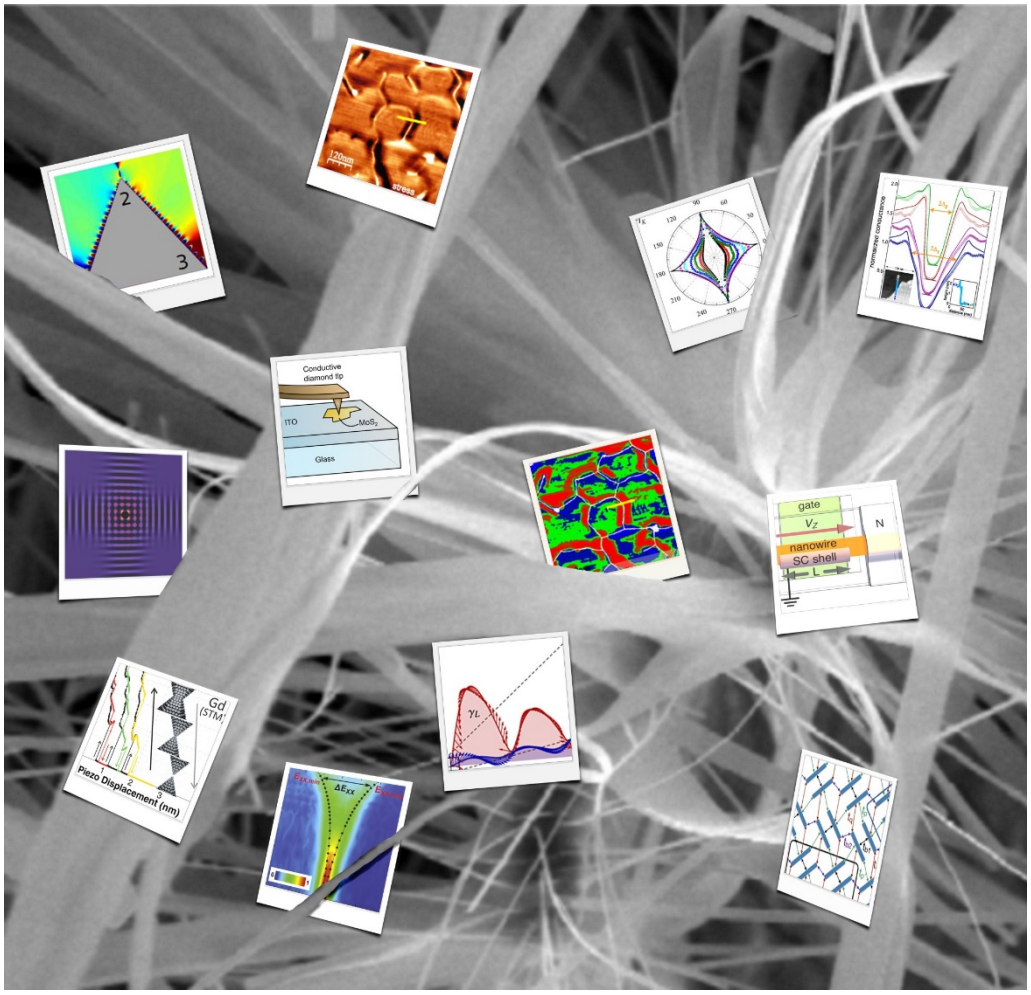
Instituto Universitario de Ciencia de Materiales Nicolás Cabrera



Activity report 2017

Universidad Autónoma de Madrid

INSTITUTO NICOLÁS CABRERA

Campus Internacional excelencia UAM CSIC

FACULTAD DE CIENCIAS

CONTENTS

Welcome

Dear reader:

The Nicolás Cabrera Summer School 2017 has gathered more participants than in most previous occasions. Nearly a hundred scientists from all over the world came to Miraflores to discuss about quantum transport in topological materials. The organizers, Eduardo Lee, Elsa Prada and Alfredo Levy Yeyati made an excellent work, even finding creative new solutions for lodging so many people. The School received ample coverage by the media, organized by the FBBVA. The next Summer School will be again organized in September by Johannes Feist, Antonio Fernández-Dominguez and Francisco José García Vidal and looks also very promising. I invite you to take a look on the list of invited speakers and to participate in the event.

It is useful to remember that the Institute manages one of the most important private supports to Condensed Matter and Materials Physics in our surroundings. The FBBVA helps us eagerly by funding the Summer School and the Colloquia and by organizing media coverage around these activities. This is a great opportunity, which we should thank by participating as far as possible in the events and activities of the FBBVA.

This past year we have continued transforming the Institute, by enhancing support to students and inviting top researchers to our meetings. For the first time, we have had invited speakers in our Young Researchers Meeting. These were Marcelo Goffman from Saclay and Leticia Taruell from ICFO. It was certainly a matter of luck (for us) that Leticia made her presentation just one day after her results appeared in Science. This made the meeting even more special and shows young researchers that luck is easier to find if you look for it. But students should also consider that most important is doing complete and solid work, the journal where it ends up is secondary—as long as you remember to include all sources for support and affiliations in the nonscientific part of the paper.

We start 2018 with a new idea to try to recognize technical work made in the INC. There are examples where such work by some members of the Institute has had an enormous impact, providing some of the most cited papers of our University and building a totally new community of scientists around a method or an instrument. However, technical work is in general difficult to assess—journals such as review of scientific instruments will always have a very low impact factor. New open source initiatives, such as software or hardware X are trying to improve this situation, but the impact factor will remain comparatively low. Confining technical work into the supplementary section of papers in "glossy" journals, is not the right choice, because it does not produce appropriate citations nor favors replication and improvement. Technical developments are at the very core of doing original science and the INC should communicate and share it in sound papers.

Hermann Suderow

Director of the Nicolás Cabrera Institute

Nicolás Cabrera Summer School

The Nicolás Cabrera Summer School is organized yearly by the Institute since 1994 and is supported by the program "Frontiers of Science and Technology" of the Fundación BBVA since 2002.

The BBVA Foundation made an extensive coverage of the School. You can find details here.

The 2017 Summer School has been directed by Eduardo Lee, Elsa Prada and Alfredo Levy Yeyati. The School was held during 4-8 September 2017 in Miraflores de la Sierra and was entitled "Quantum Transport in Topological Materials". The main objective has been to gather most relevant international experts in the topological properties of condensed matter and their application in recent discoveries in transport devices and hybrid quantum systems. Experts have given introductory lectures and reviewed the state-of-the-art of the subject. Theoretical as well as experimental progress was addressed, including detection and manipulation of quantum states in topological devices. Speakers have given a global vision, fostering discussions with students. Speakers were exclusively active scientists, leaders of their laboratories or research groups, well recognized at the international level.

The following subjects were discussed:

- Hybrid devices (quantum point contacts, nanowires and heterostructures)
- Topological insulators and superconductors
- Weyl semimetals
- Quantum topological computation.

The School was celebrated in the "La Cristalera" of UAM. In total, we had 97 students coming from 28 different countries. 79% of the participants were from outside Spain. Among these participants, we had 23 high level speakers, 71 young students and 3 organizers, the latter belonging to the UAM and also to the IFIMAC (Condensed Matter Physics Center).

The talks covered topical subjects through introductions and reviews of most recent achievements. Speakers were available for discussion with students during the whole meeting. The ambience was cordial, which facilitated interactions and a useful and agreeable working atmosphere, that lead to new connections among participants.

During the whole School, PhD students were particularly active, posing questions during the talks and holding informal meetings with speakers. Two poster sessions and the coffee breaks served these students to present their results and discuss them with the speakers and other advanced scientists. The poster session, as well as the introductory aspect of the talks, were particularly well received by the students.

All participants, and much in particular the invited speakers, highlighted the quality of the talks. The organizers made personal contacts with participants and gathered additional feedback through e-mail exchanges. The success of the School has been assessed by these interactions, with participants mostly valuing the ability to get into contact with internationally renowned experts in a cordial ambience.

In total 54 posters were presented in a cordial atmosphere. We had also the following speakers:

Ramón Aguado (ICMM-CSIC, Madrid)

Alberto Cortijo (ICMM-CSIC, Madrid)

Silvano De Franceschi (CEA, Grenoble)

Reinhold Egger (Heinrich Heine Univ., Düsseldorf)

Klaus Ensslin (ETH, Zurich)

Marcelo Goffman (CEA, Saclay)

Sophie Guéron (Univ. Paris Sud Orsay)

Jelena Klinovaja (Univ. de Basilea)

Group photo.

Leo Kouwenhoven (QuTech, Delft Univ. of Technology)

Claudia Felser (Max Planck Inst. de Física química de sólidos, Dresde)

Rosa López (Univ. Baleares)

Fabricio Nichele (Niels Bohr Institute, Copenhague)

Yuval Oreg (Weizmann Inst. of Science)

Pablo San José-(ICMM-CSIC, Madrid)

Jörg Schäfer (Univ. de Würzburg)

Patrik Recher (TU Braunschweig)

Shinsei Ryu (Univ. Chicago)

Felix von Oppen (Freie Univ. Berlín)

Coloquium

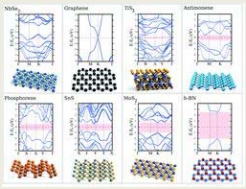
During 2017, we have had four speakers in our colloquium “Frontiers of condensed matter physics”, organized in collaboration with the FBBVA and dedicated to Professor Nicolás Cabrera. These were Greg Boebinger with the talk entitled “*Materials, Energy and Life: Entertaining Aspects of High Magnetic Field Research”,* J. Peter Toennies with the talk “*Droplets of Quantum Physics or Why Helium is The Superelement,*” Jean-Marc Triscone speaking about “*Meeting at oxide interfaces: superconductivity between insulators*” and Michel Devoret who spoke about “*Maxwell’s demon and quantum computers”*. The students and researchers of UAM and the Campus have highly valued the talks and have had extensive discussions with the speakers.

Science at the INC

All articles of the INC members are made available through the webpage of the Institute. Here we highlight some of them, with the aim to provide an overview of the different activities of the Institute.

Theory of 2D crystals:graphene and Beyond, R. Roldán, L. Chirolli, E. Prada, J.A. Silva-Guillen, P. San José, F. Guinea, Chemical Society Reviews **46**, 4387, (2017).

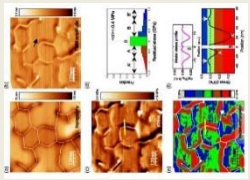
This tutorial review presents an overview of the basic theoretical aspects of two-dimensional (2D) crystals. We revise essential aspects of graphene and the new families of semiconducting 2D materials, like transition metal dichalcogenides or black phosphorus. Minimal theoretical models for various materials are presented



Intrinsic Compressives Stress in Polycrystalline Films is localized at Edges of the Grain Boundaries, E, Velasco, C. Polop, Physical Review Letters **119**, 256102, (2017).

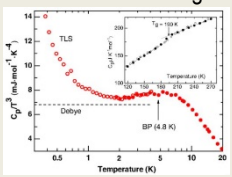
The intrinsic compression that arises in polycrystalline thin films under high atomic mobility conditions has been attributed to the insertion or trapping of adatoms inside grain boundaries. This compression is a consequence of the stress field resulting from imperfections in the solid and causes the thermomechanical fatigue that is estimated to be responsible for 90% of mechanical failures in current devices

Physical Review Letters
moving physics forward



Glassy Anomalies in the Low-Temperature Thermal Properties of a Minimally disordered Crystalline Solid, J.F. Gebbia, M. A. Ramos, D. Szewczyk, A. Jezowski, A. I. Krivchikov, Y. V. Horbatenko, T. Guidi, F. J. Bermejo, J. LI. Tamarit, Physical Review Letters **119**, 215506, (2017).

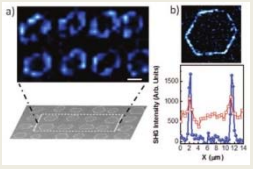
The low-temperature thermal and transport properties of an unusual kind of crystal exhibiting minimal molecular positional and tilting disorder have been measured. The material, namely, low-dimensional, highly anisotropic pentachloronitrobenzene has a layered structure of rhombohedral parallel planes in which the molecules execute large-amplitude in-plane as well as concurrent out-of-plane librational motions



Physical Review Letters
moving physics forward

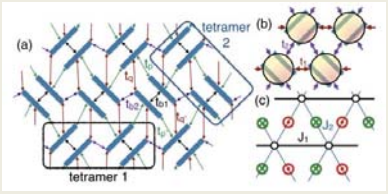
2D Arrays of Hexagonal Plasmonic Necklaces for Enhanced Second Harmonic Generation, JA. Gínez-Tornero, C. Tserkezis, L. Mateos, L. E. Bausá, M.O. Ramírez, Advanced Materials 29, 15, (2017).

Hexagonal plasmonic necklaces of silver nanoparticles organized in 2D superlattices on functional ferroelectric templates are fabricated in large-scale spatial regions by using a surfactant-free photo-deposition process. The plasmonic necklaces support broad radiative plasmonic resonances allowing the enhancement of second harmonic generation (SHG) at the ferroelectric domain boundaries. A 400-fold SHG enhancement is achieved at the near-UV spectral region with subsequent interest for technological applications.



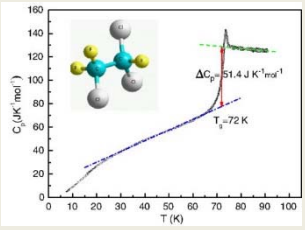
Dynamical Reduction of the Dimensionality of Exchange Interactions and the "Spin-Liquid" Phase of Kappa-(BEDT-TTF)$_2$X, B.J. Powell, E,P. Kenney, J. Merino, Physical Review Letters **119**, 087204, (2017).

We show that the anisotropy of the effective spin model for the dimer Mott insulator phase of κ-(BEDT-TTF)2X salts is dramatically different from that of the underlying tight-binding model. Intra-dimer quantum interference results in a model of coupled spin chains, where frustrated interchain interactions suppress long-range magnetic order.



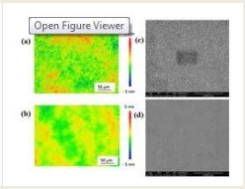
Thermodynamic and Kinetic Fragility of Freon 113: The Most Fragile Plastic Crystal, A. Vispa, M. Romani, M.A. Ramos, L.C. Pardo, F.J. Bermejo, M. Hassaine, AL. Krivchikov, J.W. Taylor, J.L. Tamarit, Physical Review Letters **118**, 105701, (2017).

We present a dynamic and thermodynamic study of the orientational glass former Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane, CCl_{2}F-CClF_{2}) in order to analyze its kinetic and thermodynamic fragilities. Freon 113 displays internal molecular degrees of freedom that promote a complex energy landscape



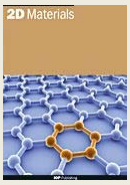
Ultrasmooth metal thin films on curved fused silica by laser polishing, G. Anemone, C. Wingarten, A. Al Taleb, C. Prieto, D. Farías, Applied Physics Letters **111**, 181602, (2017)

The fabrication of atomically smooth metal films on supporting oxides is a quite demanding task, since most physical vapor deposition methods used on metals do not work properly on oxide substrates. Here, we report an alternative procedure, based on performing laser polishing of a fused silica substrate before depositing the metallic thin film. This reduces the RMS surface roughness of fused silica by ca. 33%, and increases the maximum grain size of the metallic film from 200 nm to 1200 nm..



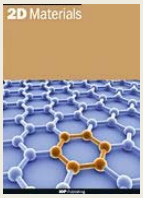
Electronics and optoelectronics of quasi-1D Layered transition metal trichalcogenides, J. Island, A. Molina-Mendoza, M. Barawi, R. Biele, E. Flores, J.M. Clamagirand, J. Ares, C. Sánchez, H. Van der Zant, R. D'Agosta, I. Ferrer, A. Castellanos, 2D Materials **4**, 022003 (2017).

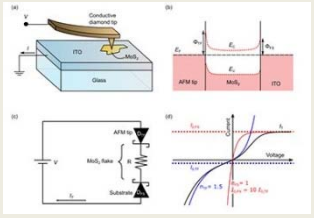
The isolation of graphene and transition metal dichalcongenides has opened a veritable world to a great number of layered materials which can be exfoliated, manipulated, and stacked or combined at will. With continued explorations expanding to include other layered materials with unique attributes, it is becoming clear that no one material will fill all the post-silicon era requirements



Strain engineering of Schottky barriers in single- and few-layer MoS_2 vertical devices, J. Quereda, J.J. Palacios, N. Agräit, A. Castellanos-Gomez, G. Rubio-Bollinger, 2D Materials **4**, 021006, (2017).

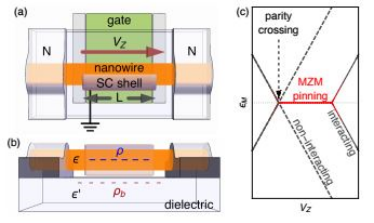
We study the effect of local strain in the electronic transport properties of vertical metal-atomically thin MoS2-metal structures. We use a conductive atomic force microscope tip to apply different load forces to monolayer and few-layer MoS2 crystals deposited onto a conductive indium tin oxide (ITO) substrate while measuring simultaneously the I–V charateristics of the vertical tip/MoS2/ITO structures..





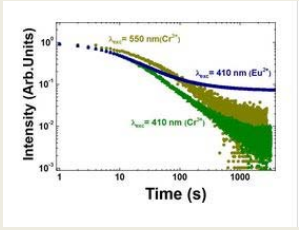
Zero-energy pinning from interactions in Majorana nanowires, F.Domínguez, J. Cayao, P. San-José, R. Aguado, A. Levy Yeyati, E. Prada, NPJ Quantum Materials **2**,13, (2017).

Majorana zero modes at the boundaries of topological superconductors are charge-neutral, an equal superposition of electrons and holes. This ideal situation is, however, hard to achieve in physical implementations, such as proximitised semiconducting nanowires of realistic length.



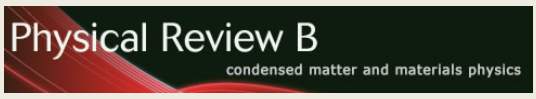
Persistent Luminiscence nanothermometers, E. Martín Rodríguez, G. López Peña, E. Montes, G. Lifante, J. García Solé, D. Jaque, L.A. Diaz-Torres, P. Salas, Applied Physics Letters **111**, 081901, (2017).

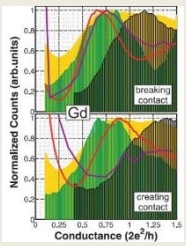
Persistent phosphorescence nanoparticles emitting in the red and near-infrared spectral regions are strongly demanded as contrast nanoprobes for autofluorescence free bioimaging and biosensing. In this work, we have developed Sr4Al14O25:Eu2+, Cr3+, Nd3+ nanopowders that produce persistent red phosphorescence peaking at 694 nm generated by Cr3+ ions.



Electronic transport in gadolinium atomic-size contacts, B. Olivera, C. Salgado, J.L. Lado, A. Karimi, V. Henkel, E. Scheer, J. Fernández-Rossier, J.J. Palacios, C. Untiedt, Physical Review B **95**, 075409, (2017).

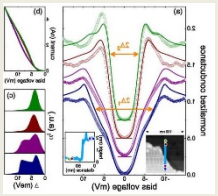
We report on the fabrication, transport measurements, and density functional theory (DFT) calculations of atomic size contacts made out of gadolinium (Gd). Gd is known to have local moments mainly associated with f electrons. These coexist with itinerant s and d bands that account for its metallic character





Nodeless Multiband superconductivity in stoichiometric single-crystalline $CaKFe_4As_4$, K. Cho, A. Fente, S. Teknowijoyo, M.A. Tanatar, T. Kong, W. Meier, U. Kaluarachchi, O. Guillamón, H. Suderow, S.L. Bud'ko, P.C. Canfield, R. Prozorov, Physical Review B **95**, 100502, (2017).

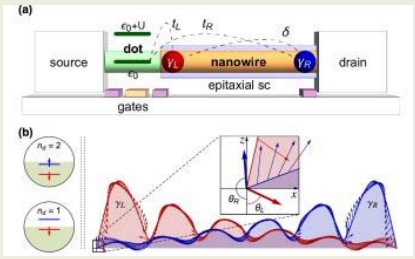
Measurements of the London penetration depth and tunneling conductance in single crystals of the recently discovered stoicheometric, iron - based superconductor, CaKFe4As4 (CaK1144) show nodeless, two effective gap superconductivity with a larger gap of about 6-9 meV and a smaller gap of about 1-4 meV..



Physical Review B
condensed matter and materials physics

Measuring Majorana nonlocality and spin structure with a quantum dot, E. Prada, R. Aguado, P. San José, Physical Review B **96**, 085418, (2017).

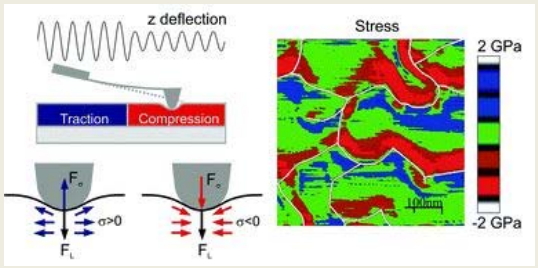
Robust zero bias transport anomalies in semiconducting nanowires with proximity-induced superconductivity have been convincingly demonstrated in various experiments. While these are compatible with the existence of Majorana zero modes at the ends of the nanowire, a direct proof of their non-locality and topological protection is now needed.



Physical Review B
condensed matter and materials physics

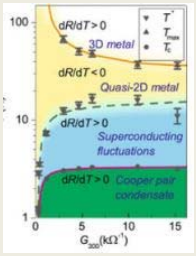
Mapping stress in polycrystals with sub-10 nm spatial resolution, C. Polop, E. Vasco, A.P. Perrino, R. García, Nanoscale **9**, 13938, (2017).

From aircraft to electronic devices, and even in Formula One cars, stress is the main cause of degraded material performance and mechanical failure in applications incorporating thin films and coatings. Over the last two decades, the scientific community has searched for the mechanisms responsible for stress generation in films, with no consensus in sight.



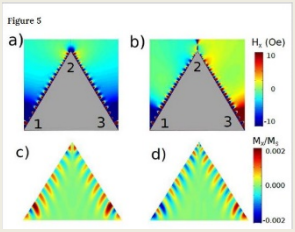
Reentrant Resistive Behavior and Dimensional Crossover in Disordered Superconducting TiN Films, S. Postolova, A. Yu, M. R. Baklanov, V. M. Vinokur, T.I. Baturina, Scientific Reports **7**, 1718, (2017).

A reentrant temperature dependence of the normal state resistance often referred to as the N-shaped temperature dependence, is omnipresent in disordered superconductors – ranging from high-temperature cuprates to ultrathin superconducting films – that experience superconductor-to-insulator transition.



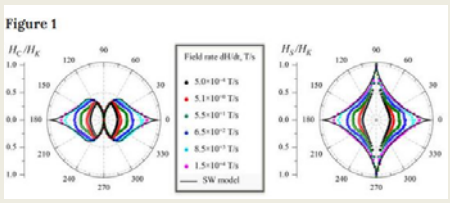
Information processing in patterned magnetic nanostructures with edge spin waves, A. Lara, J. Robledo Moreno, K.Y. Guslienki, F. Aliev, Scientific Reports **7**, 5597, (2017)

Low dissipation data processing with spins is one of the promising directions for future information and communication technologies. Despite a significant progress, the available magnonic devices are not broadband yet and have restricted capabilities to redirect spin waves.



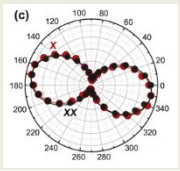
Emergence of the Stoner-Wohlfarth asteroid in thin films at dynamic regime, J.L. Cuñado, A. Bollero, T. Pérez Castañeda, P. Perna, F. Ajejas, J. Pedrosa, A. Gudín, A. Maldonado, M.A. Niño, R. Guerrero, D. Cabrera, F.J. Terán, R. Miranda, J. Camarero, Scientific Reports **7**, 13474, (2017).

The Stoner-Wohlfarth (SW) model is the simplest model that describes adequately the magnetization reversal of nanoscale systems that are small enough to contain single magnetic domains.



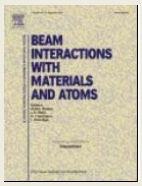
Control of single photon emitters in semiconductor nanowires by surface acoustic waves, S. Lazic, A. Hernández-Mínguez, P.V. Santos, Semiconductor Science and Technology **32**, 08402, (2017)

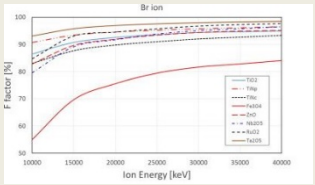
We report on an experimental study into the effects of surface acoustic waves on the optical emission of dot-in-a-nanowire heterostructures in III-V material systems. Under direct optical excitation, the excitonic energy levels in III-nitride dot-in-a-nanowire heterostructures oscillate at the acoustic frequency, producing a characteristic splitting of the emission lines in the time-integrated phtoluminescence spectra.



A Procedure to correct for target thickness effects in heavy-ion PIXE at MeV energies, A. Zucchiatti, P. Galán, J.E, Prieto, Nuclear Instruments and Methods in Physics Reserarch Section B: Beam Interactions with Materials and Atoms **407**, 1, (2017).

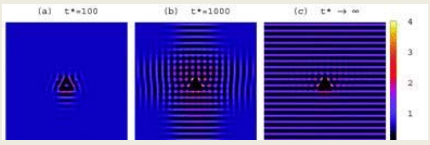
We describe a novel procedure for the calculation of correction factors for taking into account the effect of target thickness to be applied to the determination of cross sections of X-ray emission induced by heavy ions at MeV energies. We discuss the origin of the correction and describe the calculations, based on simple polynomial fits of both the theoretical cross sections and the ion energy losses. reserved..





Dynamical properties of heterogeneous nucleation of parallel hard squares, Miguel González-Pinto, Yuri Martínez-Ratón and Enrique Velasco, Soft Matter **13**, 48, (2017).

We use the Dynamic Density-Functional Formalism and the Fundamental Measure Theory as applied to a fluid of parallel hard squares to study the dynamics of heterogeneous growth of non-uniform phases with columnar and crystalline symmetries. The hard squares are (i) confined between soft repulsive walls with a square symmetry, or (ii) exposed to external potentials that mimic the presence of obstacles with circular, square, rectangular or triangular symmetries.



Young Researchers Meeting

We celebrated the Young Researchers Meeting 2017 in Miraflores de la Sierra with our PhD students. During the meeting, we presented the prize “Young researchers prize in materials science” to Alejandro Gómez Tornero for his work “2D Arrays of Hexagonal Plasmonic Necklaces for Enhanced Second Harmonic Generation”, made in collaboration with Luisa E. Bausá and Mariola O. Ramírez, and published in Advanced Science News, 1605267 (2017) and to Rubén Seoane Souto for his work “Andreev Bound States Formation and Quasiparticle Trapping in Quench Dynamics Revealed by Time-Dependent Counting Statistics”, made in collaboration with A. Martín Rodero and A. Levy Yeyati, and published in Physical Review Letters 117, 267701, (2016). This year, we thank Daniel Jaque, Pedro J. de Pablo and Carlos Tejedor for making up the prize committee and reviewing all applications. They met on 20 November 2017 and had a very difficult task, due to the large amount of excellent proposals.

The following talks were given, together with a very lively poster session:

- *"Ultrasmooth metal thin films on curved fused silica by laser polishing "* Gloria Anemone, (Departamento de Física de la Materia Condensada).
- *"Stability of colloidal 2D Titanium Carbides (MXenes)".* Sergio Pinilla (Departamento de Física Aplicada).
- *"Collective Colloid Diffusion Under Soft Confinement"*, Sergio Panzauela (Departamento de Física Teórica de la Materia Condensada).
- *"Impedance biosensor interface based on nanostructured porous silicon"*, Chloe Rodríguez, (Departamento de Física Aplicada).
- *"Multiline operation from a plasmon-assisted solid state nanolaser"*, David Hernández (Departamento de Física de Materiales).
- *"Superconducting spintronics in magnetic tunnel junctions with competing anisotropies",* Isidoro Sevilla (Departamento de Física de la Materia Condensada).
- *"Effect of the electrostatic environment in Majorana Nanowires"* Samuel Día Escribano (Departamento de Física de la Materia Condensada).
- *"Gold nanoshells: Contrast agents for cell imaging bycardiovascular optical coherencetomography"* Jie Hu, (Departamento de Física de Materiales).
- *"Novel strategy for developing antireflective coating based on liquid metal"* Flavio Nucciarelli, (Departamento de Física Aplicada.
- *"Structural Stability of Cu-Azurin in SPM experiments: insights from MD simulations",* María Ortega, (Departamento de Física Teórica de la Materia Condensada).
- *"Quasiparticle dynamics in Andreev quantum dots", Invite Talk*, Marcelo Goffman Quantronics group, SPEC, CEA Saclay, France)).
- *"Quantum liquid droplets in a mixture of Bose-Einstein condensates" Invite Talk,* Leticia Tarruell

  (ICFO-The Institute of Photonic Sciences, Castelldefels (Barcelona), Spain)

Seminars and stays

This year we had just one seminar:

Friday, 21 April 2017, “Searching for the best thermoelectric materials”, Raquel Ribeiro (Universidad Federal do ABC, Ames Laboratory).

Prizes for young students

We organized a system allowing our young students to work in our research groups and laboratories. The IFIMAC and the four Departments (https://www.fmc.uam.es/, http://dep.ftmc.uam.es/, http://www.uam.es/departamentos/ciencias/fisicamateriales/ and http://www.fa.uam.es/) participated in this activity by funding the corresponding prizes. Recipients were:

- González Sanchez, Eduardo: "Application of nanostructures for the study of Bell inequalities and quantum entanglement."

- Fresno Hernández, Alicia: "Analysis of an opto-mechanical self-adjusting interferometer".

- Sánchez Izquierdo, Luis: "Development of quantum dot devices and quantum point contacts based on InAs nanowires ".

- Robledo Moreno, Javier: "Intensificación plasmónica de las propiedades ópticas de medios de ganancia no lineales"

- Abad Arredondo, Jaime: "Cherenkov radiation in plasmonic metamaterials"

- Pérez-Ordoyo Bellido, Rodrigo: "Movilidad celular en superficies estructuradas".

- Wang, Jiahao: "Simulación de partículas activas y formación de patrones"

- Magrinyo Aguiló, Paula: "Aplicaciones de la física de sistemas complejos en procesos de diferenciación de células madre".

They all presented their work in the Young Researchers Meeting.

Publications

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Journal of Alloys and Compound **729**, 1156, (2017).

M. Gonzalez-Pinto, Y.Martínez-Ratón, E. Velasco:
Dynamical properties of heterogeneous nucleation of parallel hard squares.
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E. Velasco, C. Polop:
Intrinsic Compressive Stress in Polycrystalline Films is Localized at Edges of the Grain Boundaries
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J.E. Prieto, I. Markov:
Stranski-Krastanov mechanism of growth and the effect of misfit sign on quantumdots nucleation.
Surface Science 664, 172 (2017

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Glassy Anomalies in the Low-Temperature Thermal Properties of a Minimally Disordered Crystalline Solid.
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J. Cayao, P. San-José, A.M. Black-schaffer, et al:
Majorana splitting from critical currents in Josephson junctions.
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L. Sánchez García, M.O. Ramirez, C. Tserkezis, et al:
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J. Merino, A.C. Jacko, A.L.Khosia, et al:
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The Journal of Physical Chemistry **B**, (2017).

E. Herrera, I. Guillamon, J.A. Galvis, et al:
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Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms **410**, 102, (2017).

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