Universidad de Cádiz
Vicerrectorado de Investigación
Edificio Hospital Real. Plaza del Falla, 8.
Primera planta. 11003, Cádiz
Tel 956015165 Fax 956015746
Investigacion@uca.es

Convocatoria de Contratos Posdoctorales asociados a grupos de alto nivel productivo.

MEMORIA DE ACTIVIDADES

GRUPO DE INVESTIGACIÓN: Ciencia e Ingeniería de los Materiales (CIM)

CÓDIGO PAIDI: TEP-120

DENOMINACIÓN DE LA LÍNEA DE INVESTIGACIÓN EN LA QUE SE INTEGRARÁ EL INVESTIGADOR POSDOCTORAL:

Estudios avanzados de materiales semiconductores mediante técnicas de microscopía TEM

RESUMEN PROYECTO INVESTIGADOR A DESARROLLAR EN LA LÍNEA DE INVESTIGACIÓN
El investigador postdoctoral realizará tareas que supongan una mejora de la excelencia científica, y en la cantidad y calidad de la productividad investigadora y de transferencia del grupo Ciencia e Ingeniería de los Materiales (TEP-0120) de la Universidad de Cádiz, que es un equipo que contribuye de forma destacada, desde su creación hace más de 25 años, al posicionamiento de la UCA en los *Rankings de Investigación*. En concreto, se beneficiarían todas las líneas de investigación activas, y proyectos vivos, relacionados con las temáticas de esta propuesta, que se desarrollan en el grupo de investigación receptor (descritas brevemente en el apartado 3). Los apartados sucesivos se han cumplimentado en idioma inglés, dado que algunos de los potenciales candidatos de alto nivel podrían ser extranjeros.

1. INTRODUCCIÓN
(máximo 1 páginas)

Deben tratarse aquí los antecedentes y estado actual de los conocimientos científico-técnicos, relacionada con la actividad que desarrollará el Investigador Posdoctoral

The characterization of functional materials from bulk till nano-structured by classical and advanced electron microscopies, should provide new information that is beneficial for a detailed understanding of the structure-performance relationship and atomic-scale insights into geometric and electronic structures as well as into chemical compositions. Especially the aberration corrected (scanning-) TEM, delivers fast, precise, quantitative materials characterization in multiple dimensions at the physical edge of today's achievable resolution power. In the structures that will be studied during the length of the candidate's postdoctoral contract, a pull of imaging, diffractive and spectroscopic TEM techniques will be used to get how thick every film or nanostructure of a semiconductor-material system is (substrates, active components, connections, transitions, buffers, channels, barriers, capping, particles, etc.); the crystallography, lattice imperfections, porosities, lacks of adhesions, doping, or problems of contamination by interdiffusion within their interfaces; reticular distortions for

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deriving compositions or strain fields for the parts with the higher or lower dimensionalities in the heterosystems; knowledge about the initial stages of nucleation and growth of any of the ceramic, metallic or semiconductor phases involved in micro/nano-electronic devices (part of optoelectronics or power electronics technologies); vibrational behavior of structure bonds and their related electrical or optical parameters; sub-nanometer maps of lattice mismatches; combined maps of strain and composition; panoramic compositional maps; measurement of lattice parameters till picometer resolution; or panoramic deformation maps, electronic states, and bandgap values.

The application of all these experiments requires from a much extended expertise in various fields of research with a priority and fast access to the very singular facilities of the Institute of Research on Electron Microscopy and Materials of the University of Cádiz (IMEYMAT) and the Divisions of Electron Microscopy and Sample Preparation of the UCA Central R&D Facility Services (SC-ICYT). In this case, the research group that will host the postdoctoral researcher, fulfill both requirements and develop their works at UCA for almost the last three decades on the analyses of semiconductor, ceramic and metallic materials using accelerated electrons, spectroscopies and surface metrology. In the case of the TEM methodologies to be carried out within this project, some of them (classical and advanced) are only affordable in the framework of units as UCA IMEYMAT/SC-ICYT, with 5 available TEM microscopes. TEM is characterized by its versatility since the same experimental session allows to combine for different length scales: (i) electron diffraction (HRED, SAED, NBED); (ii) imaging (DCTEM, HRTEM, HAADF, ILH/OAH); and (iii) spectroscopies (EDX, EFTEM, EELS, and VEELS).

2. METODOLOGÍA Y PLAN DE TRABAJO

(máximo 1 páginas)

Se deben detallar y justificar la metodología y el plan de trabajo que se proponen durante los dos años del contrato posdoctoral

The TEM-associated techniques cited in this and the previous section include HRED: high-resolution electron-diffraction, SAED: selected area ED, NBED: Nano-Beam ED, DCTEM: Diffraction-Contrast TEM, HRTEM: high-resolution TEM, HAADF: High-Angle Annular Dark-Field TEM, ILH/OAH: In-Line and Off-Axis Holography, EFTEM: Energy-filtered TEM, EDXS: Energy-dispersive X-ray and EELS: Electron-Energy Loss (Spectroscopies), and VEELS: Valence EELS.

The running projects and collaborations of the “Materials Science and Engineering” group guarantees the income of interesting semiconductor material systems matter of our TEM classical and advanced studies. As a general protocol, the research group itself, and the postdoctoral researcher during the length of his/her contract, will progress their investigations as follows: Selected samples developed at each stage of the research projects and lines will be measured by preliminary methods as XRD, AFM, ES or PL, and later, prepared in both plan-view and cross-section projections for TEM. Depending on the requirements to reach the electron-transparency of the multilayered systems received at UCA, either (i) a classical method comprising mechanical grinding and polishing plus argon ion-bombardment in Gatan (PIPS) or Fischione (models 1010/1050) millers, or (ii) the fabrication of very thin lamellas by focused gallium ion beams in a FEI Quanta 3D FIB system, will be chosen.

The studies by DCTEM, HRED and SAED will be performed in the equipment JEOL 1200EX, allowing the DCTEM to reach panoramic micrographs to measure thicknesses, roughness, porosity, adhesions, and quantities of extended structural defects of each or between the stacked layers. With

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the SAED analyses, amorphous or single-/poly-crystalline natures for every component will be assigned, and the kind of heteroepitaxies or habit planes, if there were orientation relationships between any of the formed attached crystals. If crystalline, fine measures of the lattice parameters of these portions would be performed by HRED.

The microscopes JEOL 2011, 2100 and 2010-F will be used to apply HRTEM (atomic columns positions), HAADF (intensities proportional to the effective atomic mass of each position), EDX and EELS (both for direct assessments of atomic species and oxidation states). Through them, localized crystalline qualities and imperfections (threading or misfit dislocations, domain and grain boundaries, stacking faults, twins or any other planar defects), strain maps, and confident chemical quantifications will be characterized to get an idea of the compositional and structural homogeneities till very few nanometers of spatial resolution.

Finally, the FEI Titan3 Themis 60-300 system will allow applying the most uncommon and sophisticated TEM techniques as VEELS, Holography or Lorentz TEM (for the measurement of intrinsic magnetic and electric fields even live, strains at a long-range area, two-dimensional electron gas positions, and bandgap measurements); combined sub-Ångström HR-HAADF and HRTEM for very fine column by column chemical and bonding state studies; and atomic-scale quantifications by rapid and simultaneous EDX and EELS acquisitions. Ultimate 3D Chemical mapping, S/TEM tomography and dynamic TEM and STEM studies are also affordable in this equipment. TEM results will be supported by supercomputer image simulation and structure modelling. Alternative experiments (STM, SThM, XPS, MS, etc.) will be decided if needed at this stage.

During the development of these scientific tasks, the postdoctoral researcher will be as active as the results make possible, to get a high scientific production in the form of publications, considering their number and impact index. In addition, the researcher will get involved in the scout and participation in further competitive calls that allow him/her to continue having a postdoctoral experience at CIM-UCA.

3. BREVE DESCRIPCIÓN DEL EQUIPO DE INVESTIGACIÓN
(máximo 1 páginas)

Describir brevemente la actividad investigadora del grupo de investigación en el que se integra el investigador posdoctoral.

The general goal of the group “Materials Science and Engineering” is to contribute to the development of the science and engineering of the fabrication and application of functional and structural materials by means of (i) their micro- and nano-structural and compositional characterization by techniques mainly based on accelerated electron beams (SEM and TEM), X-rays or spectroscopies; (ii) the modelization of structures at different scales in addition to the development of new TEM methodologies and the simulation of TEM images by intensive computational methods; and (iii) theoretical-empirical studies of the mechanical, optical or electronic behaviors. This is done to get knowledge on the relationships among the structure of materials at different length scales, their varying properties, their methods of syntheses or processing; thus in order to elaborate and propose design rules for these materials to get the envisaged applications. In this way, the CIM-UCA group (reference TEP-0120 of the Junta de Andalucía PAIDI)*, and the IMEYMAT Institute of Research itself**, are both actively involved in the CEI.Mar International Campus of Excellence.
*http://www.campusdelmar.es/en/research-groups-transfer/TEP-120-ciencia-e-ingenieria-materiales
**http://www.campusdelmar.es/es/evaluacion/1379084730-memoria-ceimar-es.pdf (pg. 52).

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The scientific production of the CIM-UCA group in the period 2011-2015 are summarized as follows:

- 7 Doctoral Theses supervised and/or defended, 6 of them with International Mention.
- 6 patents, 2 registered software, and 68 publications (65 SJR, 54 JCR, avg. JCR-IF: 2,74).
- 9 contracts with other organisms valued in 407 k€.
- 8 R&D projects financed by 1.123 M€, plus participation in 1 European Research Network.

Main research lines that would benefit by the postdoctoral researcher:

- Engineering of GaAsSbN semiconductor alloys for high-performance solar cells and photodetectors
- Characterization and evaluation by electron-microscopy techniques of semiconductor nanowires for micro- and opto-electronic applitacions
- Multiple systems of thin films and nanostructures based on the activity of binary (InN, AlN, GaN), ternary (InAlN, InGaN, AlGaN) and quaternary (InAlGaN) III-N nitrides for optoelectronics, power electronics and photovoltaic technology
- Synthetic diamond for materials engineering

Running research projects that would benefit by the postdoctoral researcher:

- ***Green electronics with diamond power devices***. Ref. H2020-SC-SCEE-640947. European Project. Principal Investigator: D. Araujo. 01/05/2015-30/04/2019. 220.000,00 €.
- ***Dispositivo de alto voltaje para electrónica de potencia verde: relación nanoestructura-funcion***. Ref. TEC2014-54357-C2-2-R. Spanish MINECO Project, Plan Nacional I+D+i. Principal Investigator: D. Araujo. 01/01/2015-31/12/2017. 150.645,00 €.
- ***Aleaciones emergentes de nitruros diluidos III-V y nanoestructuras de ingeniería relacionadas para aplicaciones fotovoltaicas y de fotodetección de alta eficiencia***. Ref. MAT2013-47102-C2-1-R. Spanish MINECO Project, Plan Nacional I+D+i. Principal Investigator: D. González Robledo. 01/01/2014-31/12/2016. 103.220,42 €.

Group members:

- **Academic Staff:** CUs**:** Rafael García Roja; Daniel Araújo Gay; David González Robledo; PTUs**:** Francisco J. Pacheco Romero; Pilar Villar Castro; Marina Gutiérrez Peinado; Francisco M. Morales Sánchez; PCD: Teresa Ben Fernández; PAsoc: Luis Rubio García.
- **Postdoctoral Researchers:** PSIs**:** José M. Mánuel Delgado; Carlo Enzo Pastore; IC: Daniel Fernández de los Reyes.
- **PhD Students:** Fernando Lloret Vieira; José Carlos Piñero Charlo; Rocío Félix Ángel; Verónica Braza Polanco; Juan Jesús Jiménez Ríos.
- **Technical Staff:** Francisco M. León Ruiz, PAS.

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