Plenary-1

Architecting Thin-Film Morphology for Optical, Electronic, Acoustic, Biological, and Other Applications

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A collimated vapor flux can condense on a substrate to form a thin film comprising isolated parallel columns, as demonstrated conclusively by scanning electron microscopy in the 1960s though the anisotropy of these columnar thin films was optically evident much earlier. Substrate motion during deposition causes the parallel columns to grow in fanciful shapes [1], the columnar morphology of these sculptured thin films (STFs) being architected through physical (and physicochemical) vapor deposition. STFs can be made of metals, inorganic non-metals, and organic materials (including polymers). Both the material and the columnar shape are alterable during deposition. STFs can be deposited on planar surfaces, curved surfaces, and even topographically decorated surfaces.

Several different types of applications have emerged [1-5]. Optical applications include polarization filters, other filters and integrated optical devices, optical biosensors, light sources, and photonic crystals. Acoustical applications encompass shear-wave filters and phononic crystals. Electronic applications include substrates, gate dielectrics, and passivation layers for flexible devices. Biomedical applications include tissue culture substrates, free-standing films for conformal coatings for prostheses and tissue transplants, gradient panels for protein-binding assays, and coatings for resurfacing bones. Biomimetic replication of dipteran eyes and buprestid elytrons lead to applications for solar energy harvesting and decoys for pest control. Forensic applications involve the visualization of latent fingermarks and partial bloody fingermarks.

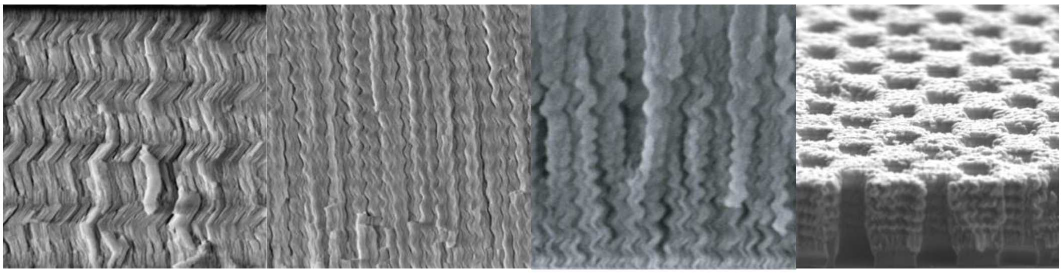

Figure 1. Scanning electron micrographs showing the diversity of architected columnar morphology.

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Plenary-2

Functional Applications of Nanostructured Surfaces Developed by Plasma and Vacuum Technologies: from Wetting to Energy Harvesting

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We present herein our last advances in the nanoengineering of thin films and supported lowdimensional materials. A key step in the development of such nanoarchitectures is the implementation of plasma-assisted and glancing angle depositions and a proprietary soft-template procedure based on organic nanowires. The presentation will provide a comprehensive overview of the preparation and application of low-dimensional nanostructured surfaces, encompassing nanocolumns, complex nanowires (NWs), and nanotubes (NTs). We will particularly focus on core@multishell nanoarchitectures and the one-reactor method. Additionally, we will outline the necessary steps for integrating these nanomaterials into supported or in-device applications. The versatility of vacuum and plasma methods enables the deposition of an unparalleled range of materials, including organic (small molecules, organic nanocomposites, polymeric layers), inorganic (metal and metal oxides), and hybrid (hybrid perovskite) materials. These materials can serve as conducting, semiconducting, dielectric, photo-absorbent, piezoelectric, or plasmonic components, either in multilayer or radial configurations. Two final applications will drive the presentation: the development of multisource energy harvesters (piezo, solar, pyro and triboelectric) and novel approaches for smart surfaces (superhydrophobic and anti-icing) and efficient de-icing by acoustic waves. Also, some hints on the exploitation of their photonics and photocatalytic properties will be presented.

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Plenary-3

Plasmonics for Label-free Optical Biosensing

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Label-free optical biosensors hold potential for applications in numerous important areas, such as molecular biology, medical diagnosis, environmental monitoring, food safety, and security. Surface plasmons are special modes of the electromagnetic field that can be excited at the metal-dielectric interface and allow for high confinement of the electromagnetic field at the metal surface. Affinity biosensors based on optically excited surface plasmons (often referred to as plasmonic biosensors) represent the most advanced optical label-free biosensor technology. Over the past two decades, plasmonic affinity biosensors have become a key method for real-time label-free investigation of biomolecular interactions. However, their penetration to clinical applications has been much slower [1, 2].

In this paper, we discuss the main challenges in developing plasmonic biosensors for applications in biomedicine and present selected advances in plasmonic biosensor research that aim to address these challenges. In particular, we cover advances in plasmonic nanostructures, sensor instrumentation, transport of target molecules in microfluidic systems, functional coatings, and assays for the detection of analytes in complex biological media. We also highlight two applications of plasmonic biosensors related to the diagnosis of Myelodysplastic syndromes (MDS) [3, 4]. We present an extremely sensitive assay for detecting MDS-related microribonucleic acids and demonstrate that in conjunction with a plasmonic biosensor the assay enables the detection of miRNAs in blood plasma with a limit of detection < 350 aM. Moreover, we use a plasmonic biosensor to quantify interactions between selected MDS-related proteins immobilized on the surface of the plasmonic imaging sensor and blood plasma and show that this interactomic approach can help discriminate among different MDS subgroups and healthy donors.

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Plenary-4

Can we exfoliate non-exfoliable materials? Down to freestanding layers of non Van der Waals materials from ultrathin films

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Since the isolation of graphene in 2004 resulting from the mechanical exfoliation of graphite crystals rendering a few micron flakes of graphene [1], the scientific community has focused on the scalable synthesis of this outstanding material [2]. Presently, the possibility of growing and transferring graphene membranes that match the properties found in mechanically exfoliated flakes has become real, opening the path to integrate graphene in current technologies for a variety of applications. Also, when considering single layers, atomically thin, of Van der Waals (VdW) layered compounds, a wealth of other materials with complementary properties to those of graphene comes into play. Among them, transition metal dichalcogenides are the best understood and their synthesis has evolved enormously in recent years providing good quality materials. This has enabled heterostructures combining graphene and thin layers of other layered materials to conform all vdW materials devices.

From the very fundamental viewpoint, the discovery of superconductivity in twisted bilayer graphene at a “magic angle” [3] have triggered the interest in twisted homolayers of many other VdW materials. However, in spite of the variety of properties exhibited by easily exfoliated VdW materials, strong orders present in non VdW materials such as high Tc superconductivity, high temperature ferromagnetism, strong room temperature ferroelectricity or multiferroicity seem to be almost absent in the VdW materials explored so far. These properties are, however, the common ground of highly correlated systems as the complex transition metal oxides (TMOs) with perovskite structure.

During the last decades, the epitaxial growth of TMOs has been polished to perfection and heterostructures with atomically sharp interfaces are build up combining these materials into new device concepts. Here we report on the epitaxial growth and transfer of freestanding layers of transition metal oxides and their integration in hybrid heterostructures with VdW materials [4]. It will be also shown that the stacking of freestanding ferroelectric perovskite layers with controlled twist angles opens an unprecedented opportunity to tailor these topological nanostructures in a way determined by the lateral strain modulation associated to the twisting [5].

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