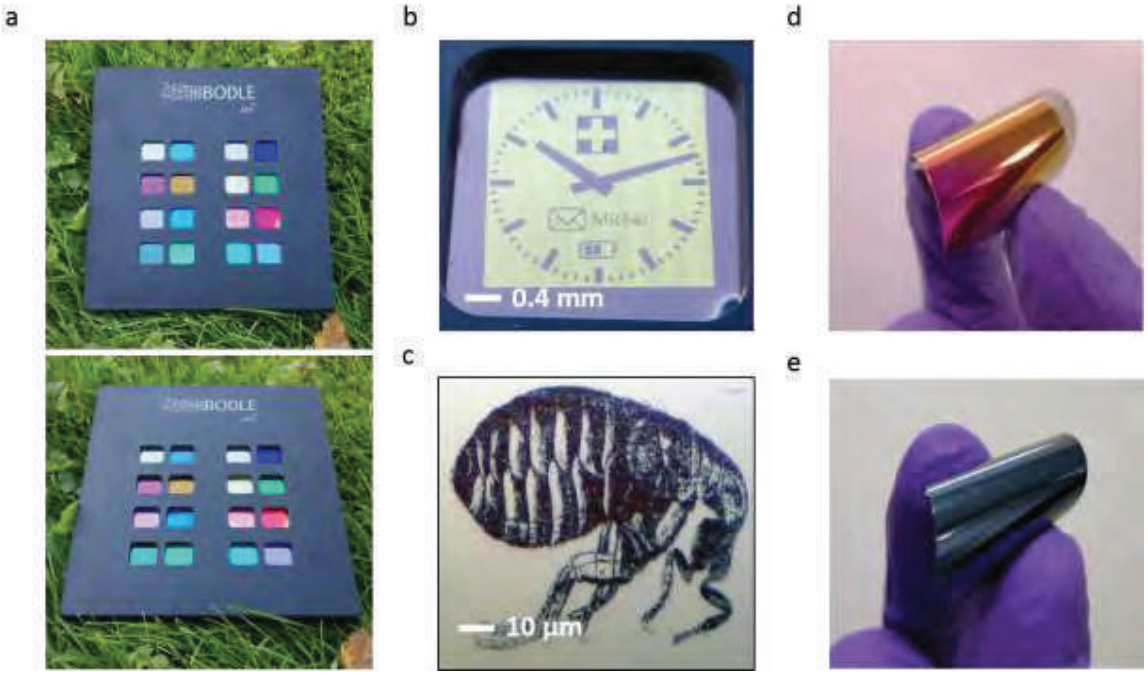

Figure 2 – Examples of various SOVD films. ***a****. 8 pairs of amorphous versus crystalline films showing high contrast upon switching and small angle dependence.* ***b****. A millimeter sized area of an SOVD switched using a visible laser scanning system.* ***c****. A nanometer sized area of a similar film switched using a conductive atomic force microscope. Extreme high resolution is a feature inherently available with PCM based SOVD.* ***d****. Example of a flexible stack deposited on a BoPET substrate. This particular stack was designed to show angle dependence upon tilting. Room temperature deposition and ultra-small thickness of the active layer make the technology readily suitable for flexible substrates.* ***e****. A different example of a flexible stack deposited on a BoPET substrate. This particular stack was designed to show near zero angle dependence.*

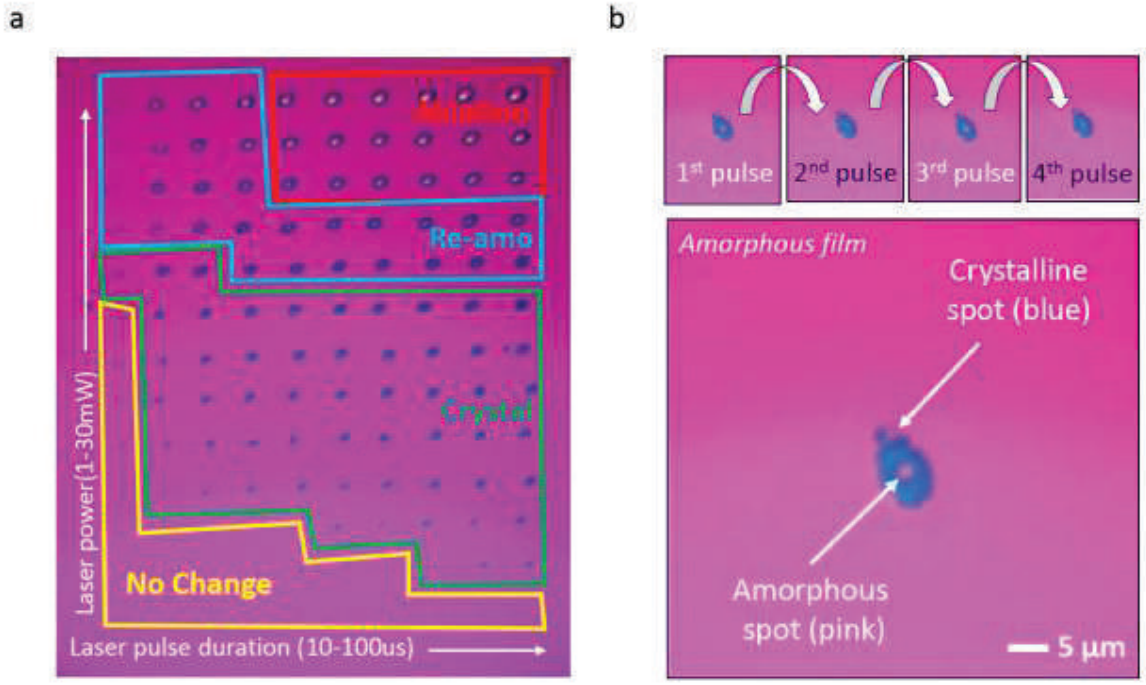

Figure 3 – Laser addressability of a high contrast SOVD film. The film was designed to switch from a pink (amorphous) colour to a blue (crystalline) colour. a. A continuous, amorphous SOVD film is pulsed with a 890 nm NIR laser with increasing power and duration. Four separate regions of Crystallisation (green), Re-amorphisation (blue), Ablation (red) and No Change (yellow) are observed. b. The cycle-ability of the SOVD film is demonstrated by re-writing a 1 µm spot several times between the amorphous and crystalline phases.

As previously discussed, laser writing of patterns over a large range of dimensions is an interesting feature of the PCM based SOVD technology. *Figure 3***a** demonstrates high resolution laser addressing of an amorphous SOVD film using a focused NIR laser. A matrix of pulses with increasing power and time defines four distinct regions of operations named: No Change, Crystallisation, Re-Amorphisation and Ablation; as expected for a purely thermal switching mechanism, the region of operation is solely defined by the energy injected into the active layer of the SOVD. *Figure 3***b** demonstrates the cycle-ability of this particular SOVD film. A blue coloured, crystalline spot is written on an otherwise continuous pink amorphous film by appropriately tuning a slightly de-focused pulse according to the power-time matrix. The same laser is then re-focused and programmed to cycle the material a few times; full erase-ability is demonstrated. It is important to note that the re-writeability of a SOVD is a feature that can be added if needed and is not fundamental towards the implementation of the optical system. A write-once SOVD film can be readily realised by employing PCM that are inherently write once in nature or that have crystallisation kinetic too fast to be cycled on a plastic or glass substrate(1).

We have already described how strong interference optical films generally show an inherently low angle dependence. In this work we show for the first time how it is possible to purposely design SOVD stacks that display large colour contrast upon switching while having a large degree of optical angle dependence at the same time. Unfortunately, given the lack of an all-encompassing analytical theory for strong interference based optical cavities, multi-environmental, optimisation approaches are currently the only practical technique used to design more sophisticated PCM based SOVD. This visually appealing feature gives an extra degree of design freedom ideally suited for overt security features. *Figure 4***a** show the simulated design for an optically variable SOVD for a continuous film with an amorphous PCM layer and a total thickness of 400 nm. The stack displays a high degree of colour contrast (from blue to red) by tilting the film over 60 degrees. *Figure 4***b** shows the simulated optical properties of the same film with the PCM layer switched to the crystalline state. A dramatic change in optical contrast is now visible at all angles with the film changing between pink and yellow over the same range of tilting angles. A prototype SOVD film showing both angle dependence and a large colour contrast between the amorphous and crystalline phases can be found in *Figure 5***a**. This PCM based film is deposited on a glass wafer and partially switched to its crystalline phase by carefully positioning half of the sample on a hot plate set at 250º C. Good similarity with the simulation shown in *Figure 4* are demonstrated. No roughening of the surface is visible as expected from a purely phase change driven induced colour contrast. *Figure 5***b** shows the same optical design deposited on a PET film and switched using a continuous, rastering type 450 nm laser system. The expected phase change induced colour contrast is followed by a small increase in roughness of the plastic film. This is attributed to a softening of the substrate induced by laser overheating. Replacing

the continuous laser system with a pulsed system approach is expected to eliminate this issue without lowering the degree of colour contrast. This is due to extremely fast crystallization dynamics of the PCM that requires a few microseconds to fully crystallise.

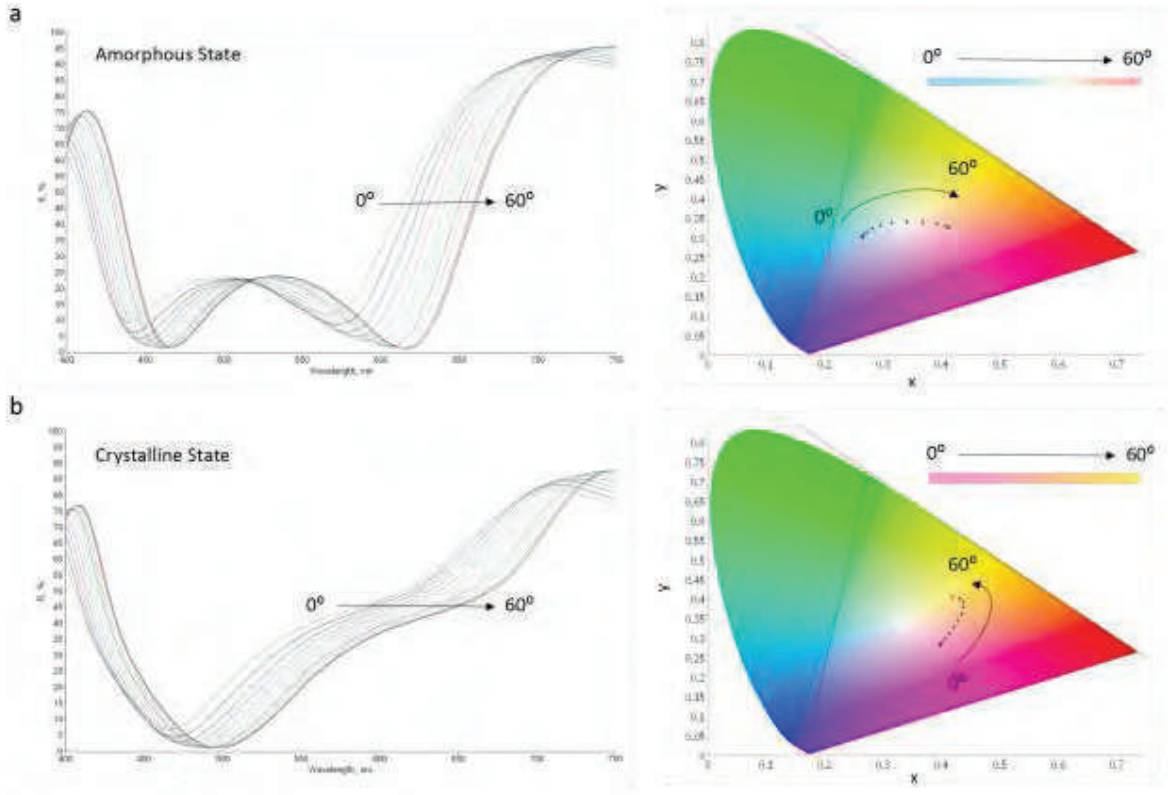

Figure 4 – SOVD with angle dependence by design. SOVD films can be designed to show colour change upon switching and tilting at the same time. ***a****. Simulated design for an optically variable SOVD for a continuous film with an amorphous PCM layer. The stack displays a high degree of colour contrast (from blue to red) by tilting the film over 60 degrees.* ***b****. The same film with the PCM layer switched to the crystalline state. A dramatic change in optical contrast is now visible for all angles.*

Figure 5 – A prototype SOVD film showing both angle dependence and a large colour contrast between the amorphous and crystalline phases. ***a.*** *An angle dependent SOVD film is deposited on a glass wafer and partially switched to the crystalline phase by carefully positioning half of the sample on a hot plate set at 250° C. No roughening of the surface is visible as expected from a purely phase change driven induced colour contrast.* ***b.*** *A film with identical optical design is deposited on a PET film and switched using a continuous, rastering type visible laser system. The expected phase change induced colour contrast is followed by a small increase in roughness of the plastic film. This is attributed to a softening of the substrate induced by laser overheating. Substituting the continuous laser system with a pulsed system approach is expected to eliminate this issue without lowering the degree of colour contrast. This is due to extremely fast crystallization dynamics of the PCM that requires a few tens of nanoseconds to fully crystallise.*

Here we demonstrate how these SOVD films can be laser switched before and after a lamination step. *Figure 6* shows a SOVD with low angle dependence and high contrast deposited on a PET substrate and switched with a continuous 450 nm laser system loaded with a pre-defined pattern. The film is then laminated with a standard office laminator at 125º C and a second pattern written through the transparent lamination using the same laser system. Both patterns are readily visible without any noticeable difference in appearance. Higher temperature lamination (>250º C) is possible by tuning the composition, and corresponding crystallization temperature as shown in PCM based high temperature data storage applications(1).

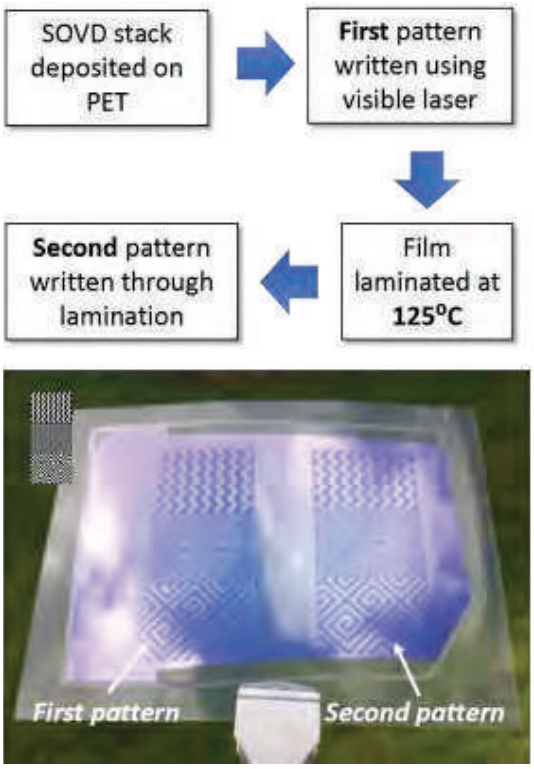

Figure 6 – SOVD films can be laser switched before and after a lamination step. Here a SOVD with low angle dependence and high contrast is deposited on a PET substrate and switched with a continuous laser system loaded with a pre-defined pattern. The film is then laminated with a standard office laminator at 125° C and a second pattern written through the transparent lamination using the same laser system. Both patterns are readily visible without any noticeable difference in appearance. Higher temperature lamination (>250° C) is possible by tuning the composition, and corresponding crystallization temperature as shown in data storage applications(1).

Finally, PCM based SOVD have the potential to move beyond angle dependence and single colour switching to a much broader range of optical switching effects. Recent work on optoelectronic applications of PCMs have shown how the same technology can be used in exciting multi-PCM, multi-colour films(9), direct writing, non-destructive holograph generation(10) and even switchable planar lenses(11). It is reasonable to envisage each of these techniques having direct applicability to the security and OVD market however a deeper understanding of the mechanical reliability of these inorganic, ultra-thin layers is still lacking and will be required prior to any commercialisation effort.

CONCLUSION

We have demonstrated for the first time a switchable OVD, named SOVD, that uses an ultra-thin chalcogenide-based phase change as active element. The film can be designed to switch between a variety of colours by tuning the thicknesses of each layer within the stack. Similar stacks can also be made angle dependent upon design if needed adding an extra degree of freedom for designing the next generation of security films. Prototype films with and without angle dependence were deposited on glass and PET substrates showing good agreement with optical simulations. A continuous, blue laser system was used to write pre-defined patterns with predictable colour contrast. Finally, SOVD film deposited on PET were shown capable of withstand a standard lamination process without losing contrast and with the possibility to write subsequent pattern before and after a lamination step,

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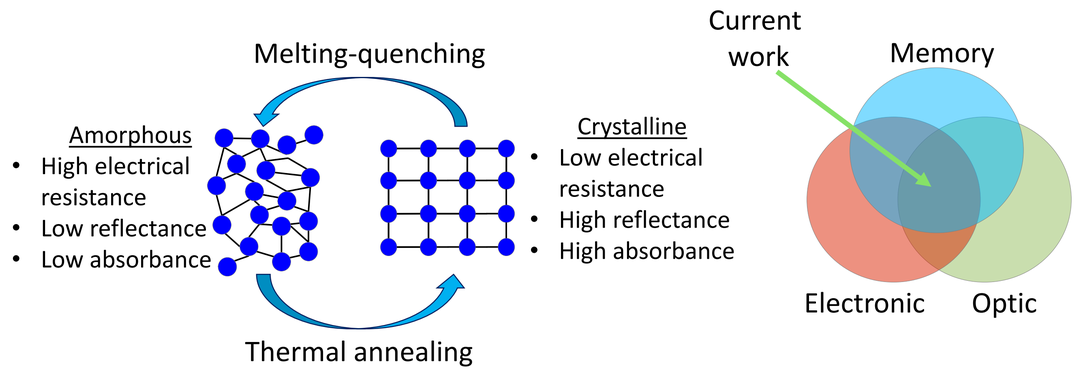
Study of $Ge_2Sb_2Te_5$ properties for opto-electronic applications

Gerardo Rodriguez-Hernandez, Peiman Hosseini, Harish Bhaskaran
Department of Materials, University of Oxford

Introduction

The Phase Change Material $Ge_2Sb_2Te_5$ (GST) has been used in memory applications due to its property of reversibly switching between amorphous and crystalline states, when optical or electrical pulses are applied. A previous work [1] has shown that it is possible to modulate colour by modifying the optical properties of a thin film of GST inside a nano-cavity as a consequence of electrically inducing phase change. In this study we show that it is also possible to control the no-volatile resistive state of a Phase Change Memory Cell (PCM) by alternating optical and electrical stimuli, effectively producing an opto-electronic memory device.



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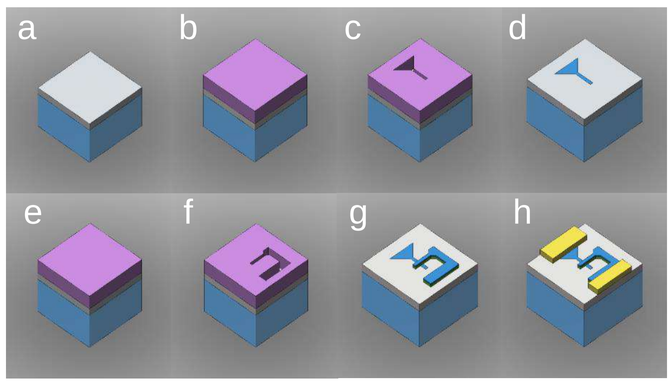
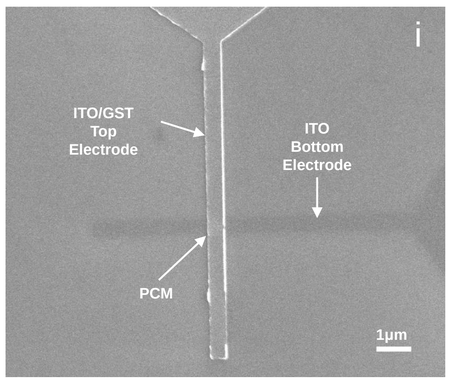
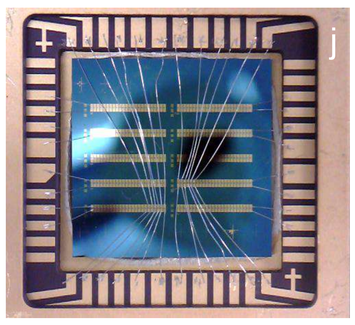
Device Fabrication

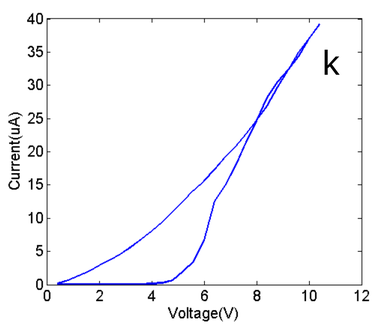
We fabricated cross bar devices by depositing a thin film of GST between Indium Thin Oxide (ITO) transparent electrodes. This allows optical and electrical access to the PCM.



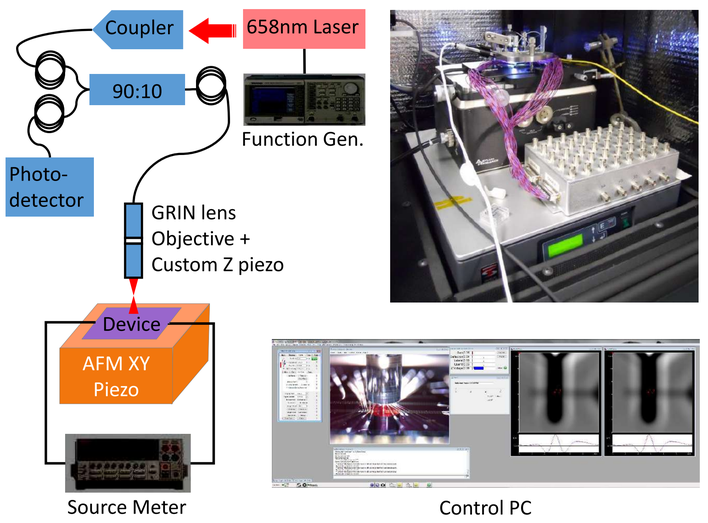


Starting with a Si/SiO2 substrate *(a)*, we patterned the bottom electrode using e-beam lithography *(b,c)*. Then we created trenches in the substrate by RIE. Later, those trenches are filled up with ITO deposited by RF sputtering. After lift off, the bottom electrode is complete *(d)*. Later, the top electrode is created by the second e-beam lithography step *(e,f)* but now GST and ITO are deposited *(g)*. Finally, Au access electrodes are added *(h)*. Many completed devices *(i)* are fabricated per chip. This chip is mounted on a chip carrier and wire bonded *(j)*. Characteristic threshold switching IV curve *(k)* shows that the devices work properly.





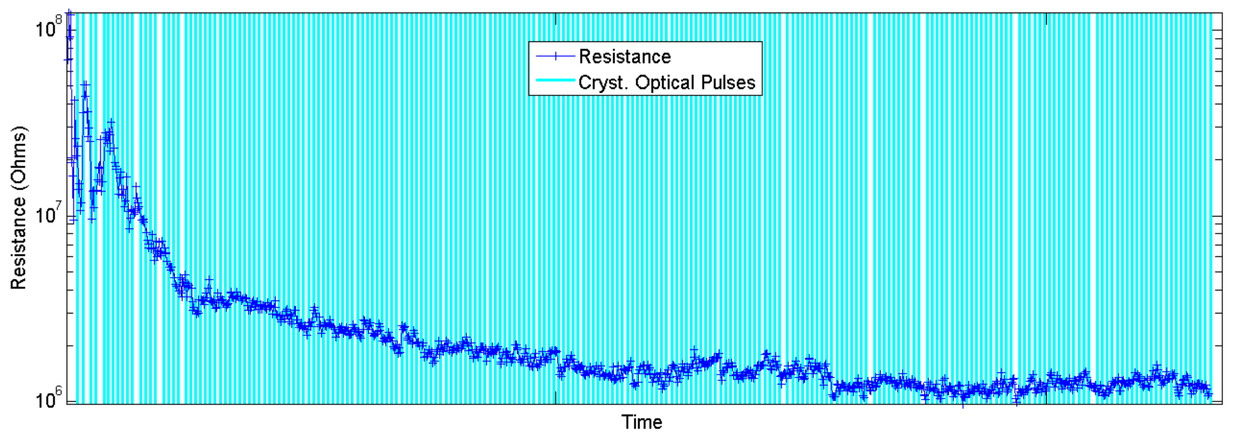
Experimental Setup



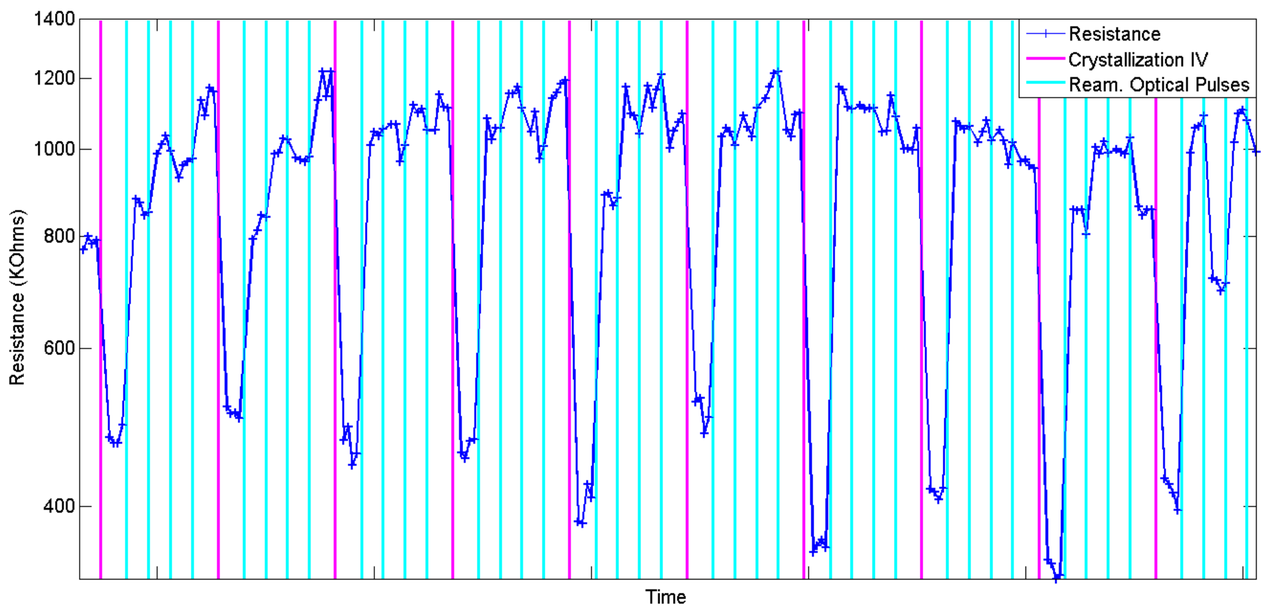
We fabricated two custom built accessories for our XY-AFM piezo stage. A magnetic holder with electrical connections for the chip carrier, and a Z stage that positions the GRIN lens objective on the devices to apply optical pulses.
Electronics and data acquisition are controlled by a PC.

Combined optical and electrical operation

By applying a series of optical pulses it is possible to incrementally crystalize the device due to the accumulation property of Phase Change Materials. The decrease in resistance confirms that it is possible to modify the electrical properties of the device by optical means.



Further, we partially re-amorphized the GST in the device by applying optical pulses and then re-crystalized it with an IV curve for over 100 iterations. (Detail of 10 typical iterations is shown.)



Conclusions

We have shown the potential of Phase Change Material $Ge_2Sb_2Te_5$ to produce a new type non-volatile devices that can be operated by a combination of optical and electrical stimuli and can be read electrically. This type of devices have the potential to integrate electronics with future photonic systems. Further study of the evolution of optical properties upon change in resistance is required to better understand the crystallization process of the material within the device, in order to optimize the operation parameters and increase the resistance contrast between high and low resistive states.

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Test Date:	13 Mar 2009
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Inst. Code:	Dept. Code:
3461	99

Registration Number:	0000 0000 0729 9613
Name:	Rodriguez, Gerardo
Gender: M	Native Country: Mexico
Date of Birth: 09 Dec 1979	Native Language: SPANISH

1 [redacted]

M02584

000065

Rodriguez, Gerardo

2 [redacted]

TOEFL SCALED SCORES	
Reading	28
Listening	28
Speaking	26
Writing	22
Total Score	**104**

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12

Reading Skills	Level	Your Performance
Reading	High (22-30)	Test takers who receive a score at the **HIGH** level, as you did, typically understand academic texts in English that require a wide range of reading abilities regardless of the difficulty of the texts. Test takers who score at the **HIGH** level, typically • have a very good command of academic vocabulary and grammatical structure; • can understand and connect information, make appropriate inferences, and synthesize ideas, even when the text is conceptually dense and the language is complex; • can recognize the expository organization of a text and the role that specific information serves within the larger text, even when the text is conceptually dense; and • can abstract major ideas from a text, even when the text is conceptually dense and contains complex language.

Listening Skills	Level	Your Performance
Listening	High (22-30)	Test takers who receive a score at the **HIGH level**, as you did, typically understand conversations and lectures in English that present a wide range of listening demands. These demands can include difficult vocabulary (uncommon terms, or colloquial or figurative language), complex grammatical structures, abstract or complex ideas, and/or making sense of unexpected or seemingly contradictory information. When listening to lectures and conversations like these, test takers at the **HIGH** level typically can • understand main ideas and important details, whether they are stated or implied; • distinguish more important ideas from less important ones; • understand how information is being used (for example, to provide evidence for a claim or describe a step in a complex process); • recognize how pieces of information are connected (for example, in a cause-and-effect relationship); • understand many different ways that speakers use language for purposes other than to give information (for example, to emphasize a point, express agreement or disagreement, or convey intentions indirectly); and • synthesize information, even when it is not presented in sequence, and make correct inferences on the basis of that information.

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Mixed-Mode Electro-Optical Operation of $Ge_2Sb_2Te_5$ Nanoscale Crossbar Devices

*Gerardo Rodriguez-Hernandez, Peiman Hosseini, Carlos Ríos, C. David Wright, and Harish Bhaskaran**

The use of phase-change materials for a range of exciting new optoelectronic applications from artificial retinas to ultrahigh-resolution displays requires a thorough understanding of how these materials perform under a combination of optical and electrical stimuli. This study reports for the first time the complex link between the electronic and optical properties in real-world crossbar nanoscale devices constructed by confining a thin layer of $Ge_2Sb_2Te_5$ between transparent indium tin oxide electrodes, forming an optical nanocavity. A novel proof-of-concept device that can be operated by a combination of optical and electrical stimuli is presented, leading the way for the development of further applications based on mixed-mode electro-optical operation.

Chalcogenide-based phase-change materials have been the subject of much scientific interest because of their ability to reversibly switch between two solid states, amorphous and crystalline, at high speed[1] and with relatively low power consumption.[2] Transitions between states are achieved via localized heating with energy applied either optically or electrically.[3] One of the most common phase-change materials is $Ge_2Sb_2Te_5$ (GST). Each of the atomic configurations of GST have different physical (optical, electrical, and mechanical) properties.[4] The crystalline phase is more reflective and up to three orders of magnitude more electrically conductive than the amorphous phase.[1] These differences in the physical properties between phases, in addition to the ability to retain either phase state for a long time at ambient temperatures,[5] have been utilized in technologies such as rewritable optical data storage (DVD-RW, Blu-ray RW) and nonvolatile electronic phase-change memories (PCMs).[6] Exploiting both optical and electrical properties of phase-change materials simultaneously, and the possibility of modulating optical effects using electrical excitations, has only very recently opened up new application fields, such as low-power, nonvolatile, phase-change nanodisplays.[7–9] A deeper understanding of the relationship between the optical and electrical properties of phase-change materials, such as GST, is now urgently required to spur the development of new optoelectronic applications.

Some previous studies have examined the basic relationship between reflectance and electrical resistance of phase-change materials. For instance, by comparing the crystallization times of $Ge_{15}Sb_{85}$ in planar films excited optically and in bridge nanodevices excited electrically, it was shown that optical and electrical properties are interrelated.[10] Furthermore, simultaneous measurements of reflectivity and electrical resistivity of GST thin films during isothermal crystallization showed a decrease in resistivity preceding an increase in reflectivity, explained by the appearance of small crystalline nuclei that enable electrical conduction by percolation prior to the formation of a crystalline region large enough to be optically detectable.[11] Similar observations have been reported by measuring the transient crystallization response of as-deposited-amorphous GST exposed to single-nanosecond laser pulsed excitations.[12]

In the above-mentioned works, films were driven from fully amorphous to fully crystalline by applying either a continuous heat source or laser pulse. However, intermediate partially crystalline states can of course also exist. In particular, GST allows for the existence of nanometer-sized crystalline nuclei in the amorphous phase by having a nucleation dominated crystallization mechanism.[13] The eventual increase in the size and number of crystalline nuclei usually accounts for the transition to the fully crystalline state. Therefore, by applying a series of pulses with a controlled amount of energy, it is possible to transition between fully amorphous and fully crystalline states in discrete incremental steps. This property has been referred to as accumulation and occurs by means of optical as well as electrical pulses.[14–16]

In this work therefore we investigate the phase transition of GST by simultaneously examining the optical and electrical responses of crossbar-type nanoscale devices exposed to cumulative optical and electrical excitations.

In order to apply laser pulses and measure the reflectance of the samples, we used a custom-built reflective laser scanning

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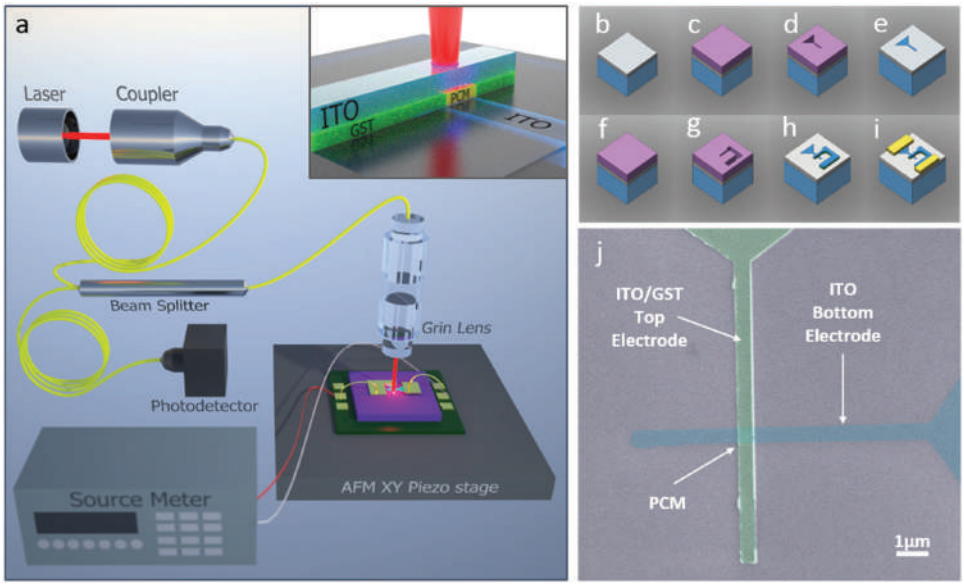

Figure 1. a) Schematic diagram of our experimental setup, inset contains a representation of the optical nanocavity formed by the different layers of the crossbar device (not to scale). b–i) Fabrication steps of crossbar nanodevices. b) Initial Si/SiO_2 wafer, c) bilayer PMMA resist (495 + 950), d) e-beam patterning and development of bottom electrode design, this mask is used for reactive ion etching (RIE) of trenches, later the trenches are filled with ITO deposited by radio frequency (RF) sputtering, e) completed bottom electrode after lift-off, f) second bilayer PMMA resist (495 + 950), g) e-beam patterning and sputtering of GST/ITO layers to form the top electrode, h) top and bottom electrodes completed after lift-off of the top electrode mask, and i) Cr/Au access electrodes are added to complete the device. j) Digitally colored scanning electron microscopy image of a completed 500 × 500 nm^2 crossbar nanodevice, inset describes the optical stack formed by the crossbar area.

microscope (**Figure 1**a). A 658 nm (red) laser diode (ROHM RLD65PZB5) is coupled to a single mode optical fiber using an aspheric lens coupler/collimator (Thorlabs F280APC-B). Once coupled, the beam passes through a 90:10 fiber beam splitter (Thorlabs FC632-90B-APC) that allows the reflected signal to be sensed by a photodetector (New Focus 2001). The scanning objective was built in a confocal configuration by assembling a ferrule terminated single mode optical fiber (Thorlabs SMPF0206-APC) to a 0.29 pitch gradient index (grin) lens (Thorlabs GRIN2906). This configuration allows the fiber to be used as a pinhole[17] in the path of the reflected light. The optimum values for the trade-off between working distance and spot size were calculated following a transfer matrix model[18] and set to 328 and 2.24 μm, respectively. The scanning objective was mounted on top of the precision XY piezo stage of an Asylum MFP-3D atomic force microscope (AFM) using a custom-built base in contact to the XY piezo by a three groove kinematic clamp. By using the MFP-3D AFM it is possible to perform the XY movements to construct the image as well as to use one of the integrated AFM analog/digital converters to acquire the photodetector signal simultaneously with the raster scan. Such synchronization allows for precise positioning of the laser beam subsequently to the scan. The focus of the laser spot on the sample (Z axis) was controlled by a combination of a manual linear stage (Thorlabs DT12/M) for coarse adjustment and a custom-built multielement piezo linear actuator[19] for fine adjustment. Essentially, we adapted the extremely fine linear (*x*–*y*) piezo of our Asylum AFM to our home-built optical probe, in order to optically test our devices. Similar laser probing configurations have been reported previously in the literature.[20] In this case, however, we used fiber coupled optical components in order to reduce the footprint of the custom made laser accessory so it could be accommodated in the existing MPF-3D AFM system.

For our experiments we fabricated crossbar nanoscale devices following the process shown in Figure 1b–j, with indium tin oxide (ITO) transparent electrodes which confine a small GST area forming an optical nanocavity that is accessible optically and electrically. Starting with a thermally oxidized Si wafer (320 nm SiO_2) (Figure 1b) and by employing a bilayer positive resist (polymethyl methacrylate (PMMA) 495 + PMMA950) (Figure 1c), the bottom electrode design was patterned by e-beam lithography (Figure 1d). After development, reactive ion etching (RIE) was used to produce 20 nm deep trenches in the SiO_2. The trenches were then filled with 20 nm ITO deposited by RF plasma sputtering (Figure 1e). After lift-off, the sample was annealed at 300 °C for 30 min in air to improve the conductivity of the ITO bottom electrode. The trenches in the SiO_2 substrate serve as a simple planarization mechanism, which is used to increase the yield of the devices by avoiding short circuit between the top and bottom electrodes in the cross bar structure, in addition to improving thermal properties of the device. A second e-beam lithography process was used to pattern the top part of the cross bar device (Figure 1f–g). In this case a 15 nm thin-film of GST was deposited by RF sputtering, followed by 20 nm of ITO that serves as the transparent top electrode. Both materials were deposited within the same deposition run, avoiding the GST being exposed to oxygen from air (Figure 1h). Then, a set of larger electrodes were added to access the device electrically. These electrodes were created by a third e-beam lithography process followed by thermal evaporation of 30 nm Cr as an adhesive layer followed by 60 nm

Au. The considerable thickness of the Cr adhesive layer (30 nm) was used to improve the electrical contact between the ITO and the Au electrodes.[21] A batch of 48 devices of each size 100, 200, 300, 500 nm, and 1 μm were fabricated simultaneously during the fabrication process, it was found during characterization that 500 nm and 1 μm gave the better response in terms of reliability and optical response and were therefore used for our experiments. Finally, electrical access to the devices was achieved by wire bonding each device to a chip carrier. The chip carrier was mounted on a custom-made magnetic holder designed to firmly fix the device in place during the raster scan of the laser microscope. Electrical measurements were performed with a source meter (Keithley 2614B).

It is known that thermal characteristics play an important role in the operation of phase-change memories.[22] Good heat containment accounts for more efficient devices, by reducing thermal losses. The use of ITO electrodes in the present design serves two purposes: it enhances thermal isolation because of its low thermal conductivity, ≈11 W mK^{-1}, compared to metallic electrodes while simultaneously allowing optical access to measure the changes in reflectance induced by the change of phase of the GST layer.

Three combined mixed-mode experiments were carried out to explore the simultaneous electrical and optical behavior of phase-change materials (in this case GST) in a nanoscale device context. The first experiment was to ascertain how optical pulses would modulate the resistance of the devices. We subjected our devices to a series of optical pulses to induce crystallization; the resistance of the device was then measured after each optical pulse. The optical pulses were 50 ns in duration and 13 mW in power (output power radiated from the grin lens), a combination that allows for a steady progression from the initial as-deposited amorphous state to the crystalline phase. **Figure 2**a shows the evolution of the resistance for two devices of dimensions 500 nm × 500 nm and 1 μm × 1 μm. As it can be seen, the resistance value in both devices gradually drops, by approximately three orders of magnitude in this case, as the cumulative effects of the optical pulses lead to crystallization. It is important to notice that despite the large change, the device is highly resistive at all times (≈1 MΩ in the low value) this is caused by the parasitic resistance of the ITO electrodes. As the GST becomes more crystalline, the electrical resistance decreases in both devices of different sizes. The difference in the accumulative response of both devices is due to an increase of the thermal losses associated with wider electrodes. Therefore the optical pulses applied to the larger device were less effective in inducing crystallization, and more were required to reach the lowest resistive level.

In the second experiment, we examine how electrical excitation pulses affect the optical properties, specifically the reflectance, of a device. We thus applied a series of electrical pulses to a 500 nm × 500 nm crossbar cell, measuring its resistance and reflectance after each pulse. The applied voltage pulses were of 2.5 V and 100 ns duration, which again allows for a steady accumulative phase transition. Our optical measurements were performed by acquiring sequential images with our laser scanning microscope using a low intensity laser beam of 1 mW. The images were then post-processed following the methodology described in Section S1 of the Supporting Information (using such a methodology serves two purposes: first, after every scan it is possible to reposition the laser before applying the next pulse in case of unexpected stage drift; second, we can use the imaged substrate reflectance as a reference to compensate for laser intensity variations).

Figure 2b shows the evolution of the reflectance and resistance of the crossbar device as a function of the number of electrical pulses applied. The electrical resistance drops as the number of pulses increases, as would be expected for a device undergoing crystallization via an accumulation process. Surprisingly, however, the reflectance of the devices decreases with increasing number of applied pulses. This behavior is counterintuitive, given that it is known that the reflectance of blanket GST films increases upon crystallization for wavelengths in the visible spectrum.[23] In this case, however, such response is a consequence of a shift, upon partial crystallization, in the resonance of the optical cavity formed by stacking the different layers (ITO/GST/ITO) that form the cell. This shift is produced by the change of the refractive index of the GST upon partial crystallization[7] (for more information see Section S2, Supporting Information).

It can also be seen in Figure 2b that the evolution of the reflectance occurs before the final resistance drop. The fact that

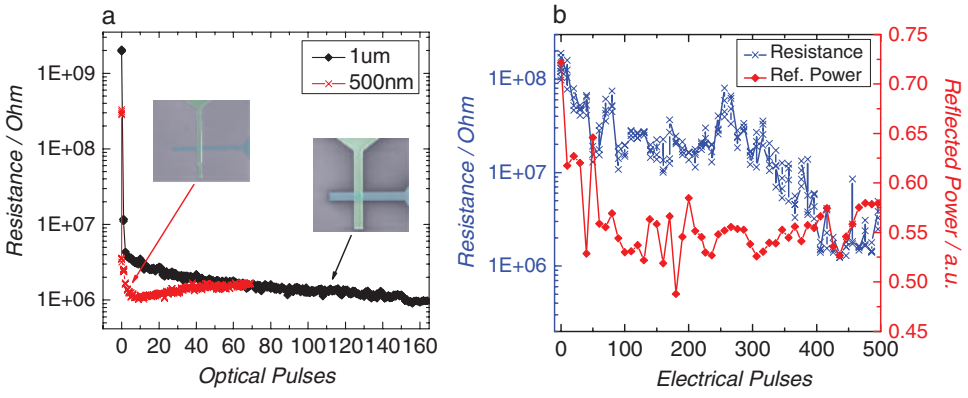

Figure 2. a) Evolution of electrical resistance in response to consecutive optical pulses. b) Evolution of resistance and optical reflectance in response to consecutive electrical pulses applied to a 500 nm device.

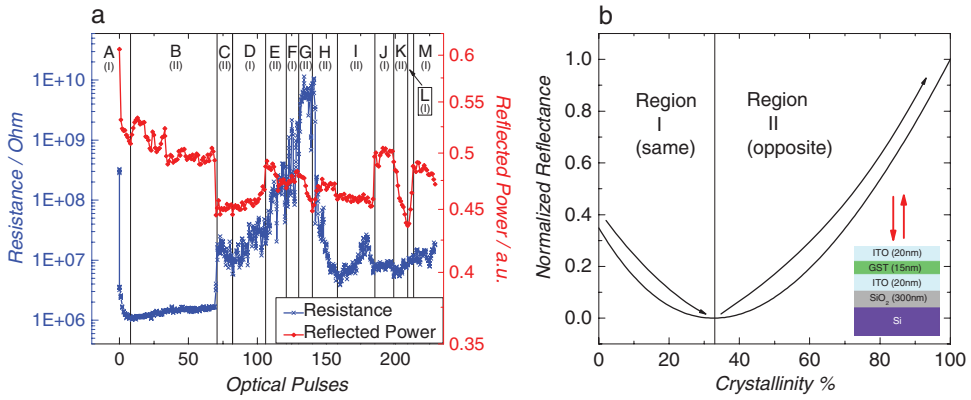

Figure 3. Explanation of the change in reflectance versus resistivity as a consequence of the optical cavity effect. a) Evolution of resistance and reflectance by applying optical pulses, divided into regions where trends either follow or oppose each other. b) Calculated optical response of the nanocavity formed by an ITO/GST/ITO crossbar cell as a function of the fraction of crystallized material in the cell. The scale is normalized against the maximum change of reflectance for the specific stack design.

both measurements evolve differently suggests that the crystallization of the GST within the device may not be occurring homogeneously. These findings are similar to the previously observed by Liang et al.,[12] who explained a delay in the evolution of the reflectance respect to the resistance by a 2D percolation model.

Thus far, we have shown that subjecting the GST crossbar cell to optical pulses produces an observable change in resistance and that electrical pulses produce and observable change in reflectance. However, in order to further understand the relationship between the changes of these two physical properties we performed an additional experiment applying a series of 50 ns, 13 mW optical pulses to a 500 nm × 500 nm device and measured both the resistance and the reflectance after each pulse. These results are shown in **Figure 3**a. The graph has been divided into sections, and each section has been selected to highlight how the trends of the reflectance and resistance changes are either opposite or in tandem to each other as the GST freely changes phase.

In these results, the change in reflectance follows a similar behavior to the one observed in the previous experiment (Figure 2b). As explained before, the reflectance initially decreases upon partial crystallization due to the resonance change of the optical nanocavity caused by the change of the refractive index of GST. Figure 3b shows the simulated non-monotonic optical response at 658 nm of the optical nanocavity as a function of the crystalline fraction.

This curve is divided into two regions: in region (I) the reflectance decreases as the GST partially crystallizes; in region (II) a further increase of crystallization induces an increase in reflectance, reaching the peak value when the GST becomes fully crystalline. Given that an increasing crystallization fraction will produce a monotonic decrease of resistance, as was shown previously in Figure 2a, within region (I) the trends in the change of resistance and reflectance will be opposite to each other, whereas in region (II) they will be the same. Thus, different degrees of crystallization are responsible for the changes shown in the various regions (A–M) of Figure 3a, as the GST in the device traverses between regions (I) and (II) of the optical response shown in Figure 3b. This remarkable opto-electronic response is a consequence of the optical resonance characteristics of the optical nanocavity formed by the crossbar cell, along with the fact that, for the particular optical excitation pulses used here, the cell "oscillates" between regions (I) and (II) due to a process of partial crystallization and partial reamorphization induced by successive excitations in tandem with the change in absorbance of GST between amorphous and crystalline states[24] (this can be inferred from the observation that the partial reamorphization takes place only after sufficient crystallization has occurred—see Figure 3a, region A).

Up to this point, we have shown that a correspondence exists between resistance and reflectance when either optical or electrical excitation pulses are applied and that such correspondence depends on the degree of partial crystallization. In our third experiment we demonstrate true combined electro-optical operation of our devices (mixed-mode) at the nanoscale. A 500 nm × 500 nm device was conditioned optically until it reached the lowest resistance state. We then iteratively applied a series of 50 optical pulses of 80 ns at 65 mW of optical power (measured at the GRIN lens output) to reamorphize the GST, followed by an incremental staircase voltage signal (Figure S4, Supporting Information) from 0 to 4 V to electrically crystallize the material again.

Figure 4 shows the result of ten iterations of our mixed-mode experiment. It is seen that after the application of a series

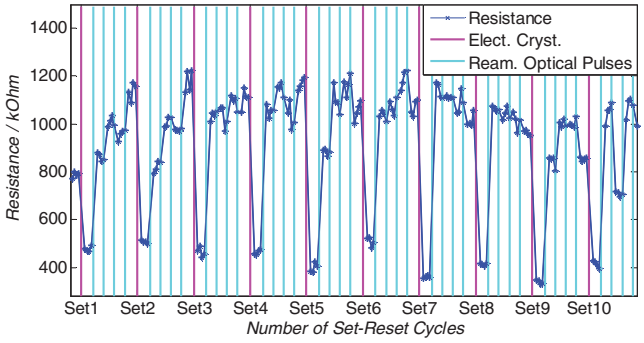

Figure 4. Detail of the change in electrical resistance during ten iterations of an electrically induced crystallization followed by an optical pulse induced remorphization.

of optical pulses, an increment in the resistance is observed. Similarly, after an electrical triangular staircase signal is applied, the resistance decreases again as the GST recrystallizes. The change of the resistance is approximately one order of magnitude, which is significantly less than the change observed in the first transition from as-deposited amorphous state reported previously in Figures 1 and 2. Also the operation occurs in the lower range of the resistance, near the fully crystalline region. Both of these indicate that the optical pulses do not fully reamorphize the material (see Section S4, Supporting Information). However, partial reamorphization does occur and modulates the resistance, demonstrating mixed-mode operation for the very first time in nanoscale devices. We repeated the behavior seen in Figure 4 for over 100 iterations.

In conclusion, we have experimentally shown for the very first time in nanoscale GST phase-change devices that there exists a complex relationship between the resistance, reflectance, and crystallinity of the GST. Such a relationship exists irrespective of the means used to induce the crystallization (i.e., electrical or optical pulses). An optically induced phase-change can readily produce a change in device resistance while at the same time an electrically induced phase-change can be observed as a change in reflectance. We have also shown that partial crystallization due to accumulation of pulses occurs, and we suggest that partial crystallization of the GST within our mixed-mode device is not homogeneous. Further investigation is required to understand whether crystalline and amorphous phase segregation occur within the device, in order to optimize the optical contrast and energy required for the operation. Moreover, we have provided a proof-of-concept GST nanodevice in mixed-mode electro-optical operation by crystallizing it electrically and reamorphizing it optically while the resistance values show two different repeatable states. Our results are a first step toward the realization of a memflector[25] (the optoelectronic analogue of the memristor), as well as other optoelectronic devices for future applications that require a memory element capable of operating electrically and optically. Such applications include optoelectronic interfaces for integrated photonic circuits,[26,27] in addition to potential new technologies like accumulative optical pulse detectors or synthetic retinas.

Experimental Section

E-Beam Lithography: A Jeol-5500 Series E-beam lithography tool and a PMMA bilayer resist (PMMA495 + PMMA950) were used. The final lithographic step to create access electrodes used a single PMMA495 resist layer.

Reactive Ion Etching: At a base pressure of 5×10^{-6} mTorr, 20 nm of SiO_2 was etched using 25 sccm CHF_3 + 25 sccm Ar, and an operating pressure of 30 mTorr for 1 min @ 200 W.

Bottom Electrode Deposition: This was carried out in a Nordiko system; ITO was sputtered from a 2 in. target (Testbourne, UK) with a base pressure of 1×10^{-7} mbar, operating pressure of 7×10^{-3} mbar, 100 sccm Ar @ 30 W for 9 min 30 s.

Radio Frequency Sputtering GST/ITO Top Electrode: $Ge_2Sb_2Te_5$ was sputtered from a 2 in target (Super Conductor Materials, USA) with a base pressure of 1×10^{-7} mbar, a chamber pressure of 7×10^{-3} mbar, flow of 100 sccm Ar, at a power of 30 W for 4 min 10 s. The ITO top electrode was then sputtered in situ, with the same parameters as bottom ITO electrode.

Thermal Evaporation: 30 nm of Cr + 60 nm Au was evaporated from a Cr rod and Au wire on W crucible, respectively, at rate of 0.1 nm s^{-1} monitored by a crystal deposition monitor. Chamber base pressure was 2×10^{-6} mbar.

Supporting Information

Supporting Information is available from the Wiley Online Library or from the author.

Acknowledgements

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Conflict of Interest

H. Bhaskaran serves on the Board of Directors of Bodle Technologies Limited where he is also a consultant. P. Hosseini is the Chief Technology Officer of this firm. Both are co-founders of the firm and hold equity interests in this company. The results of this paper were not funded by Bodle. There are several patent applications surrounding the use of these materials in device applications by G. Rodriguez-Hernandez, C. Ríos, P. Hosseini, and H. Bhaskaran.

Keywords

nanodevices, optoelectronics, phase-change materials, phase-change photonics

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Scaling Limits of Graphene Nanoelectrodes

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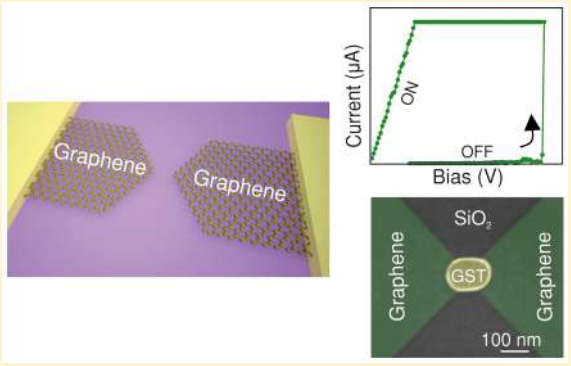
Supporting Information

ABSTRACT: Graphene nanogap electrodes have been of recent interest in a variety of fields, ranging from molecular electronics to phase change memories. Several recent reports have highlighted that scaling graphene nanogaps to even smaller sizes is a promising route to more efficient and robust molecular and memory devices. Despite the significant interest, the operating and scaling limits of these electrodes are completely unknown. In this paper, we report on our observations of consistent voltage driven resistance switching in sub-5 nm graphene nanogaps. We find that such electrical switching from an insulating state to a conductive state occurs at very low currents and voltages (0.06 μA and 140 mV), independent of the conditions (room ambient, low temperatures, as well as in vacuum), thus portending potential limits to scaling of functional devices with carbon electrodes. We then associate this phenomenon to the formation and rupture of carbon chains. Using a phase change material in the nanogap as a demonstrator device, fabricated using a self-alignment technique, we show that for gap sizes approaching 1 nm the switching is dominated by such carbon chain formation, creating a fundamental scaling limit for potential devices. These findings have important implications, not only for fundamental science, but also in terms of potential applications.



KEYWORDS: *Graphene nanogaps, electroburning, phase change material, self-alignment approach*

The ability to create nanometer-sized gaps in sp^2-bonded carbon materials offers a means of contacting nanoscale objects, for example, nanocrystals and single molecules, that cannot be achieved with conventional metallic electrodes. The fact that these materials have a thickness of only a single or few atomic bond lengths strongly reduces electrostatic screening and enables gating of molecular orbitals.[1] Moreover, the reduced contact area between atomically thin electrodes and phase change material nanocrystals has been shown to lower the power requirements for current-induced phase changes.[2] Because of the strength of the sp^2 carbon−carbon bond, the atomic mobility of carbon atoms is significantly lower than that of metal atoms, and carbon-based electrodes are therefore expected to be significantly more robust, even at room temperature.[3] However, we find that the intense electric fields generated by applying a bias voltage across a nanometer-size graphene gap result in the spontaneous rearrangement of atoms and bonds that lead to reversible switching of the resistance. Here, we investigate the scaling limits imposed by this switching behavior in the context of phase change memory (PCM) devices. However, our findings carry equal significance for all applications based on graphene nanogaps, including single-molecule electronics[1,4,5] and graphene-based genome sequencing.[6]

The energy consumption and access speed of phase change memories[2] and other data storage technologies, including oxide memory,[7,8] have been shown to improve significantly as a result of scaling down the dimensions between the contact electrodes. Ultimately, the performance of these memory devices is determined by the active volume that switches between two states of contrasting electrical resistance. In theory, this volume could be scaled to the dimension of a single unit cell volume[9] that requires sub-2 nm spaced electrodes. In this paper, we find that it is the intrinsic switching behavior of the graphene electrodes, rather than the properties of the phase change material, that ultimately limits the device scaling and therefore its performance.

We use a method of feedback-controlled electroburning to create graphene nanogaps ranging from ∼1 to 60 nm and, using a self-alignment approach, we deposit a small volume of $Ge_2Sb_2Te_5$ (GST) over the gap. Only in the case of large nanogaps (>20 nm) do we find that the resistance switching is due to the GST, while for smaller gaps it is fully dominated by the graphene. We characterize the graphene switching by studying bare graphene nanogaps and estimate the critical electric field for switching F_{crit} = 40 mV/Å. This critical field dictates the maximum operating voltage for a given gap-size, or minimum gap-size for a given operating voltage, for any technology based on graphene nanoelectrodes.

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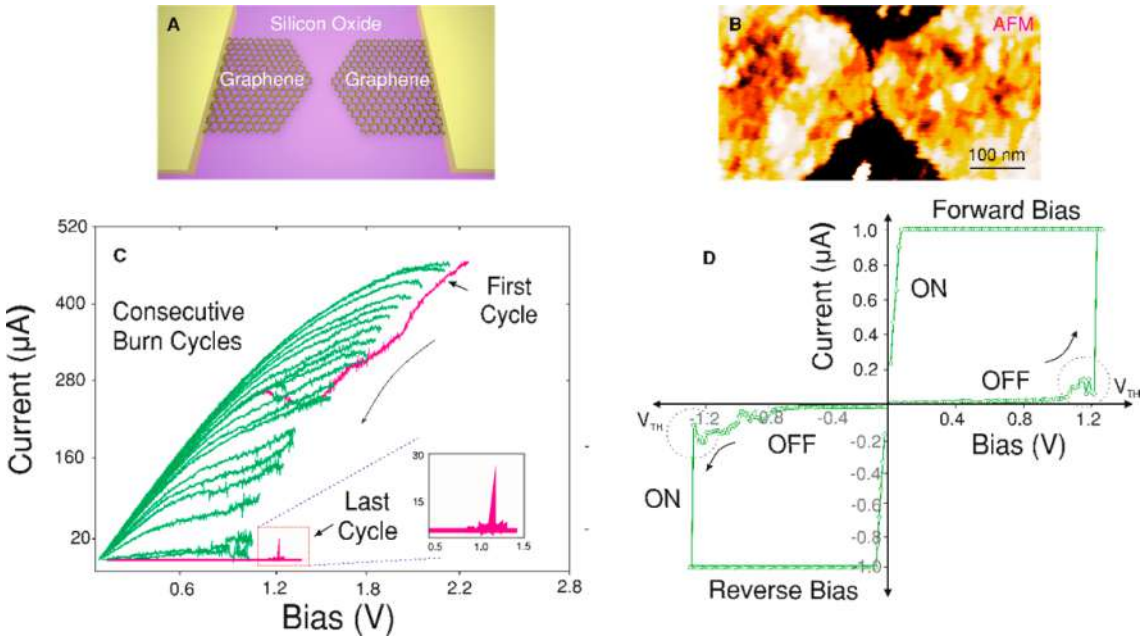

Figure 1. A graphene nanogap device. (A) Schematic representation of a graphene nanogap device; gap size is exaggerated for visualization. (B) AFM image of a graphene nanogap device; the gap (~1 nm) is not resolvable near the center of the constriction. (C) Current–voltage (I–V) characteristics during feedback-controlled electroburning of graphene in ambient conditions. Inset represents the last cycle of the burning process, which shows a spike in conductance just before the gap forms. This current spike is attributed to single carbon filament formation. (D) Low-bias switching of a graphene nanogap device (3 nm gap size) in ambient conditions. The first quadrant represents switching with a forward (positive) bias. The device switched from a high resistive state to a low resistive state in ambient conditions at a switching voltage of 1.22 V and current 60 nA. The third quadrant shows the current–voltage characteristics of the same device under reverse (negative) polarity. The device switched at a voltage of 1.28 V and current of 100 nA. For all reversible switching experiments, a current compliance of 1000 nA was used.

We use a feedback-controlled electroburning[1,10] technique that relies on controlled Joule heating to form a nanoscale gap between two electrodes in an appropriately patterned graphene ribbon. This method has previously been used to create sub-5 nm gaps in mechanically exfoliated graphene,[1] chemical vapor deposition (CVD) grown graphene,[10,11] and epitaxial graphene.[12] Here, we use this method to create nanogaps in 2–3 layer CVD-grown graphene that was transferred onto a Si/300 nm SiO_2 substrate with Au connectors and bond pads prefabricated on the substrate. We use few-layered graphene rather than single-layer graphene in order to limit the effects of defects induced by sputter deposition of GST.[13] The graphene was patterned into a bow-tie geometry with a 100 nm wide constriction (see Figure 1B) using electron beam lithography and oxygen-plasma etching. During the electroburning process, nanogaps form at the constriction, where the current density and therefore the Joule heating are highest.[10] At each stage of the electroburning process, we monitor the source-drain current when the voltage across the device is ramped up (see Figure 1C). As the current drops due to electroburning of graphene at the constriction, the resistance increases; the feedback-control is programmed to then ramp down the applied bias voltage back to zero. This process is repeated until the device has a resistance >500 MΩ. By adjusting the feedback-control parameters, we can fabricate nanogaps ranging from approximately 1 to 100 nm.

We estimate the size of the nanogaps by fitting the measured current–voltage curve to the Simmons model.[14] From these fits (see Section S2) we find that the smallest gaps range from 0.5 to 3.5 nm. Using atomic force microscopy (AFM) we confirm that the nanogap formation starts at the corners of the constriction and then propagates inward (see Figure 1B). In approximately half of the devices, we observe a sharp increase in the conductance prior to the formation of a nanogap (see inset Figure 1C). Similar conductance enhancement behavior has been reported before[15−17] and is attributed to the formation of carbon filaments. Density functional theory and tight-binding simulations have shown that the transition from a multipath configuration to a single-path configuration may lead to an enhancement of quantum transport.[17] In the following section, we describe the observation of reversible resistance switching in our devices, which we attribute to the controlled formation of carbon filaments.

After we form a nanogap using feedback-controlled electroburning, we can set the device back to its low resistance state by sweeping the bias voltage past a threshold voltage in ambient conditions (see Figure 1D). We observe that this switching behavior is independent of the bias polarity after having switched the device from the high resistive "OFF" to the low resistive "ON" state and by applying a forward bias we switch it OFF by repeating the electroburning and then switch it ON again by applying a negative bias. As shown in Figure 2B, the conductance switching is fully reversible; we can switch the device from the ON to the OFF state by performing the feedback-controlled electroburning process (see Figure 2C) and switch back from the OFF to the ON state by sweeping the bias voltage beyond the threshold voltage (Figure 2D). We can repeat SET (from OFF to ON) and RESET (from ON to OFF) multiple times.

Reversible conductance switching of graphene nanogaps has previously been reported for graphene on SiO_2 and suspended graphene in vacuum.[18−20] The temperature dependence observed in these studies, as well as in this paper (see Figure S4d) provides a strong indication that the switching process

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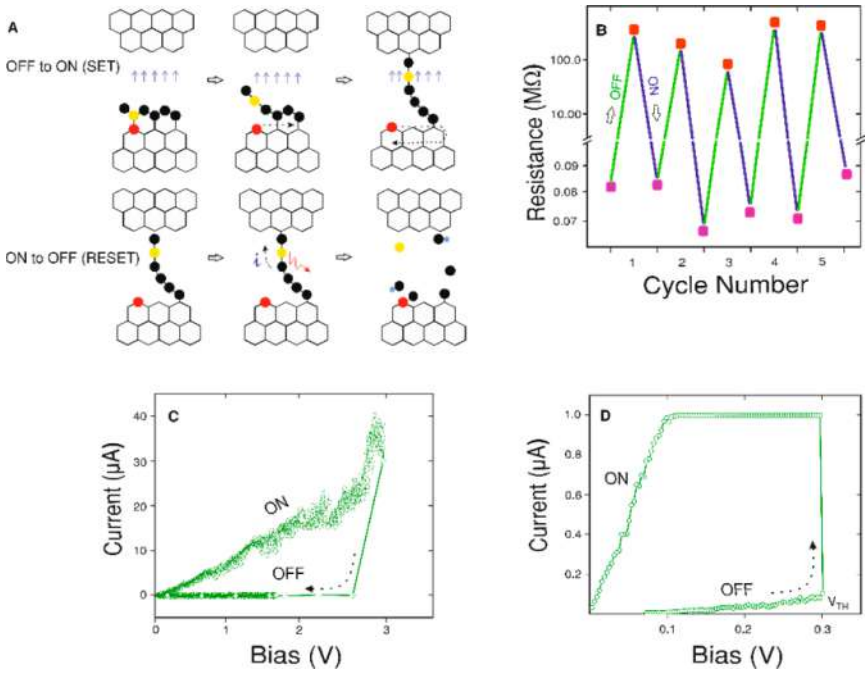

Figure 2. Cyclic switching via filamentation in a graphene nanogap device. (A) Proposed scheme for the formation and breaking of carbon filaments following ref 21. During SET (OFF to ON), formation of a carbon filament initiates from the edge of the graphene; when the local electric field at atomically sharp edges gets sufficiently high, it breaks a bond parallel to the axial electric field (between red and yellow atoms in the schematic). Filamentation then proceeds in a row-by-row fashion as indicated by the dashed arrows. For RESET (ON to OFF), Joule heating provides sufficient thermal energy for the rupture of bonds through oxidation of carbon atoms (oxygen represented by blue circles). (B) The device is switched between the high resistance and low resistance state multiple times in ambient conditions. (C) Current−voltage behavior during RESET in ambient conditions showing similarity to electroburning traces in the previous electroburning cycle (Figure 1c). (D) Illustrates a typical SET $I-V$ characteristic in ambient conditions. The device switched at a switching voltage of 300 mV and current 80 nA.

involves the rearrangement of atoms and/or chemical bonds that requires overcoming a barrier.[18] A possible mechanism for this rearrangement is the formation of carbon filaments, which in the case of carbon nanotubes was identified as the process through which they unravel by the action of an electric field.[21] Figure 2A shows a schematic depiction of the filamentation process; the force exerted by the electric field breaks the C—C bond of an edge atom with incomplete sp^2 bonding. The filamentation process then proceeds as a rupture of C—C bonds parallel to the graphene edge. The fact that we observe reversible switching in ambient conditions is potentially because of the feedback-control when switching the device OFF. The gap size resulting from electroburning without feedback-control strongly depends on the oxygen concentration of the atmosphere and ranges between ∼100 nm in ambient condition to ∼5 nm under a vacuum ∼10^{-5} mbar.[22] We find that we are unable to SET devices when electroburning without feedback-control.

The SET requires a field strength F_{crit} = 40 mV/Å by assuming to a first approximation that the applied bias voltage drops linearly across the 0.75 nm gap. This field strength is similar to that observed previously[19] for a gap size of ∼10 nm, which switched at ∼4 V, suggesting that there is a critical field strength required to unzip the carbon filament(s) from graphene. Interestingly, this electric field strength is 2 orders of magnitude lower than the field strength that has been theoretically estimated (≥2 V/Å)[23,24] for unravelling a carbon filament from a graphene edge. We attribute this discrepancy to weakening of the C—C bond strength resulting from incomplete sp^2 hybridization and enhancement of the local electric field at atomically sharp graphene edges.[25]

On the basis of measurements of the critical field required for switching graphene, we estimate that to switch a $Ge_2Sb_2Te_5$ (GST) volume with a voltage less than 4 V, we require a gap size of at least 10 nm. To demonstrate this, we compare GST contacted in both 1 and 20 nm wide graphene nanogaps. To place the GST volume over the graphene nanogap, we use a self-alignment method that relies on the local removal of PMMA in the vicinity of the graphene constriction during the electroburning process. Similar self-alignment techniques have been previously demonstrated for fabrication of CNT nanogaps-based PCM devices,[26] however, not in combination with feedback-controlled electroburning. Here we demonstrated the applicability of this technique on CVD grown graphene, which allows for scalability as graphene can be grown on wafers and subsequently patterned using lithography. The simplified one-step process requires no high-resolution lithography or vacuum. After several cycles of electroburning, we spin-coated ∼100 nm of poly(methyl methacrylate) (PMMA) onto our devices. Continuing the feedback-controlled electroburning process, we locally heat up the graphene constriction, which leads to the formation of trenches resulting from the local evaporation of PMMA. These trenches serve as self-aligned windows for subsequent deposition of the phase change material, which in our demonstrator case is GST. The size of the trenches depends on the number of electroburning cycles, that is, the resistance of the graphene device, prior to spinning the resist. We have simulated the electroburning process (see Section S3) using finite element analysis. The resulting trench sizes agree well with our experimental observations. Figure 3A,B shows an AFM image of a self-aligned trench in PMMA, and a scanning electron microscopy (SEM) image of the device after sputter-

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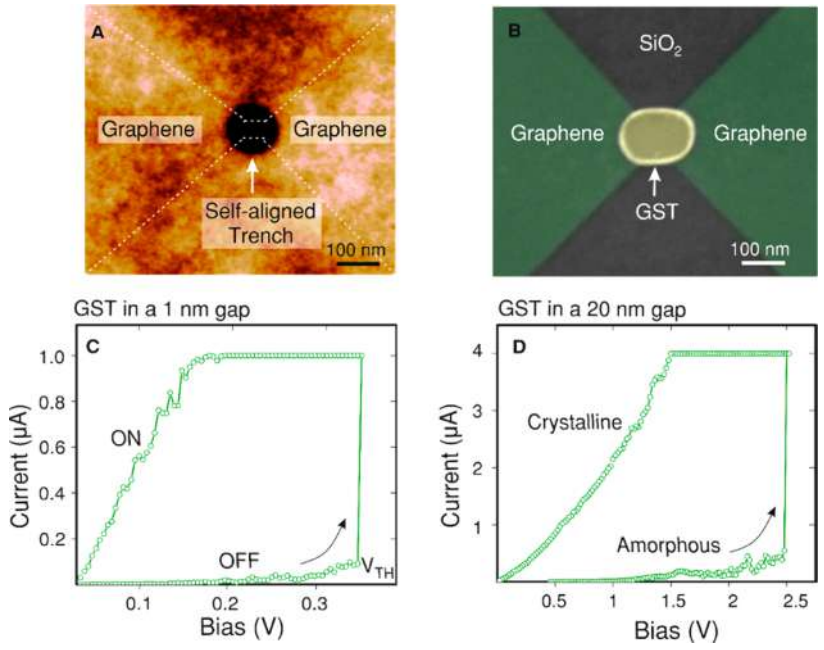

Figure 3. Self-alignment approach and phase change memory device. (A) AFM image showing a trench of size 148 nm (largest lateral dimension) in PMMA. This trench is formed in situ from local degradation of PMMA due to Joule heating during the electroburning process. Dotted line outlines the graphene ribbon underneath PMMA. (B) Colored SEM image of a self-aligned PCM device showing the phase change material (GST) in the nanogap. The trench in the PMMA ensures that the GST is self-aligned to the gap in the graphene electrodes, thus eliminating the need for sub-10 nm alignment. (C) Current−voltage trace of a GST nanogap device; GST is aligned to make contact to graphene in a 1 nm nanogap. The device switches from a high resistive state to a low resistive state in ambient conditions at a switching voltage of 370 mV and current 100 nA. (D) Current−voltage characteristics of a GST device with a gap size of ∼20 nm. GST switches from a highly resistive amorphous state to a less resistive crystalline state at a bias of 2.5 V and current 500 nA. The ratio of resistance between these states averages to ∼1000.

deposition of GST (∼12 nm) and PMMA lift-off. We avoided capping layers in order to eliminate any probable interfacial interactions between the capping layer and GST, which are known to influence switching behavior.[27]

Figure 3C shows the current−voltage characteristics of a self-aligned PCM device in a 1 nm wide nanogap. The device switches from a highly resistive state to a low resistive state at ∼2.5 V (Figure 3D) similar to the observed switching in bare graphene nanogaps in Figure 2A,B. GST is a semiconductor in both its amorphous and crystalline states, and we therefore do not expect to observe a linear $I-V$ character in either the ON and the OFF state. However, the $I-V$ characteristics of the ON state of the GST in a 1 nm gap is linear, similar to the bare nanogap. From this, we infer that the switching in the 1 nm nanogap is dominated by the formation of carbon filaments. By contrast, for GST deposited in a 20 nm gap the $I-V$ characteristics shows an exponential dependence in both the ON and the OFF state, which is in agreement with previous measurements of GST. Switching in GST devices occurs at a relatively high power and the resistance ratio between the highly resistive and less resistive state is ∼1000, indicative of switching in GST.[4,15] Finally, we test a device with a ∼ 20 nm nanogap without GST and find that the device has an open circuit characteristics, displaying no switching behavior even at very large bias values. At very large voltages of ∼120−150 V, dielectric breakdown of the underlying SiO_2 substrate is seen to occur (see Figure S4a). We attribute the absence of filamentation in wider gaps to instabilities of long carbon filaments.[28,29]

Reversible conductance switching has also been observed in SiO_2-based devices. To exclude effects[7,8] of SiO_2 mediated conductance switching we carried-out two experiments. In the first experiment, we placed 15 nm thick SiO_2 in the sub-4 nm gaps using the self-alignment technique. We observed no switching behavior, other than dielectric breakdown at ∼10 V (see Figure S4b). In the second, we created graphene nanogaps on an SiN substrate (see Figure S 5d), a material that shows no intrinsic switching.[8] We observed a similar switching behavior on this substrate as observed on the SiO_2 substrate. Furthermore, formation of Si nanoclusters through reduction of SiO_2 is recognized as the mechanism behind resistance switching in SiO_2 switching. Therefore, an oxygen deficient atmosphere is a prerequisite[7,8] for switching in unpassivated SiO_2. Our devices can be switched both ways readily in ambient conditions. It is therefore highly unlikely that SiO_2 switches in our devices because the switching site, which is the surface, is exposed to an oxygen rich atmosphere. In addition, the ratio of resistance between the OFF and the ON state is typically[7,8,30] > 10^4 in SiO_2, which is an order magnitude more than observed in our devices.

Having thus established sufficient evidence for switching from carbon filament(s) formation in nanogaps, an important question is how filamentation is possible when the phase change materials we use ($Ge_2Sb_2Te_5$ or GST) fills the 0.75 nm gap. The answer lies in structuring of the GST film during sputter deposition. Chalcogenide (which GST is) atoms show strong bonding preference for each other over SiO_2 for reasons relating to minimization of strain and surface energies and in the case of GST on SiO_2, this results in poor adhesion with the SiO_2 substrate.[31] Thus, it is expected that the island growth mode or the Volmer−Weber mode is preferred over layer by layer growth mode during deposition.[32] Furthermore, graphene shows a catalytic property toward the growth of chalcogenides.[33] This would result in the GST islands on graphene

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growing in all directions bridging, but not filling, the gap. This is supported by the absence of switching in the graphene nanogaps with SiO_2 in the gap. Furthermore, we deduce from experiments (see Figure S6) that for a 1 nm gap, GST should switch at ~2.15 V. However, switching in GST-bridged sub-5 nm devices occurs mostly at $V_T \sim 0.6$ V (with standard deviation of 0.5 V), which is similar to observed in empty graphene nanogaps. This strongly supports the argument that the presence of sputtered GST does not influence the switching behavior. Thus, there is a clear indication that regardless of the switching mechanism, there is a fundamental limit to scaling graphene nanogaps for such relevant material systems. This perhaps also applies for carbon nanotube nanogaps, which share similar bonding configuration (sp^2) as graphene and could be a subject of future work. Importantly, molecular electronics where the actual gap is not filled entirely by the molecule, but has several areas where such chains can grow, might also have a similar scaling limit.

Therefore, our observations indicate resistance switching in graphene nanogaps, which we attribute to the controlled formation and breakdown of carbon filaments. Analyzing the switching behavior, we find that the formation of carbon filaments is electric field dependent and only occurs in sub-5 nm gaps. These experiments demonstrate for the first time, reversible resistance switching in graphene nanogaps in ambient conditions. For PCM devices with electrode separations less than 5 nm, we find the resistance switching to be fully dominated by the formation of carbon filaments. Whereas the actual mechanisms that we propose (carbon filamentation) need further unambiguous proof, nonetheless our results point toward a key scaling limit to using such electrodes.

Thus, electric-field driven resistance switching in graphene nanogaps constrains the operational voltages possible in such devices. We find that at room temperature, switching can occur at $V_{th} < 0.4$ V, which, for example, is the typical operating voltage for single-molecule devices. The noise typically observed in graphene-based single-molecule transistors at room temperature is likely to be the result of rearrangement of atoms and bonds at the edges of the electrodes. Our results highlight the importance of gaining better knowledge of the edge chemistry in graphene nanogaps. These initial findings need further investigation by research groups specializing in techniques such as atomic-scale imaging to verify the nature of these atomic chains, as well as the influence of the actual material in the gap on the formation of these chains.

Although the potential formation of graphene filaments poses challenges to the development of graphene-based nanoelectrodes, it also offers exciting opportunities to study charge transport in atomic carbon chains. The formation of carbon chains (cumulene and polyyne chains) have been observed using transmission electron microscopy.[34] If these structures could be controllably formed between graphene nanoelectrodes, they could serve as a test bed for the observation of a plethora of transport phenomena predicted in atomic chains[28,29,35] and could further also be extended for various applications such as all carbon-based transistors.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.nanolett.7b00909.

Device fabrication and electrical characterization, tunneling current fitting model, finite elemental analysis, switching characteristics in more devices, gap size-dependent scaling behavior of GST's threshold voltage (PDF)

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Notes

The authors declare no competing financial interest.

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Nano Lett. 2017, 17, 3688−3693

UNIVERSIDAD DE GUADALAJARA

Talent Land 2019

La Universidad de Guadalajara

extiende la presente

CONSTANCIA

Gerardo Rodríguez Hernández

Por su participación en el pabellón de la Universidad de Guadalajara
con la charla "**Supercómputo y sus posibilidades**" el día 26 de abril de 2019

"Piensa y Trabaja"
Guadalajara, Jalisco

Dr. Héctor Raúl Solís Gadea
Vicerrector Ejecutivo

X challenge
By cleantech challenge

X ploration camps

Otorga la presente

CONSTANCIA A:

Gerardo Rodríguez Hernández

Por ser uno de los participantes seleccionados de X Challenge y por su destacada participación en el Xploration Camp con duración de 16 horas, celebrado el 1 y 2 de julio en la Sede Guadalajara.

"IMPOSIBLE ES LO QUE QUEDA POR LOGRARSE"

—JULIO VERNE

Zapopan, Jal., 2 de julio de 2019.

Dr. Luis Aguirre–Torres
Presidente, X Challenge

Centro de Sustentabilidad y Energía Renovable

UAG Universidad Autónoma de Guadalajara

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4° Congreso Internacional de Sistemas Embebidos

ICES18

La Asociación Mexicana de Software Embebido y La Universidad Autónoma de Guadalajara

otorgan el presente:

RECONOCIMIENTO

al

Dr. Gerardo Rodríguez Hernández

Por la presentación de su **CONFERENCIA MAGISTRAL:**

Nuevos paradigmas de diseño en ingeniería usando metodologías de modelado de elemento finito

en el 4to Congreso Internacional de Sistemas Embebidos

Dr. Marco Antonio Aceves Fernández
Presidente de a Asociación Mexicana de Software Embebido

Mtro. Gilberto Ochoa Ruiz
Comite Organizador de la Universidad Autónoma de Guadalajara

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PROPUESTA DE PLAN DE TRABAJO PARA EL CARGO DE DIRECTOR DE INTELIGENCIA DE DATOS DEL SISTEMA ESTATAL ANTICORRUPCIÓN DEL GOBIERNO DEL ESTADO DE JALISCO

PRESENTADA POR EL DR. GERARDO RODRÍGUEZ HERNÁNDEZ

Secretaría Ejecutiva del Sistema Estatal Anti -Corrupción de Jalisco,

Presente:

La presente propuesta de plan de trabajo sugiere una serie de acciones a realizase desde la Dirección de Inteligencia de Datos del Sistema Estatal Anticorrupción del Gobierno del Estado de Jalisco. Dichas acciones se presentarán como propuestas de iniciativas ante el Comité Coordinador, para que sean evaluadas y aprobadas. También se pretenderá producir informes periódicos, sobre el progreso de las actividades de la Dirección.

Las actividades propuestas estarán orientadas en los siguientes ejes de acción:

1. **Estrategia de comunicación con el público en general mediante el uso de redes sociales**. Una de las componentes principales del combate a la corrupción se refiere al acceso a la información de la normatividad por parte del público en general. Por ello se pretenderá utilizar las redes sociales como mecanismo de divulgación de los derechos y obligaciones de los ciudadanos en lo referente al combate a la corrupción y demás actividades realizadas por el Sistema Estatal Anticorrupción. Se propondrá además la creación de material multimedia de fácil acceso, con la intención de educar a la ciudadanía.

2. **Estrategia de comunicación y asesoría hacia las instancias de gobierno.**
   Uno de los frentes más importantes del combate a la corrupción consiste en la capacitación de los servidores públicos que trabajan en las distintas instancias de gobierno. Se propondrá crear un mecanismo de capacitación utilizando medios electrónicos, para los servidores públicos del gobierno del estado. Adicionalmente, se propondrá que la Dirección de Inteligencia de Datos, proporcione asesoría en el desarrollo de procesos y adquisición de datos digitales de las distintas instancias gubernamentales.

3. **Establecimiento de un esquema de bases de datos en cooperación con diferentes instancias gubernamentales**.
   Se propondrán estrategias de cooperación, para la obtención, captura y procesamiento de datos de distintas instancias gubernamentales del estado, así como se buscará la integración con instancias de otros estados como parte de la estrategia del Sistema Nacional Anticorrupción.

4. **Alineación con disposiciones legales estatales, nacionales e internacionales.**
   Se propondrán al comité coordinador estrategias de adquisición almacenamiento y manejo de datos, acorde con las distintas disposiciones legales aplicables, en el ámbito estatal, nacional e internacional.

5. **Procuración de recursos.**
   Se buscará mediante distintos mecanismos, obtener recursos disponibles para programas de combate a la corrupción basados en Tecnologías de la Información, a fin de expandir las capacidades operativas de la Dirección de Inteligencia de Datos.

6. **Establecimiento de colaboraciones con la academia.**
   Se procurará la vinculación con Universidades y Centros de Investigación a fin de obtener recursos humanos capacitados en el uso de las Tecnologías de la Información, para la generación de modelos y análisis de datos de acuerdo con las necesidades de la Dirección de Inteligencia de Datos. Se buscará el desarrollo de proyectos de Tesis de posgrado, realizando actividades de investigación en beneficio de la Dirección.

7. **Establecimiento de colaboraciones con la iniciativa privada.**
   Se propondrán estrategias que faciliten la captura de información y garanticen la veracidad de esta, a fin de que las instancias privadas que reciben fondos gubernamentales puedan de forma fácil y oportuna proporcionar información sobre el uso de los recursos asignados, en pro de facilitar el trabajo de auditoría del Sistema Estatal Anticorrupción y de las mismas instancias privadas.

8. **Desarrollo de políticas de privacidad y confidencialidad de la información.**
   Se propondrán políticas para garantizar la privacidad y la confidencialidad de las bases de datos generadas y/o administradas por la Dirección de Inteligencia de Datos.

9. **Generación de modelos para la identificación de actos de corrupción.**
   Utilizar técnicas de Inteligencia Artificial, para la generación de Modelos computacionales a partir de la información disponible en las bases de datos de la Dirección y otras instancias colaboradoras, que permitan identificar potenciales actos de corrupción, a fin de generar las denuncias a las instancias jurídicas correspondientes. Cada modelo se orientará a la identificación de un tipo de actividad de corrupción en particular. Los objetivos de identificación de los modelos se discutirán para su aprobación y priorización ante la Secretaría Ejecutiva del Comité Coordinador.

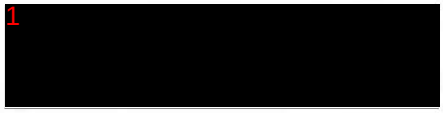
10. **Apoyo técnico al Comité Coordinador.**
    La Dirección de Inteligencia de Datos proporcionará modelos y análisis que ayuden en la toma de decisiones del Comité Coordinador.

Las actividades a realizar por parte de la Dirección de Inteligencia de Datos se programarán por etapas como se describe a continuación:

1. Diagnóstico (3 meses)
   Desarrollo de métricas, evaluación de las bases de datos disponibles, evaluación de recursos humanos y de infraestructura, así como de capacidades jurídicas y obligaciones de la Dirección de Inteligencia de Datos.
2. Planeación y diseño de estrategias (3-6 meses)
   Basado en los resultados de la Etapa de Diagnóstico en conjunción con las instrucciones de la Secretaría Ejecutiva, se generará un plan de actividades detallado, siguiendo los 10 Ejes de Acción mencionados anteriormente.
3. Implementación (Ciclos Trimestrales)
   Basado en la estrategia generada en la Etapa de Planeación, se crearán periodos trimestrales de implementación.
4. Evaluación (Ciclos Trimestrales)
   Se realizarán de forma trimestral, a fin de evaluar los objetivos correspondientes al periodo anterior de la Etapa de Implementación, utilizando las métricas definidas en la Etapa de Diagnóstico.

Agradezco de antemano su atención ante la presente propuesta de plan de trabajo y le solicito que en caso de cualquier duda o necesidad adicional de información no dude en contactarme.

Atentamente:



Dr. Gerardo Rodríguez Hernández

Se eliminan los datos 1 (firma). Por ser considerados un dato personal identificable.
Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

Zapopan Jalisco a 7 de Agosto de 2019

Secretaría Ejecutiva del Sistema Estatal Anticorrupción de Jalisco.

Por medio de la presente, me permito exponerle mis motivos para aplicar al puesto de Director de Inteligencia de Datos del Sistema Estatal Anticorrupción de Jalisco. La principal motivación para ocupar esta posición radica en mi interés en colaborar con mis habilidades y experiencia, a fin de producir un cambio positivo y muy necesario en nuestro país. Al regreso de mis estudios de Posgrado en el extranjero, he participado en distintos foros e iniciativas en pro del uso de las tecnologías para el beneficio social. Además de la motivación social, la descripción técnica de la posición coincide en gran medida con mi formación académica y experiencia. Técnicamente, poseo experiencia en Desarrollo de Software, Sistemas de Inteligencia Artificial, Big Data y Cómputo de Alto Rendimiento. Poseo experiencia en el desarrollo de proyectos Académicos y de la Iniciativa Privada. He sido Liaison y líder técnico de proyectos internacionales y cofundador de iniciativas sin fines de lucro como parte de un equipo multidisciplinario a nivel internacional. Recientemente mi interés científico y académico, se ha visto enfocado de nuevo en los temas referentes al uso de técnicas de Inteligencia Artificial para la solución de problemas, perspectiva que estudié durante mi tesis de Maestría en Inteligencia Artificial Aplicada. Adicionalmente, esta posición representa en lo personal una oportunidad de desarrollo profesional y brinda la libertad de proponer iniciativas y desarrollar simultáneamente, actividades de administración, investigación y divulgación en proyectos de impacto.

Le agradezco de antemano su consideración ante la presente propuesta y quedo a la espera de su pronta respuesta, o en caso de requerir más información por favor no dude en contactarme, sin más por el momento, me despido.

Atentamente

Dr. Gerardo Rodríguez Hernández

Se elimina la firma (1) por ser considerados un dato personal identificable.
Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

Escrito de aceptación
de los términos de la convocatoria y publicidad

Secretaría Ejecutiva del Sistema Estatal Anticorrupción.
P r e s e n t e.

Quien suscribe, con el carácter de candidata/to para ocupar el puesto vacante de Director de Inteligencia de Datos, dentro del proceso de reclutamiento y selección convocado por esta Secretaría el día 11 de ~~junio~~ Julio de 2019 dos mil diecinueve, manifiesto por este medio que acepto los términos de la convocatoria, las bases y los lineamientos que regularan este proceso, mismos que son de mi pleno conocimiento en cuanto a su contenido y alcance.

Así mismo, manifiesto de manera libre, voluntaria, previa, especifica, informada e inequívoca que doy mi consentimiento expreso para que sean tratados mis datos personales para los fines que se me informan en el *Aviso de Privacidad Integral para el Reclutamiento y Selección del Personal de la Secretaría Ejecutiva del Sistema Estatal Anticorrupción* el cual he leído en su integridad, así mismo, expreso mi voluntad para que (si) (no) Si se publique mi nombre, y los documentos en versión pública relativos a mi candidatura, así como la demás documentación y resultados generados en torno a mi participación en cada una de las etapas del proceso de reclutamiento y selección al que acudo, y en los que se vean reflejados datos o información que tengan que ver con mi persona, hasta la conclusión del proceso.

Lo anterior, de conformidad con lo dispuesto por el artículo 14 numerales 1 y 4 de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; así como lo referido en el artículo 8 fracción V inciso d de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios.

Guadalajara, Jalisco a 07 del mes de Agosto de 2019.

Dr. Gerardo Rodríguez Hernández

[redacted] 1

Nombre y firma del candidata o candidato

Se elimina la firma (1) por ser considerados un dato personal identificable.
Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo, por tratarse de un dato personal identificativo.

AVISO DE PRIVACIDAD INTEGRAL

PARA EL RECLUTAMIENTO Y SELECCIÓN DEL PERSONAL DE LA SECRETARÍA EJECUTIVA DEL SISTEMA ESTATAL ANTICORRUPCIÓN

Domicilio del responsable del uso y protección de sus datos personales.
Avenida Arcos número 767, en la colonia Jardines del Bosque, en la ciudad de Guadalajara, Jalisco, con código postal 44520.

Datos personales que serán sometidos a tratamiento, identificando aquellos que son sensibles.

Se entiende por datos personales a cualquier información concerniente a una persona física identificada o identificable, es decir, cualquier tipo de datos que pueden ser utilizados para identificar de forma directa o indirecta a una persona, siendo los datos que serán sometidos a tratamiento por este sujeto obligado los siguientes:

Nombre, fecha de nacimiento, nacionalidad, edad, estado civil, domicilio, correo electrónico particular, clave de elector, cédula única de registro de población "CURP", firma, fotografía, número de teléfono celular, número de teléfono de casa, registro federal de contribuyentes "RFC", número de afiliación al Instituto Mexicano del Seguro Social "IMSS", número de pasaporte, grado máximo de estudios, formación académica, trayectoria educativa, calificaciones, títulos, certificados, reconocimientos, número de cédula profesional estatal, número de cédula profesional federal, nombramientos, datos sobre procedimientos administrativos, referencias personales, referencias laborales, actividades extracurriculares, capacitaciones, hojas de servicio, información fiscal, cuentas y números de cuentas bancarias, cuenta clabe interbancaria y datos socioeconómicos.

Además de los anteriores, se recabarán por este sujeto obligado, datos personales **SENSIBLES**, entendiéndose por aquellos que se refieran a la esfera más íntima de su titular, o cuya utilización indebida pueda dar origen a discriminación o conlleve un riesgo grave para éste, que de acuerdo al artículo 14 punto 4 de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios, requieren el consentimiento expreso y por escrito del titular para su tratamiento, a través de su firma autógrafa; salvo en los casos previstos en el artículo 15 del citado ordenamiento legal, siendo éstos los siguientes:

Huellas decadactilares, estado de salud, tipo de sangre, enfermedades, datos sobre antecedentes en archivos criminalísticos.

Los datos personales podrán ser recabados por la Secretaría Ejecutiva del Sistema Estatal Anticorrupción de Jalisco, directa o indirectamente, por escrito, a través de medios electrónicos o tecnológicos o de manera física. Los datos personales proporcionados a esta Secretaría Ejecutiva, serán única y exclusivamente utilizados para llevar a cabo su objetivo, fines y en cumplimiento de sus atribuciones, previstos en el artículo 25 de la Ley del Sistema Anticorrupción del Estado de Jalisco y artículos 3 y 10 último párrafo del Estatuto Orgánico de la misma.

Fundamento legal que faculta al responsable para llevar a cabo el tratamiento.
El tratamiento de sus datos personales, se realiza con fundamento en lo establecido en el artículo 6, Apartado A, fracción II y III y 16 segundo párrafo de la Constitución Política de los Estados Unidos Mexicanos, 4 y 9 fracciones V de la Constitución Política del Estado de Jalisco; en el artículo 31 punto 1, 32, punto 1, fracción III, VI, y VII 35 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; y en el artículo 3. 1. fracciones III, XXXII, 10, 19.2, 24, 87.1. fracciones I y X, y 88 punto 1, fracción II y III de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados Del Estado de Jalisco y sus Municipios. Y el fundamento legal, que faculta en lo particular, a la Secretaría Ejecutiva del Sistema Estatal Anticorrupción, para llevar a cabo el tratamiento de sus datos personales, en cumplimiento de su objeto y atribuciones, se lo confieren los artículos 107 Ter de la Constitución Política del Estado de Jalisco, 24 y 25 de la Ley del Sistema Estatal Anticorrupción del Estado de Jalisco, y artículo 3 y 10 último párrafo del Estatuto Orgánico de la misma, quien protegerá los datos que nos proporcione y se encuentra obligado a cumplir con los principios y deberes enmarcados en la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios.

Las finalidades del tratamiento para las cuales se obtienen los datos personales, son las siguientes:
Los datos personales serán recabados para cumplir con los objetivos y atribuciones de esta Secretaría Ejecutiva; para crear, revisar y valorar expedientes de las personas que pretendan ocupar un puesto vacante en la Secretaría Ejecutiva, derivados de los procedimientos de reclutamiento y selección; para publicar en cualquier medio de difusión el currículum y evaluación documental en versión pública de los candidatos y candidatas a ocupar las plazas vacantes de los puestos con la jerarquía administrativa inferior, a la del Secretario Técnico, esto es, Directores y Coordinadores, a que hace referencia el artículo 18, fracción IV del Estatuto Orgánico de la Secretaría Ejecutiva del Sistema Estatal Anticorrupción de Jalisco; para crear e integrar los expedientes personales de quienes laboran o prestan sus servicios profesionales, su servicio social o prácticas profesionales en esta Secretaría Ejecutiva; para el pago de la nómina, a través de transferencia

electrónica a las cuentas bancarias respectivas, o en su caso, para la apertura de cuentas bancarias para dichos efectos; para mantener el control de las asistencias del personal; para la atención de requerimientos judiciales, resoluciones o mandatos fundados y motivados por autoridades competentes; para realizar certificaciones de documentos que obran en los expedientes del personal de esta Secretaría Ejecutiva; para realizar informes requeridos por las autoridades judiciales sobre datos contenidos en los expedientes del personal de la Secretaría Ejecutiva; para realizar los resguardos de los bienes muebles e inmuebles en posesión y/o propiedad de la Secretaría Ejecutiva; para llevar el registro de incidencias del personal; para atender y tramitar las solicitudes del derecho de acceso a la información y protección de datos personales; para tramitar y realizar el pago de personas físicas bajo el régimen de asimilados a salarios; para enviar las declaraciones informativas respectivas al Sistema de Administración Tributaria del personal que labora o presta sus servicios profesionales en la Secretaría Ejecutiva; para llevar a cabo la revisión de auditorías; y para la identificación, integración y seguimiento de los procedimientos de investigación administrativa, de los procedimientos de separación y de las quejas entabladas por ciudadanos.

Las finalidades del tratamiento de datos descritas en el presente aviso en las que se requiere el consentimiento de su titular, con las excepciones previstas en el artículo 15 de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios, serán las siguientes:

Cuando se realice el tratamiento de datos personales sensibles para la apertura e integración de los expedientes personales, para el caso de los candidatos y candidatas a los puestos vacantes de esta Secretaría Ejecutiva de jerarquía inmediata inferior al Secretario Técnico, en el desarrollo de las etapas correspondientes reconocidas en los *Lineamientos de Reclutamiento y Selección de Personal de la Secretaría Ejecutiva del Sistema Estatal Anticorrupción* y en lo relativo a la publicación en cualquier medio de su nombre, y los documentos en versión pública relativos a su candidatura, así como la demás documentación y resultados generados durante el proceso de correspondiente que para el caso apliquen y acorde a lo establecido en el artículo 14, punto 4 de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco.

Asimismo, se informa que los datos personales recabados en los sistemas de datos personales de la Secretaría Ejecutiva del Sistema Estatal Anticorrupción, podrán ser tratados sin consentimiento del titular, siempre en respeto a sus derechos; teniendo como supuestos de excepción a los principios que rigen el tratamiento de datos, disposiciones de orden público, o en su caso, para proteger los derechos de terceros, según lo establece el segundo párrafo del artículo 16 de la Constitución Política de los Estados Unidos Mexicanos, concatenado con lo dispuesto en el artículo 15 de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios.

Los mecanismos, medios y procedimientos disponibles para que los titulares de datos puedan ejercer sus derechos ARCO son los siguientes:
El titular de los datos personales puede ejercer sus derechos de acceso, rectificación, cancelación y oposición de datos personales (**Derechos ARCO**), de conformidad con el artículo 16 párrafo segundo de la Constitución Política de los Estados Unidos Mexicanos, y a lo que señala el Título Tercero, Capítulos I y II de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios, mediante escrito libre presentado en la Unidad de Transparencia de la Secretaría Ejecutiva del Sistema Estatal Anticorrupción, que se ubica en la avenida Arcos número 767, en la Colonia Jardines del Bosque, en Guadalajara, Jalisco, con código postal 44520, en un horario de atención de Lunes a Viernes de 9:00 nueve a 15:00 quince horas.

El domicilio de la Unidad de Transparencia.
Se ubica en la avenida Arcos número 767, en la colonia Jardines del Bosque, en la ciudad de Guadalajara, Jalisco, con código postal 44520, con un horario de atención de Lunes a Viernes de 9:00 nueve a 15:00 quince horas.

Los medios a través de los cuales el responsable comunicará a los titulares los cambios al aviso de privacidad.
El presente Aviso de Privacidad puede sufrir modificaciones y/o actualizaciones derivadas de nuevos requerimientos legales, de las necesidades de esta Secretaría Ejecutiva del Sistema Estatal Anticorrupción, por mejora de sus procedimientos internos y sus prácticas de privacidad, o por otras causas.

Usted puede consultar este Aviso de Privacidad Integral, en su última versión, directamente en las oficinas que ocupan esta Secretaría Ejecutiva del Sistema Estatal Anticorrupción, ubicadas en la avenida Arcos número 767, en la colonia Jardines del Bosque, en la ciudad de Guadalajara, Jalisco, con código postal 44520, en su página *web*, disponible en la dirección electrónica http://seajal.org, así como en su Portal de Transparencia, particularmente en su artículo 8, fracción IX de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios.

Reconozco haber leído en su totalidad el presente aviso de privacidad y otorgo mi consentimiento expreso para el tratamiento de mis datos personales y datos personales sensibles.

Atte.

Dr. Gerardo Rodríguez Hernández

[redacted]1

(Nombre y firma)

Se elimina la firma (1) por ser considerados un dato personal identificable.
Fundamento legal: Artículo 21.1 de la Ley de Transparencia y Acceso a la Información Pública del Estado de Jalisco y sus Municipios; Artículos 2 y 3 incisos IX y X de la Ley de Protección de Datos Personales en Posesión de Sujetos Obligados del Estado de Jalisco y sus Municipios; y de los Lineamientos Generales en materia de Clasificación y Desclasificación de la Información, así como, para la Elaboración de Versiones Públicas emitidos por el Consejo Nacional del Sistema Nacional de Transparencia, Acceso de la Información Pública y Protección de Datos Personales en su quincuagésimo sexto, quincuagésimo séptimo y quincuagésimo octavo,

por tratarse de un dato personal identificativo.