Symposium Spain as Guest of Honor (SYES)

organized by the DPG Condensed Matter Division (SKM),
chaired by the EPS Condensed Matter Division (EPS-CMD)
and the Condensed Matter Division of the Spanish Royal Physics Society (RSEF-GEFES).

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The 'Guest of Honor' Symposia celebrate the European physics community in general and the cooperation of the respective learned societies in particular. Thereby, the German Physical Society aims to further collaborations between individual scientists, research groups and institutions.

This year's 'Guest of Honor' Symposium honors the numerous ties between Spanish and German physicists by highlighting five fields of common interests, each represented by a pair of Invited Talks from distinguished scienctists from Spain and from Germany.

Overview of Invited Talks and Sessions

(Lecture halls HSZ 01 and HSZ 02)

Invited Talks

SYES 1.1	Thu	9:30–10:00	HSZ 02	**Understanding the physical variables driving mechanosensing** — •Pere Roca-Cusachs
SYES 1.2	Thu	10:00–10:30	HSZ 02	**Mechanics of life: Cellular forces and mechanics far from thermodynamic equilibrium** — •Timo Betz
SYES 1.3	Thu	10:30–11:00	HSZ 02	**A hydrodynamic approach to collective cell migration in epithelial tissues** — •Jaume Casademunt
SYES 1.4	Thu	11:15–11:45	HSZ 02	**The spindle is a composite of two permeating polar gels** — David Oriola, Benjamin Dalton, Franziska Decker, Frank Julicher, •Jan Brugues
SYES 1.5	Thu	11:45–12:15	HSZ 02	**Adding magnetic properties to epitaxial graphene** — •Rodolfo Miranda
SYES 2.1	Thu	15:00–15:30	HSZ 01	**Interactions in assemblies of surface-mounted magnetic molecules** — •Wolfgang Kuch
SYES 2.2	Thu	15:30–16:00	HSZ 01	**Towards phononic circuits based o optomechanics** — •Clivia M. Sotomayor-Torres
SYES 2.3	Thu	16:00–16:30	HSZ 01	**Optical properties of 2D materials and heterostructures** — •Janina Maultzsch
SYES 2.4	Thu	16:45–17:15	HSZ 01	**Bringing nanophotonics to the atomic scale** — •Javier Aizpurua
SYES 2.5	Thu	17:15–17:45	HSZ 01	**Infrared signatures of the coupling between vibrational and plasmonic excitations** — •Annemarie Pucci

Sessions

SYES 1.1–1.5	Thu	9:30–12:15	HSZ 02	**Spain as Guest of Honor I**
SYES 2.1–2.5	Thu	15:00–17:45	HSZ 01	**Spain as Guest of Honor II**

SYES 1: Spain as Guest of Honor I

Time: Thursday 9:30–12:15 Location: HSZ 02

Invited Talk SYES 1.1 Thu 9:30 HSZ 02
Understanding the physical variables driving mechanosensing — •Pere Roca-Cusachs — Institute for Bioengineering of Catalonia (IBEC), the Barcelona Institute of Technology (BIST), 08028 Barcelona, Spain

Cell response to force regulates essential processes in health and disease. However, the fundamental mechanical variables that cells sense and respond to remain largely unknown. During this talk, I will discuss how this process of mechanosensing can be understood in physical terms, and used to predict cell response to both external force application, and passive mechanical properties such as Extracellular Matrix (ECM) rigidity.

Invited Talk SYES 1.2 Thu 10:00 HSZ 02
Mechanics of life: Cellular forces and mechanics far from thermodynamic equilibrium — •Timo Betz — Institute of Cell Biology, University Münster, Germany

Living organisms are dauntingly complex structures that operate with high robustness on the micrometer scale. Inherently, cells and tissues are dealing with both thermal but also active noise, which is generated by random uncorrelated internal forces driving the system far away from thermodynamic equilibrium. From a research perspective these characteristics are one reason why biological systems are so challenging to measure and to perform reproducible experiments on. The complexity also challenges theoretical models, as these aim at simplification. Here we focus on the mechanical aspects and force generation in single cells and tissue by exploring their non-equilibrium nature. We discuss recent experimental and theoretical approaches which reveal new insights in the underlying physics used in biological systems to perform their individual functions.

Invited Talk SYES 1.3 Thu 10:30 HSZ 02
A hydrodynamic approach to collective cell migration in epithelial tissues — •Jaume Casademunt — University of Barcelona, Barcelona, Spain

Collective migration of cohesive groups of cells is a hallmark of the tissue remodeling events that underlie embryonic morphogenesis, wound repair and cancer invasion. In this collective migration, supra-cellular properties such as collective polarization or force generation emerge and eventually control large- scale tissue organization. This suggests that a coarse-grained approach based on a hydrodynamic description of tissues as continuous active materials may shed some light into our understanding of tissue dynamics. Specifically, an appealing open question is to what extent the complex biological regulation at play can be encoded in a series of material parameters within a purely mechanical description. Here we present an overview of hydrodynamic modeling of cell tissues as active polar fluids, and discuss some examples where this approach has been instrumental to elucidate physical mechanisms behind collective cell behavior in epithelia: the occurrence of elastic-like waves, the wetting-dewetting transition in spreading monolayers, and the understanding of morphological instabilities of tissues.

Coffee Break

Invited Talk SYES 1.4 Thu 11:15 HSZ 02
The spindle is a composite of two permeating polar gels — David Oriola[1,2], Benjamin Dalton[1,2], Franziska Decker[1,2], Frank Julicher[1], and •Jan Brugues[1] — [1]MPI PKS; PoL; CSBD; Dresden, Germany — [2]MPI CBG, Dresden, Germany

During cell division, correct segregation of chromosomes depends on the ability of microtubules to self-organize into a bipolar spindle. Spindle assembly is based on the interplay between spatial microtubule nucleation and microtubule transport. It has been recently shown that branching nucleation is the main mechanism driving microtubule nucleation in spindles. However, microtubule branching leads to explosive waves of microtubule nucleation that rapidly travel away from initially created microtubules much faster than the microtubule flux velocity. This behavior should normally result in spindles with inverted polarity, yet spindles manage to robustly assemble bipolar spindles despite slow microtubule flux. Here, we used experiment and theory to study how spindles acquire the proper microtubule organization despite the slow microtubule transport and branching nucleation. We found that microtubules self-organize into two mechanically distinct microtubule networks that undergo a gelation transition. This gelation allows the propagation of long-range extensile stress from the center of the spindle that push these two gels apart. This process globally transports microtubules independently of their local polarity environment, and explains how microtubules can be sorted out into the proper bipolar structure in the presence of branching nucleation despite the slow microtubule transport.

Invited Talk SYES 1.5 Thu 11:45 HSZ 02
Adding magnetic properties to epitaxial graphene — •Rodolfo Miranda — IMDEA Nanociencia, Madrid, Spain — Dept. Condensed Matter Physics, Universidad Autónoma Madrid

The intrinsic magnetic properties of pristine graphene are negligible, but we show that, by either adsorption of suitable molecules or intercalation of heavy metal atoms, one can create long range magnetic order in hybrid graphene systems, introduce a giant spin-orbit coupling into the π bands of graphene or produce chiral domain walls protected by graphene at 300 K.

A monolayer of TCNQ molecules on graphene grown on Ru(0001) acquire charge and a magnetic moment. The TCNQ monolayer develops spatially extended, spin-split, electronic bands and a magnetically ordered ground-state as visualized by spin-polarized STS. The long range magnetic order is due to direct exchange interaction mediated by overlapping frontier orbitals of the molecules.

Pb-intercalated Graphene grown on Ir(111)develops a giant (70-100 meV) spin-orbit coupling in the π bands of graphene, as detected by spin-ARPES, which is a suitable candidate for the observation of Spin Hall Effect in graphene

Finally, epitaxial graphene/Co(111)/Pt(111) stacks grown on MgO(111) crystals exhibit enhanced Perpendicular Magnetic Anisotropy for Co layers up to 4 nm thick and generate left-handed Néel-type chiral Domain Walls stabilized by interfacial DMI interaction. The magnetic texture is protected by graphene, stable at 300 K in air, and amenable to transport measurements.

SYES 2: Spain as Guest of Honor II

Time: Thursday 15:00–17:45 Location: HSZ 01

Invited Talk SYES 2.1 Thu 15:00 HSZ 01
Interactions in assemblies of surface-mounted magnetic molecules — •Wolfgang Kuch — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Organic magnetic molecules have great potential for defining the spin of electrons, logic operations, or data storage in future miniaturized electronic devices. For that, the molecules need to be immobilized and contacted, which involves adsorption on solid surfaces. Understanding and controlling the interactions of adsorbed metal–organic magnetic molecules with each other and the environment is thus an important step towards a surface-mounted molecular spin electronics.

X-ray absorption spectroscopy (XAS) is particularly well suited for the experimental investigation of such interactions. The elemental specificity of X-ray magnetic circular dichroism allows to explore the magnetic interaction between ferromagnetic substrates and adsorbed molecules. It is found to persist even across a layer of graphene and could be used, for example, to stabilize the molecule's magnetic moments against thermal fluctuations. Field-dependent measurements yield insight into the magnetic interaction between neighboring molecules in one- or two-dimensional molecular surface assemblies. The decisive role of the substrate on the magnetic properties of adsorbed molecules is emphasized by the change in spin state caused by a relatively subtle modification of the substrate such as a different crystallographic surface orientation. Finally, directly probing the d

occupation by XAS, cooperativity in the thermally induced spin-state switching between adsorbed spin-crossover molecules is identified.

Invited Talk SYES 2.2 Thu 15:30 HSZ 01

Towards phononic circuits based o optomechanics — •Clivia M. Sotomayor-Torres — Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and BIST,*Campus UAB, Bellaterra, 08193 Barcelona, Spain ICREA, Passeig Lluis Companys, 08010 Barcelona, Spain — ICREA, Passeig Lluis Companys, 08010 Barcelona, Spain

he optomechanical interaction using suspended nanobeams where overlapping confined mechanical and optical modes is chosen to realise circuit elements. Room temperature mechanical quality factors reached Q > 103. We demonstrated a coherent phonon emitter at 0.3 GHz via self-pulsing and up to 5 GHz via dynamical back-action. The nanobeam is coupled evanescently via a tapered fibre either directly to the OM cavity or to an integrated photonic waveguide. The non-linear interactions can be controlled to reach a chaotic regime and, with an external laser, the coherent phonon emission can be modulated. The physics of synchronisation, of nanobeams coupled to optical waveguides and the coupling to surface acoustic waves to excite and detect phononic signals have been studied and reproducible functionalities demonstrated. We report on the progress to integrate elements in a proof-of-concept phononics chip.

Work in collaboration with D. Navarro-Urrios, M. Colombano, G. Arregui, J. Maire, N. Capuj, A. Griol, A. Martinez, J. Ahopelto, T. Makkonen, A. Pitanti, S. Zanotto, B. Djafari-Rouhani, Y. Pennec, D. Mencarelli and L. Pierantoni , partners of the EU H2020 FET Open project PHENOMEN (713450) www.phenomen-project.eu

Invited Talk SYES 2.3 Thu 16:00 HSZ 01

Optical properties of 2D materials and heterostructures — •Janina Maultzsch — Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

The physical properties of two-dimensional semiconductors, such as transition-metal dichalcogenides (TMDCs), can be modified through the presence of adjacent materials, as in van-der-Waals heterostructures or in covalently functionalized layers. As an example for such an interlayer interaction, we present recent results on the interlayer excitons in $MoSe_2$-WSe_2 and MoS_2-WSe_2 heterostructures [1]. We show that the interlayer excitons are indirect both in real space and in reciprocal space. Furthermore, we predict the structures and properties of two-dimensional antimony oxide [2], which may form if few-layer antimonene is oxidized in ambient conditions. Depending on the stoichiometry, the oxidized antimonene layers are semiconducting with band gaps between 2.0 eV and 4.9 eV. Therefore, oxidation of few-layer antimonene may result in natural heterostructures composed of semiconducting antimonene oxide and semimetallic few-layer antimonene.

[1] R. Gillen and J. Maultzsch, Phys. Rev. B 97 (2018), pp. 165306. [2] S. Wolff, R. Gillen, M. Assebban, G. Abellán, J. Maultzsch, https://arxiv.org/abs/1909.01204

Coffee Break

Invited Talk SYES 2.4 Thu 16:45 HSZ 01

Bringing nanophotonics to the atomic scale — •Javier Aizpurua — Center for Materials Physics (CSIC-UPV/EHU), San Sebastian, Spain

A plasmonic nanogap is a superb configuration to explore the interplay between light and matter. Light scattered off, or emitted from a nanogap carries the information of the surrounding electromagnetic environment with it. In metallic nanocavities with ultrasmall gaps, electron currents across the gap at optical frequencies efficiently produce a strong nonlinear optical response. All these effects can be further controlled when a bias is applied across the gap, enabling the possibility of active control of light emitted from the cavity. This situation becomes even more appealing when a molecule is located in the gap of the plasmonic cavity or in its proximity, with the molecule playing an active role either in the electromagnetic coupling with the cavity, or even participating in processes of charge injection and transfer, which can be revealed through molecular electroluminescence. Here, we will address situations of light emission in electron tunneling configurations where atomic-scale resolution is achieved due to the presence of picocavities within the gap. The process of interaction between a molecular emitter and a tunneling cavity will be addressed both in the weak and strong coupling regimes, as revealed in light absorption and in emission. Strong coupling between a molecule and a plasmonic cavity shows great technological potential as it produces hybrid molecule-cavity polaritonic states which can be used for quantum information or in induced chemical reactivity.

Invited Talk SYES 2.5 Thu 17:15 HSZ 01

Infrared signatures of the coupling between vibrational and plasmonic excitations — •Annemarie Pucci — Kirchhoff-Institut für Physik (KIP), Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 691210 Heidelberg, Germany

Related to confinement, free charge carriers in nanostructures show strong plasmonic resonances in the infrared. Depending on the charge carriers' plasma frequency and on electronic damping, the coherent oscillations are accompanied by a more or less enhanced resonant electro-magnetic nearfield. So, at the plasmonic resonance of a tailored nanostructure, an extraordinarily high nearfield enhancement and thus strong surface enhanced infrared absorption (SEIRA) of a vibrational dipole with the same resonance frequency and sitting inside the nearfield can be obtained, see our work together with J. Aizpurua (Donostia-San Sebastian), for example [1-3]. Combining the ideas of the nearfield enhancement in narrow gaps and tailored resonant plasmonic structures leads the application of nano-apertures for vibrational sensing, for example of ultrafine silica particles. The SEIRA signal of a single particle with diameter below 50 nm could be seen as a Fano-type anti-absorption on the background of resonant plasmonic extinction measured with a commercial infrared-spectroscopic microscope.[4] [1] F. Neubrech et al., Appl. Phys. Lett. 89 (2006) 253104. [2] F. Neubrech et al., Phys. Rev. Lett. 101 (2008)157403. [3] T. Neuman, er al., J. Phys. Chem. C 119 (2015) 26652. [4] C. Huck, et al., Phys. Rev. Applied 11(2019) 014036.