

Editorial

Special Issue: Current Research in Thin Film Deposition: Applications, Theory, Processing, and Characterisation

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Today, thin films are near-ubiquitous and are utilised in a very wide range of industrially and scientifically important areas. These include familiar everyday instances such as antireflective coatings on ophthalmic lenses, smartphone optics, photovoltaics, decorative and tool coatings. There exist also a range of somewhat more exotic applications, such as astronomical instrumentation (e.g., ultra-low loss dielectric mirrors and beam splitters in gravitational wave detectors, such as Laser Interferometer Gravitational-Wave Observatory (LIGO)), gas sensing, medical devices and implants, and accelerator coatings (e.g., coatings for the Large Hadron Collider (LHC) and Compact Linear Collider (CLIC) experiments at European Organization for Nuclear Research (CERN)).

The aim of this Special Issue is to provide a platform for researchers working in any area within this highly diverse field to share and exchange their latest research findings.

Thin films are everywhere in the modern world, with many of the technologies we depend upon in daily life being, in turn, dependent upon thin film technology. These may range in dimension from an atomic or molecular monolayer—perhaps only a few ångströms thick—to either mono- or multilayer coatings with a thickness of several microns.

Such materials may have a huge range of extremely useful properties; they may be, for example, anti-reflective, impervious to oxygen and/or other gases, optically transparent yet electrically conductive, catalytic, and self-cleaning. Everyday examples featuring thin film technology include, but are not limited to, mobile phones, touch screens, laptops, and tablets [1,2].

Other important applications of thin films include bandpass filters as used in gas analysis [3], mirrors used in astronomy [4–6], protective (e.g., biomedical, anticorrosive, and antimicrobial) coatings [7], architectural glass coatings (e.g., to reflect heat while transmitting visible light) [8], photovoltaic electricity generation [9,10], and a great many others.

There are also a great many routes to deposition of thin film materials, including electron beam evaporation [11,12], ion beam sputtering [4,6,13,14], chemical vapour deposition (CVD) [7,15–18], magnetron sputtering [19–21] and atomic layer deposition (ALD) [22,23].

As a result, thin film deposition continues to be a very active area of research and development. This Special Issue contains 11 original research articles.

In their article, Hseih et al. [24] report on the effect of hydrogen dilution ratio ($R = \text{H}_2/\text{SiH}_4$) on the structure and optical performance of nano-crystalline hydrogenated silicon (nc-Si:H) thin films, deposited by plasma-enhanced chemical vapour deposition (PECVD). They describe the process by which the transition from the amorphous to nanocrystalline state can be controlled by careful adjustment of R and suggest an optimal range of $R = 30\text{--}40$ to favour nc-Si:H growth. This is likely to be of great interest within the fields of photovoltaic energy generation and optoelectronics.

Schwinger et al. [25] discuss a novel, non-vacuum, liquid phase method of depositing thin films of aluminium on spherical glass substrates, comparing the results to those obtained by a more

conventional physical vapour deposition (PVD) process for reference. It is reported that reflectance of solid micro glass spheres can be increased by around 30%, a comparable result to that achieved using PVD.

This could have applications in, for example, road stripe paints and in mid-infrared reflective interior architectural paints, which can potentially reduce energy usage for the heating of buildings. Li et al. [26] describe a study carried out using metal-organic chemical vapour deposition (MOCVD) of β -Ga₂O₃ films. They systematically explore the effects of oxygen:gallium ratio during deposition on the structural and optical properties of the films, and on the growth rate; an optimum ratio for crystal quality of 11.2×10^3 is established. This may be beneficial in a range of device fabrication applications.

In their paper, Sriubas et al. [27] utilise electron beam evaporation to deposit scandia-doped zirconia and scandia-alumina co-doped zirconia thin films. XRD and Raman spectroscopy are used to probe the structure of the films; the addition of aluminium dopant hinders the formation of the cubic zirconia phase while stabilising it at temperatures >300 °C. Relations between substrate temperature, crystallite size and ionic conductivity are presented. This work is likely to be of interest in fuel cell and oxygen sensor development.

Lee et al. [28] investigate a novel variant of CVD as a fabrication method for durable superhydrophobic coatings. This method allows the manufacture of such coatings at relatively low temperatures and negates the requirement for substrate pre-treatment. The applicability to paper and cotton fabric is also demonstrated. This class of material has many potential uses, including in antifouling, water repellents and self-cleaning surfaces.

Stachiv and Gan [29] present a very interesting application of microcantilevers as typically used in conventional atomic force microscopy (AFM), repurposed to facilitate measurement of Young's and shear moduli, Poisson's ratio, and film density. This could have significance in ultrathin film analysis, relevant in photovoltaic, optical, microelectronic and sensor applications.

In their paper, Tillmann et al. [30] discuss a combination of thermal spraying and PVD (magnetron sputtering) for the manufacture of Ni/Ni-20Cr thin film thermocouples for use in process monitoring of flat plastic film extrusion. Polypropylene foils of good surface quality are shown to be producible using such devices, which are also highly stable in operation. This work demonstrates that PVD-deposited thermocouples are a promising approach for automated manufacturing process monitoring.

Zhang et al. [31] investigated the use of an oxygen ion beam to improve the performance of magnesium fluoride (MgF₂) as an optical coating layer in the visible, near infrared (NIR) and mid-wavelength infrared (MWIR) spectral regions. They report that as oxygen flow increases, the film density and refractive index increases; an MgO phase is formed within the MgF₂ matrix, with oxygen filling F[−] ionic vacancies. This hinders the combination of magnesium ions with hydroxyl groups present in the atmosphere, and water adsorption is also decreased and thus reducing optical absorption of the film in the infrared. This also, however, has the undesirable effect of increasing film stress and weakening adhesion to the substrate. To circumvent this issue, the authors propose a solution involving a very thin MgF₂ layer being deposited first, without ion assist, followed by a second oxygen ion beam-assisted MgF₂ layer. MgF₂ is a commonly used material in optical coatings, particularly in anti-reflection coatings, and so this research is likely to be of great interest in the optical coating field.

In their paper, Zhang et al. [32] propose a metal-insulator-metal structure, designed to operate as a dual-function metalens. This metalens has a focal length of 5 μ m for x -polarisation and 15 μ m for y -polarisation, and functions within the 750–850 nm waveband. The structure may also function as a type of beam splitter. This is likely to be of interest within the field of metamaterials research.

In the area of tribological coatings research, Smolik et al. [33] investigate the effect of tungsten doping of magnetron sputtered titanium diboride coatings. They report improvement of brittleness and fracture toughness of such coatings by addition of tungsten in the range of 0–10% at. This has the effect of changing the coating's microstructure, from a typical columnar structure to a nanocomposite structure, decreasing the energy of individual cracks during fracture testing and consequently increasing the

fracture toughness. This could have many potential applications, including in armour manufacture, wear-resistant coatings and cutting tools.

Finally, and staying on the topic of tribological coatings, Skordaris et al. [34] describe the reduction in residual stresses in 5 µm-thick nanocrystalline diamond coatings deposited on cemented carbide insert tools, via an optimised annealing process. This results in an impressive enhancement of fatigue strength and milling performance of such tools, increasing the components' service life by up to four times that of a non-annealed coated tool. This is likely to be of great interest in diamond coating research and industrial cutting applications.

Conflicts of Interest: The authors declare no conflict of interest.

Correction Statement: This article has been republished with a minor change. The change does not affect the scientific content of the article and further details are available within the backmatter of the website version of this article.

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