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Editorial

Special Issue "Materials Processing for Production of Nanostructured Thin Films"

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The field of thin film technology [1] dates back many decades and has led to applications in areas such as display technology, the development of surfaces with desirable optical reflectance properties, coatings of medical devices for biocompatibility, corrosion protection, semiconductor device fabrication, polymer coatings for tuning wettability, coatings for providing hardness or protection, piezoelectric transducers, photovoltaic films for solar panels, chemical and biological sensors, and other areas. Many of the techniques for production of thin films, typically in the microns range in thickness, were developed in earlier decades such as electrodeposition, electroplating, spin-coating, dip coating, vacuum sputtering, chemical vapor deposition, physical vapor deposition, thermal evaporation, atomic layer deposition, molecular beam epitaxy, electron beam deposition, pulsed laser deposition and other advanced technologies that have driven the modern age. When combined with advances in lithography into the extreme ultraviolet [2], and newer approaches such as microcontact printing [3], thin film technology has made possible many of the advanced devices introduced in the past decade. New methods such as molecular imprinting [4] are open for further investigation.

The emergence and rapid growth of nanomaterials science throughout the period since the 1980s, has added an entirely new dimension to thin film technology in the realization that introducing nanostructured features into thin films in an intentional and designed manner can impart novel and useful properties and also alter existing properties for films prepared by traditional methods. The Special Issue on "Materials Processing for Production of Nanostructured Thin Films" presents a number of articles and reviews in which the properties and applications provided by the introduction of features on the nanometers scale into thin films are described and investigated. The introduction of nanoscale features represents a new frontier in thin film technology that will have major impacts in the coming decades in industries ranging from catalysis, renewable energy, sensor technology, device technology, biotechnology and others.

The paper by Nauman et al. [5] demonstrates that nanostructures can be embedded into flexible substrates for use in the growing field of flexible electronics. In this study, bath sonication is used to cause the intercalation of expanded graphite particles into polydimethylsiloxane (PDMS) substrates formed in a mold. Sonication was used to intercalate silver or silver oxide into the graphite particles, while electrolysis was used to intercalate sulfate anions. The graphite modified PDMS could flex 1000 times and remain functional and with favorable mechanical properties.

The paper by Sheng et al. [6] helps to illustrate how the introduction of nanostructures and the geometric features of the nanostructures in a thin film can depend on the adjustment of multiple parameters in the production process. In this paper, vertically oriented zinc oxide nanorods are formed on sapphire substrates with large diameters using chemical bath deposition. Such arrays of ZnO on substrates have applications in solar cells and other technologies. The variables of precursor concentration, reaction temperature, reaction time, and ratio of Zn^{2+} to citrate anion influence the diameter of the nanorods in a way that was able to be modeled using the statistical approach of response surface methodology. The approach was more efficient than changing one variable at a time and used experiments in which multiple variable were changed. Spin-coating was also involved in priming the sapphire substrates with a thin layer of zinc oxide.

The paper by AlQarni et al. [7] describes the discovery of a new alkali metal phosphate material with the novel property of fast ionic conduction. The new material, $Na_2CaP_{1.5}As_{0.5}O_7$ was produced by the heating and grinding of precursors to produce a polycrystalline powder. The characterization methods of X-ray powder diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), energy-dispersive X-ray spectroscopy (EDX), scanning electron microscopy (SEM), and impedance spectroscopy were used to provide insight into how the material structure gave rise to fast ionic conduction as explained using a bond-valence site energy (BVSE) model.

The paper by Filip et al. [8] also illustrates how the production of a nanostructured thin film can depend on a complex set of variables in the case of forming electrospun layers of polyethylene (PEO). These electrospun fibers that form a nonwoven textile can have applications as filters, in tissue engineering, drug delivery, and other fields. In this study, the correlations between the variables of polymer molecular weight, polymer concentration and solution viscosity with nanofiber diameter are established for electrospinning from solutions in distilled water.

The review by Zhang et al. [9] provides a comprehensive survey of the formation of thin films of metal–organic frameworks (MOF) that are versatile structures formed by the coordination of multidentate organic linkers to metal cations. MOFs provide access to tenability of pore size and have found use in gas storage, catalysis and sensor development. A wide range of thin film formation methods are covered in this review including spin-coating, dip-coating, template synthesis, layer by layer deposition, evaporation-induced crystallization, hydro/solvothermal synthesis, electrochemical synthesis, atomic layer deposition, chemical vapor deposition and physical vapor deposition, and some others. The variety of possible substrates on which MOF thin films can be formed ranges from Si, SiO_2, to metals, metal oxides and nylon. The review emphasizes the role of surface pretreatment with self-assembly monolayers, and the possibilities for postsynthesis modification and patterning of the MOF thin films. In addition to the tuning of pores by the selection of metal cations and linkers, the preparation conditions determine the nanostructured texture or pattern of the MOF thin films.

The review by Bhattarai et al. [10] describes the growing field of nanostructured thin films with plasmonic properties such as localized surface plasmon resonance, propogating surface plasmon resonance and surface-enhanced Raman responses. The tuning of the nanoscale features of these films, referred to as plasmonic active thin films (PANTFs), can vary the plasmon wavelengths and refractive index sensitivity when used in biosensor applications. Methods for their production including electron beam lithography, nanosphere lithography, focused ion beam milling, porous membrane lithography and others used to make a wide variety of PANTFs are described. The creation of PANTFs with nanoscale gaps and nanoholes is described, along with those presenting arrays or patterns of elevated features such as nanodomes or nanopillars.

It is hoped that the papers in the Special Issue will inspire further development of nanostructured thin films by new and creative approaches. The Guest Editor thanks Ms. Tami Hu for her dedicated and generous assistance in the development of this Special Issue.

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