Keynote presentation k02

Plasma enhanced chemical vapor deposition (PECVD) and plasma enhanced atomic layer deposition (PEALD) in advanced thin film processing

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PECVD has been extensively used in thin film deposition, especially the inductively coupled plasma enhanced chemical vapor deposition (ICPECVD) enables low damage deposition of different thin films such as SiO_2 and Si_3N_4 at low temperature in semiconductor industry. PEALD plays a key role in advanced patterning fabrication processing [1], thanks to its unique benefits of conformality enabling 3D deposition and thickness control at an atomic scale.

In this paper, low stress ICPECVD SiO_2 and Si_3N_4 depositions and their applications as passivation layer, dielectric layer in capacitors or in trench filling will be presented. Furthermore, PEALD processes such as SiO_2, Al_2O_3 and HfO_2 and their applications in optical devices or as high-k dielectrics in power or RFdevices will be discussed. In addition, a recently developed PEALD NbN process as superconductor will be shortly addressed. As a highlight, an example of an individual PEALD process such as Al_2O_3 monitored by SENTECH Atomic Layer Real Time Monitor (AL RTM) as shown in Figure 1 will be presented, which allows to visualize thickness change in each sequential process step to understand the surface reactions, thereby to accelerate process development and optimization.

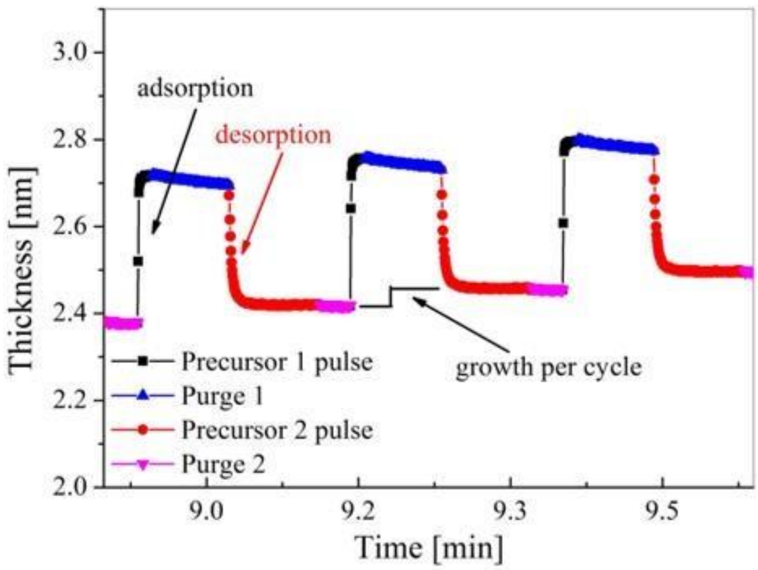

Figure 1. In-situ thickness measurement by SENTECH Atomic Layer Real Time Monitor (AL RTM)

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Keynote presentation k03

Advanced microscopic characterization strategies to better understand dynamics of PVD nanostructured films

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Evolution of nanostructured thin films is closely related to their small scale. Therefore, adapted characterization tools and techniques have to be developed, to highlight such relationships. The talk will then focus on two advanced surfaces: thin film metallic glasses (TFMGs) on the one hand, plasmonic films on the other hand, for which a specific microscopic approach was developed, and will be described.

Metallic glasses (MGs) have been intensively studied since the 60’s, for their amorphous structure and associated properties. However, applications of MGs have stayed limited due to the fast quenching imposed to limit the crystallization process, and leading to small pieces of multicomponent materials. The condensation from the vapor phase to form a solid film in PVD process is another way to design metallic glasses. TFMGs indeed may show, for instance, particular interest in terms of physico-chemical and bactericide behaviors, coupled with an enhanced ductility [1]. Thermal stability of such amorphous metals nevertheless remains an issue, so that we have adapted a non-conventional *in situ* technique, high-temperature scanning indentation (HTSI) [2], to monitor the physical changes occurring in ZrCu-TFMGs during heat treatment. Thanks to this high-speed nanoindentation technique, the entire mechanical evolution with temperature was characterized in only a few hours. A complementary study was also done in parallel with the same film exposed to the same thermal conditions, at the TEM scale using specific heating chip.

The optical response of bi-phased plasmonic films is directly linked to the nanoparticles (NPs) distribution into the amorphous matrix. However, this distribution is most often difficult to determine directly. The adapted techniques that gives access, at the nanometric level, to its 2D and 3D characterization is the electron tomography (ET) [3]. ET principles will be briefly exposed on plasmonic films characterized by Au NPs dispersed in magneton sputtered TiO_2 thin films. The goal was to quantify the particles size distribution, their position within the film and to correlate these characteristics with their plasmonic response. It was found that films had a bimodal heterogeneous size distribution of Au NPs with bigger nanoparticles segregated at the surface of the film, while smaller nanoparticles were embedded in the TiO_2 [4].

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Keynote presentation k05

Using microfluidics and nanobiosensors for precision diagnostics

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The field of nanotechnology has revolutionized many industries in the last decades, including healthcare, by enabling better medical imaging, more efficient therapies, vaccines and implants, and more sensitive diagnostic tools. On the other hand, microfluidics is considered a key enabling technology, allowing the precise manipulation of liquids at small scale, and the integration and automation of multiplex processes at low cost.

The Medical Devices group of INL works in close collaboration with hospitals, and is dedicated to Translational Medical Research by focusing on the development of solutions based on microfluidics, biosensors and nanotechnology towards early diagnosis and better understanding of diseases.

In this talk, I will discuss the advantages of microfluidics and nanobiosensors for the efficient enrichment of disease biomarkers from body fluids and their multiplex characterization in real settings. I will also present our most recent work in the development of these technologies and their application and validation in clinical settings, mainly in the field of cancer.

Acknowledgement

This work is supported by the European Union through the call H2020-FETOPEN-2018-2020 in the framework of the BIOCELLPHE project (965018); by the project SENTINEL funded through the framework of the Incentive Scheme to Research And Technological Development (Si I&Dt), Corporate R&D – Copromotion Projects: International Partnerships. This work has also received funding and support from the “BioPrinted hydROgel MicrofluIdicS to mimic patient-specific tumor mEtastatic microenvironment (PROMISE) “project funded through the Caixa Health Research program from La Caixa Foundation (HR20-00637); and by the project NORTE-01-0145-FEDER-000055, supported by

Norte Portugal Regional Operational Programme (NORTE 2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF). This project also received funding of the project Health From Portugal (C630926586-00465198), supported by Component C5–Capitalisation and Business Innovation, under the Portuguese Resilience and Recovery Plan, through the NextGenerationEU Fund.

Keynote presentation k06

Halide Perovskites/MXene thin films for Stable Perovskite Solar Cells

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MXene have been applied in Perovskite solar cells (PSCs) demonstrating the improvement of their power conversion efficiency. However, device stability studies are still missing. Especially under real outdoor conditions where devices are subjected to the synergy of multiple stressors. In this work, functionalized 2D Ti_3C_2 MXene is employed in normal PSCs configuration and applied at the interface between the halide perovskite and the hole transport layer (Figure 1). The functionalization of the Ti_3C_2 MXene was made utilizing the same organic additive passivating the halide perovskite layer. Our functionalizing strategy creates a continuous link between the MXene and the halide perovskite layer to obtain MXene-based PSCs with a ~22 % power conversion efficiency, in comparison with the control device showing 20.56 %. Stability analyses under different conditions (dark, continuous light irradiation and real outdoor analysis) reveal that the enhancement of the PSCs lifespan is always observed when the MXene layer is employed. To our knowledge, this is the first report of the stability analysis of MXene-based PSCs carried out under real outdoor (ISOS-O) conditions.

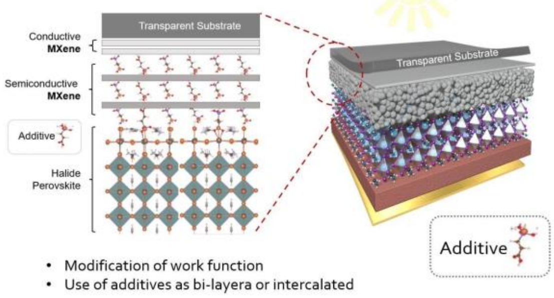

Figure 1. MXene-based Perovskite solar cells. Application of additives to functionalize the MXene/Perovskite thin film.

Acknowledgement

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Keynote presentation k07

Surface Waves on dielectric stacks and related applications in photonics

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Recent results on light manipulation by means of Bloch surface waves on multilayers is provided. Planar multilayers sustaining either in-plane- or out-of-plane-polarized BSW offer new opportunities for light management at the nanoscale, expanding and perhaps improving some of the features offered by Surface Plasmon Polaritons (SPP) on metals. Compared to SPPs, BSWs present some advantages, such as lower absorption, narrower mode resonances, stronger near-field surface enhancement effects, longer propagation length, spectral and polarization tuneability.

In this contribution, I will show how light can be propagated, manipulated and spatially confined by means of BSWs, in a sort of quasi-2D world, wherein light is flowing onto a basically flat surface, decorated with deep subwavelength patterns. In particular, applications of BSW platforms will include: label-free and fluorescence-based sensing [1], spatial phase manipulation of freely propagating and surface-bound radiation [2,3] and radiative emission control from organic dyes embedded within the photonic structure [4]. In Figure 1, schematic illustrations of the main application examples discussed are shown.

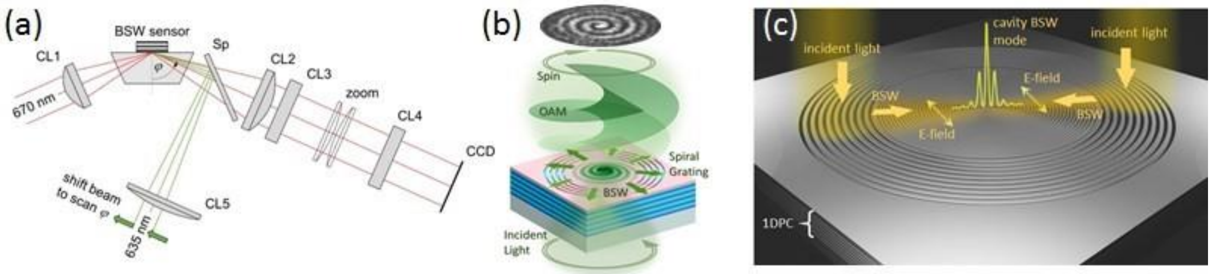

Figure 1. (a) Sketch of a BSW-based biosensing platform operating in both label free and fluorescence modes (from [1]); (b) vortex-beam outcoupling from phase-manipulated BSW by spiral gratings (adapted from [2]); (c) circular micro-cavity for BSW surrounded by a grating outcoupler (adapted from [3]).

Acknowledgement

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Keynote presentation k08

Surface and interface driven environmental reliability and crack propagation resistance of 3D-printed ALD-coated nanoceramics

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3D-printed micro- and nano-architected ceramic metamaterials are lightweight materials with exceptional strength and stiffness. However, their application is hampered by the lack of knowledge of their mechanical reliability. Recently, the sensitivity of nanoceramics crack propagation resistance to environmental conditions has been evidenced [1], with a reduction of 20% in the average fracture toughness value reported at high relative humidity levels of testing (RH>60%) from the generally performed low-humidity-based testing. A possible solution to improve the environmental reliability of those materials is represented by the possibility of controlling their surface characteristics via coating processes. To this scope, a population of TPP glassy carbon micro-pillars and uniform 2.5D structures have been coated with highly conformal ALD-deposited Al_2O_3 thin films (having a thickness of 50 nm, Figure 1a). The effects of the deposited films on the fracture toughness of 5.8 µm diameter micropillars as a function of two extremal testing RH levels (<5% "and" >60%) are elucidated in correlation with localized residual stress measurements [2]. It is evidenced that the fracture toughness of ALDcoated pillars is incremented from that measured on the pristine defective high-humidity tested ones (Figure 1b), gaining independence from the relative humidity conditions. However, It was found that tensile residual stresses (Figure 1c) within the coating interact with the crack as an additional reservoir to the opening system, preventing full recovery of the Kc values as reported for the non-coated pillars at low RH. The statement is enforced by cohesive-zone elements simulations of the splitting, including parametric investigations of the ALD film's residual stress states, elastoplastic energy during indentation and film thickness.

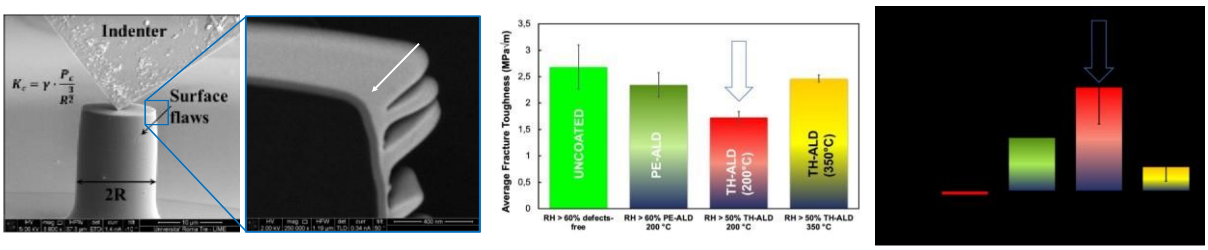

Figure 1. Effects of 50 nm ALD coatings on the crack propagation resistance of TPP-3D printed nanoceramics: a) pillar-splitting on coated micro-pillars; b) crack propagation resistance as a function of environmental conditions and ALD deposition temperature; c) FIB-DIC ring-core measurements of average films residual stress states.

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Keynote presentation k09

Surface-enhanced Raman scattering in materials research. Present and future trends

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Surface-enhanced Raman scattering (SERS) method could be used for enhancing the light-matter interaction during the Raman process, mainly by nanostructures. The enhancement of the SERS process depends on the material, shape, and geometrical parameters of the nanoparticles, while at the same time on the excitation wavelength and the nature of the selected analyte. Different nanostructures (nanoislands, nanoparticles, nanotrees) were created and analyzed, and their parameters were optimized to obtain a higher enhancement factor and to find out the detection limit of the selected analyte. Also, the different creation methods were compared from the point of view of the sensing application. Raman spectroscopy is a branch of vibrational spectroscopy that allows highly sensitive structural identification of various chemical and biological materials based on their unique vibrational characteristics, all without destroying the sample. Raman spectroscopy is an effective tool for analytical studies, but the low intensity of Raman signals is a major disadvantage of the method [1]. SERS is a commonly used technique to enhance the signal, that allows the analysis of low-concentration samples or even the detection of a single molecule. The SERS effect can occur when the analyte is in close vicinity of a nanoscale-structured metal surface. By using metal surfaces with optimal parameters, the intensity of Raman signals can be enhanced by several orders of magnitude [1]. As our previous research shows that thermal dewetting of thin metallic layers could be used for SERS application [2-4]. In this research, we compare the results obtained during the examination of nanostructures created by spark ablation and vapor-liquid-solid techniques, to find the optimal creation parameters for the SERS substrate with a higher enhancement factor, which is suitable to detect the least analyte and will be suitable for further applications. In Figure 1, the Scanning electron microscope images of different nanostructures for the SERS application can be seen.

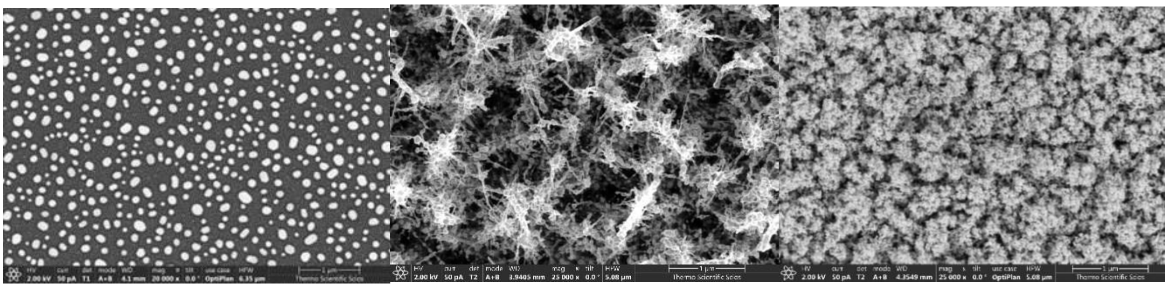

Figure 1: Scanning electron Microscope images of the created and investigated nanostructures:
a) Thermal dewetted gold nanostructures, b) Silicon nano trees covered by gold layer, c) Ag-Au gold nanostructures created by arc-discharge method.

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Keynote presentation k10

Thin film ionic and mixed ionic-electronic conductors for energy and information applications

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Nanoionics and Iontronics are emerging disciplines dealing with the ionic transport properties at the nanoscale and the effect of a tuneable arrangement of ions on the electronic properties, respectively. These two disciplines try to understand and exploit the subtle interplay between electrons and ions and its application to innovative solid state-based devices to promote a revolution similar to the one driven by nanoelectronics few decades ago. In particular, since the main conversion and energy storage technologies are based on ionic, electronic or mixed-ionic electronic conductors (MIEC), these new disciplines are called to revolutionize the energy field by giving rise to entirely new and disruptive technologies.

In this talk, we will present last advances in thin film oxides with ionic conduction for their application in solid oxide cells [1-3], solid-state lithium ion batteries[4-6] and switchable devices for information technologies[7].

Acknowledgement
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Keynote presentation k11

Epitaxial van der Waals materials for spintronics

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Layered materials are a class of quantum materials with electronic properties of exceptional interest for many domains of solid-state physics. Their crystal structure with van der Waals bonding between unit layers makes it feasible to stabilize single 2D layers and to form a wide range of heterostructures without the constraint of lattice matching. In this family of materials, transition metal dichalcogenides and topological insulators hold great promise for spintronics owing to their large spin-orbit coupling and the locking between the electron spin and momentum [1]. The recent discovery of van der Waals 2D magnets has also opened exciting opportunities to explore low dimensionality magnetism, proximity phenomena in heterostructures and all-van der Waals spin devices [1].

While most research on these materials is currently performed with nanoflakes mechanically exfoliated from bulk crystals, molecular beam epitaxy is emerging as a powerful method to grow largearea 2D materials with fine tuning of the composition, control of the thickness down to the 2D limit and ability to fabricate heterostructures with sharp and clean interfaces. I will discuss the specificities and challenges of van der Waals epitaxy and review recent progress in the fabrication of van der Waals materials by this technique, including topological insulators [2], transition metal dichalcogenides [3] and 2D magnets [4]. I will then illustrate the potential of these materials for spintronics with examples of heterostructures in which spin-charge interconversion is implemented, leading to large spin-orbit torques and current-driven magnetization switching. [5]

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Keynote presentation k12

Efficient and stable perovskite light-emitting diodes

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Metal halide perovskites (MHPs) has attracted great attention as a promising light emitter for nextgeneration display application because of their high color purity (FWHM ~ 20 nm) and low process cost. Although a lot of strategies have been reported, electroluminescence efficiency and stability of MHP still lag behind existing light-emitting diodes (LED). In this talk, advantages and strategies for commercialization of MHP will be delivered.

First, for high electroluminescence efficiency, we reported a comprehensive material strategy for suppression of defect formation in colloidal perovskite nanocrystal (PNC). Doping of guanidinium (GA^+) into formamidinium lead bromide ($FAPbBr_3$) PNCs leads to smaller PNCs with more carrier confinement.[1] Furthermore, a PNCs surface-stabilizing bromine-based small molecule, 1,3,5tris(bromomethyl)-2,4,6-triethylbenzene (TBTB), was applied as a halide vacancy healing agent.[1] In addition, for large-area applications, we developed a modified-bar coating method to fabricate largearea devices which have similar high efficiency to that of small-area devices made by the spin-coating method.[2] Lastly, we report simultaneously efficient, bright, and stable perovskite LEDs by developing an in-situ core/shell PNC structure. By splitting large 3D crystals into nanocrystals and surrounding them with small organic ligands, significant improvement in both efficiency and lifetime could be achieved with both excellent charge transport and charge confinement.[3]

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Keynote presentation k13

Electric field manipulation of magnetic properties of Pt/Co/oxide thin films

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The manipulation of magnetism with a gate voltage, and in particular by magneto-ionics - where the magnetization is controlled by an electric field driving the migration of ionic species - is a fast developing research field which opens the perspective of energy efficient magnetic devices. Magnetoionic effects under micropatterned electrodes in solid-state devices allow modifying magnetic properties locally, in a nonvolatile and reversible way. In this work, we illustrate some of the results obtained on Pt/Co/oxide thin films using HfO2 or ZrO_2 thin layer as a solid state ionic conductor. We demonstrate that tuning magnetic anisotropy, magnetization and DzyaloshinskiiMoriya interaction allows modifying "at will" the dynamics of nontrivial magnetic textures such as skyrmions and chiral domain walls. Through photoemission electron microscopy measurements, we show that the change of magnetic properties can be directly attributed to the modification of the oxidation state of the ferromagnetic layer via electric field driven oxygen ion migration.

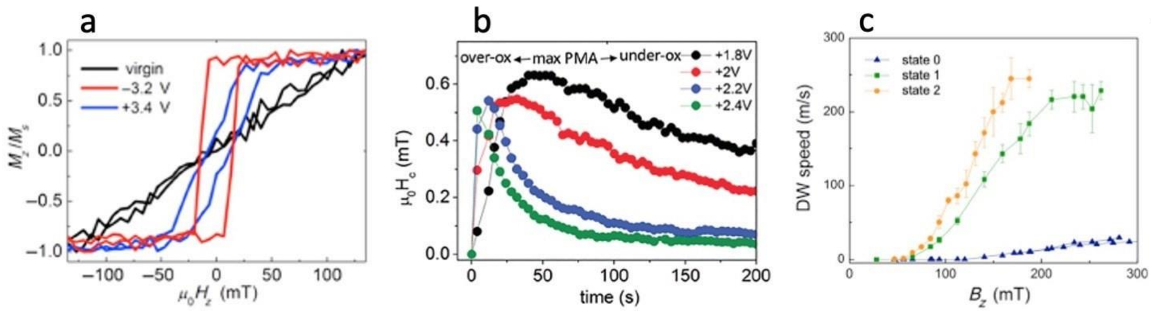

Figure 1. (a) Polar Kerr hysteresis loops showing the electric field induced reversible change of easy axis magnetization from in plane to out-of-plane in Pt/Co/TbOx thin films [1]; (b) time-dependence of the magnetic anisotropy with applied gate voltage [2]; Electric-field induced variation of chiral domain wall dynamics in Pt/Co/Tb/AlOx thin films [3].

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Keynote presentation k14

Challenges and Opportunities in Thin Film Coatings for Particle Accelerators

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Thin film coatings are extensively utilized in particle accelerators to modify the surface properties of beam pipes and other components. Various examples include highly resistive films employed to eliminate electrical charges in ceramic chambers and Radio Frequency (RF) waveguides [1]; low resistivity coatings used to reduce the RF impedance of absorber blocks for beam collimation [2]; superconducting films employed to enhance the performance of RF cavities for beam acceleration [3]; amorphous carbon films with low emission of secondary electrons to mitigate electron multipacting [4]; and Non Evaporable Getters (NEG) used to provide distributed vacuum pumping and low emission of secondary electrons [5]. These films are typically deposited through sputtering, either in planar or cylindrical configurations, and large-scale production takes place either at accelerator laboratories or in the industry [6, 7].

In this contribution, we explore the peculiarities associated with the production of different thin films used in particle accelerators. The challenges often arise from the geometry of the systems, such as tubular vacuum chambers with lengths exceeding 10 meters, inner apertures ranging from half a meter to a few millimetres, and significant variations in the distance between the sputtering target and the substrate. Other difficulties are related to surface preparation, which defines adhesion and surface roughness, as well as the deposition process conditions, such as the angle of arrival of atoms onto the substrate, the energy available for the film to grow with the desired microstructure, and the purity of the deposition atmosphere. Additionally, the quantities involved in these processes, reaching several kilometres of beam pipes, present further challenges. Furthermore, we address the development opportunities posed by future projects, such as the upgrade of the Large Hadron Collider at CERN [8], which necessitates the development of technology for in-situ deposition of amorphous carbon films on several hundreds of meters of beampipes within the accelerator's tunnel. We also discuss the ongoing studies of materials and large-scale coating technology for the superconducting RF accelerating cavities for the Future Circular Collider project [9].

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Keynote presentation k15

Changing the skin of an ultrathin ferromagnet

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Low dimensionality provides a means to tune the properties of even the well-known elemental ferromagnets. In this respect, ultrathin films constitute an important playground with sensitive changes in their electronic, structural and chemical parameters due to the presence of surface/interface [1]. As a consequence, spin reorientation transitions (SRT) [2] and exotic magnetic structures [3] can be observed in ultrathin magnets.

In this talk, the focus will be on cobalt films grown on single crystalline surfaces. In particular, we investigate the effects of carbon adspecies on the magnetic properties of ultrathin Co films. CO adsorption and its beam-induced dissociation was shown to result in an SRT of Co/Re(0001), where Co magnetization reorients perpendicular to the film plane [4]. Moreover, the resulting out-of-plane domains are delimited by chiral boundaries originating from the strong spin-orbit coupling of the Re substrate [5]. On another front, graphene-Co interface was studied from structural [6] and spin-polarized electronic [7] perspectives. Similar effects of surface carbides and graphene on the magnetic anisotropy of Co call for a comparative study between different carbon species [8]. Thus, we will discuss different contributions to the magnetic anisotropy in cobalt ultrathin films and how they are influenced by the surface carbon chemistry. From the experimental perspective, a range of techniques will be introduced in order to address the interplay between structure (low-energy electron diffraction and microscopy), chemistry (x-ray photoemission spectroscopy), electronic structure (spin-polarized angle-resolved photoemission spectroscopy) and magnetism (x-ray magnetic circular dichroism and magneto-optical Kerr effect).

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Keynote presentation k16a

New developments in industrial magnetron sputtering and arc PVD technologies. Equipment and examples of industrial processes

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Physical Vapour Deposition is gaining presence in industrial sectors and value chains as a key enabling technology for surface modification of materials and components. In this paper, it will be presented the conceptualization, development and features of a recently implemented magnetron sputtering Pilot system to shorten the timings needed from research phases to industrial applications. The system is equipped with sputtering power supplies of the type DC_pulsed, HIPIMS+ (HIP+) and Dual-Bipolar, which can be operated simultaneously, therefore providing enormous possibilities for coating design purposes. The paper will exhibit examples of recent developments of tribological coatings for tooling protection. Titanium di-borides (TiB_2) grown by HIP+ and hybrid HIP+-DC_pulsed processes will be presented, along with the characterization of the coatings by nanoindentation, scanning electron microscopies, friction, wear and corrosion. The tribological characterization against Aluminium alloys will show that the TiB_2 films exhibit very low tendency to stick this metal, which opens the possibility for significant lub reductions in industrial processes such as Al-stamping or Al-die-casting.

The presentation will run over additional applications, such as coatings for high temperature applications, photocatalytic coating for air cleaning, or even as antimicrobial interfaces. Finally, a brief introduction of medium entropy alloy coatings, the compositional dependencies of the mechanical properties, and the possibilities of industrial PVD systems to bring this novel type of coating formulations to the market.

Figure 1. Industrial magnetron sputtering equipment at AIN.

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Keynote presentation k16b

A Review in Magnetron Sputtering

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Magnetron sputtering is a mature and well establish PVD deposition technique. Since the introduction of commercial planar magnetrons in the 1970s there are few vacuum coating sectors that haven't been touched by successful implementations of this deposition technique. In the 1970s the semiconductor industry was revolutinonized by the introduction of planar magnetron sputtering as an alternative to evaporation and diode sputtering. Nearly forty years later, still magnetron sputtering is at the heart of many of the manufacturing processes from small to large area, with different degrees of functionality, from decorative, to energy, transport, architectural, automotive, aerospace, display, photovoltaic, thermal solar, electronics, etc. Depending on the application the market has seen different design concepts emerging. In this presentation we'll be looking at key milestones in designs and applications which have been driving the technology over more the last 50 year.

Keynote presentation k17

Laboratory Ice Astrochemistry at Larger Scale Facilities

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Complex organic species are expected to be formed in a variety of interstellar environments at the surface of ice grains by means of a combination of energetic and nonenergetic processing, such as photons, electrons, ions, and atoms. However, to date, many fundamental questions on the physicochemical origin of the molecular complexity observed in space by the ground-based Atacama Large Millimeter/submillimeter Array (ALMA) remain unanswered [1,2]. The recent scientific achievements of the spaceborne James Webb Space Telescope (JWST) are marking the onset of a new era for space science, astrophysics, astrochemistry, and astrobiology [3]. The unprecedented combination of JWST and ALMA is currently mapping and characterizing the ice and the gas content of the interstellar medium toward a variety of space environments and physicochemical conditions, revolutionizing our understanding of the star formation process [4]. In my talk, I will discuss new emerging laboratory techniques at larger scale facilities in Europe that will allow for a correct interpretation of observational ice data to help address some of the "Grand Challenges" in astrochemistry of the next decade.

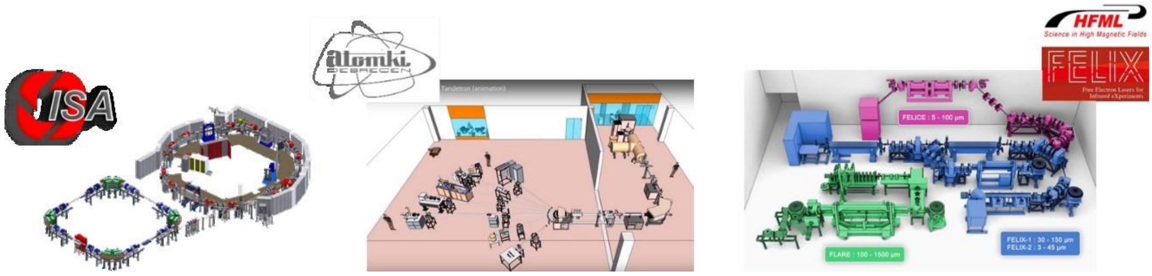

Figure 1. Left: ISA, Centre for Storage Ring Facilities, Aarhus, Denmark. Center: Atomki, Institute for Nuclear Research, Debrecen, Hungary. Right: HFML-FELIX, High Field Magnet Laboratory and FreeElectron Lasers for Infrared eXperiment, Nijmegen, Netherlands.

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Keynote presentation k18

Surface analysis of Cultural Heritage objects at the New AGLAE facility

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Cultural heritage objects represent invaluable treasures from the past, offering profound insights into human history, art, and civilizations. The preservation and understanding of these artifacts require non-invasive analytical methods that can reveal their material composition and degradation mechanisms. Surface analysis has emerged as a pivotal field, bridging the gap between science and cultural heritage conservation, allowing for a deeper comprehension of these objects' hidden secrets.

Located in Le Louvre premises, the AGLAE facility – New AGLAE since its automation in 2017 – is the unique state-of-the-art platform totally dedicated to non-destructive ion beam analysis of cultural heritage objects [1].

Key techniques implemented at the New AGLAE facility include Particle-Induced X-ray Emission (PIXE), Particle Induced Gamma-ray Emission (PIGE), Rutherford Backscattering Spectroscopy (RBS), ion beam induced ionoluminescence (IBIL), etc. These techniques empower researchers to precisely determine the chemical composition and distribution of elements within artifacts, offering a deeper understanding of their craftsmanship, historical context, and state of preservation.

Case studies on objects coming from various geochronological contexts and with different questionings will illustrate the absolute necessity of these surface analyses to address human science issues without compromising their integrity.

Then, the lecture will highlight instrumental and methodological developments that are currently undergoing, in particular in scientific image processing, leveraging machine learning algorithms to automate data processing and decrease calculating time.

Finally, while preserving tangible cultural heritage objects is paramount, the challenge of transforming data acquired by the New AGLAE facility into digital cultural heritage will be outlined, along with the state of progress of concrete solutions to achieve this objective.

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