Atomic Layer Deposition (ALD) - An Old Tool for Modern Nanoscience

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Atomic layer deposition (ALD) is a thin film deposition technique which was developed in the 1970s to meet the needs for processing thin film electroluminescent displays (TFEL). Technically and chemically it is similar to chemical vapor deposition (CVD). However, in contrast to CVD, ALD incorporates as a specific feature the separation of the chemical reaction into two half-reactions. The exposure of the substrate to separate precursor vapors allows for chemical saturation of the substrate surface with a monolayer of the precursors and thus for a precise sub-Å growth control in a cycle by cycle manner. In addition, being a non-line-of-sight deposition technique, ALD allows for good coating conformality even with 3D nanostructured substrates or structures with a high aspect ratio together with a good capability for upscaling [1].

Presently, the vast majority of research performed involving ALD is based on the deposition of thin film high-κ materials, such as HfO_2. Aside from these technological applications, an increasing number of researchers make use of the precision of ALD for fabrication or functionalization of nanostructures, optical coatings, catalytically active coatings, encapsulation, corrosion protection or even infiltration of soft materials with metals. Among these research fields, functional coatings for optics are of special interest. A combination of nanostructures and multilayer coatings can provide tunable optical filters which can be used in spectroscopy [2] (see fig. 1). Even X-ray optics can benefit from thin film nanolaminate coatings [3].

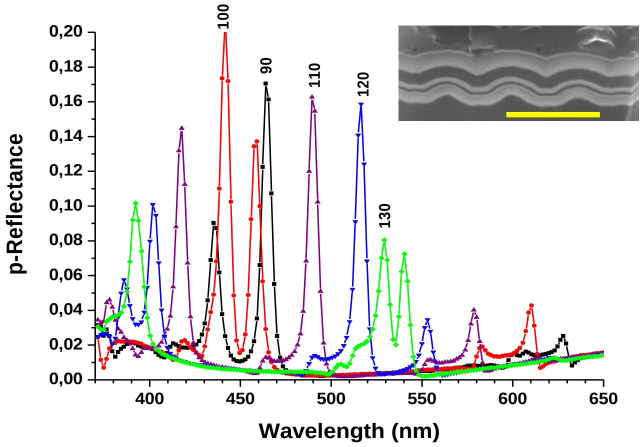

Fig. 1: Selected reflection spectra as function of the rotation angle of a coated nanostructure (shown in the inset of the figure) upon irradiation with white light. The scale bar in the inset corresponds to 400 nm [2].

The most recently evolving application of ALD deals with the modification of mechanical properties of soft materials after infiltration of metals by ALD. Although the detailed chemistry behind the approach is not yet understood, biological materials, such as spider silk, collagen, or some polymers can positively or negatively alter their mechanical properties after being treated with pulsed vapors of metal precursors. The toughness of such materials increased by up to 10-fold, outperforming most manmade materials [4] (see fig. 2). Properly adjusted, in the future this approach can potentially be used in the textile industry or the production of artificial tissues.

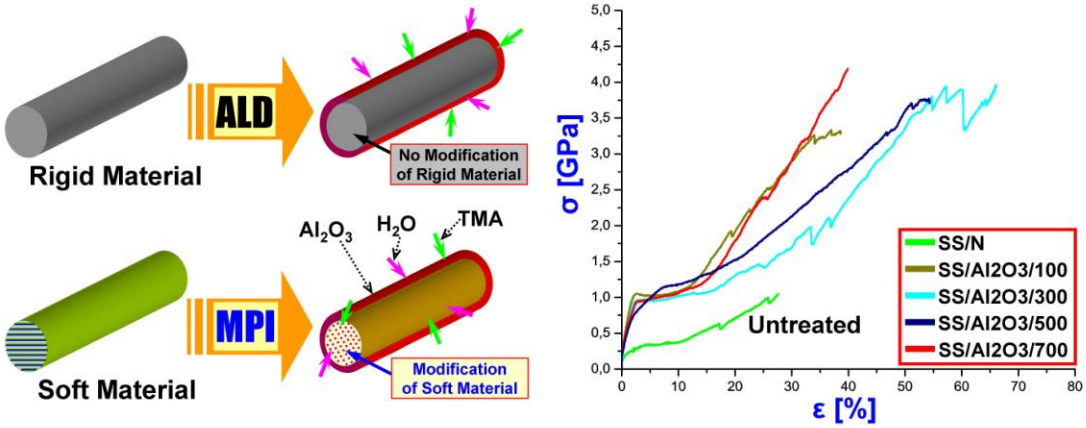

Fig. 2: left: Schematic view in the difference of the classical atomic layer deposition and the infiltration occurring during ALD on some soft materials. Right: Simultanous increase of strength and ductility (leading to a toughness increase) of spider silk after an infiltration process.

Most commercial ALD tools were developed for use in the microelectronics industry. Therefore, the tool design is far from being perfect for many other nanotechnology applications. Developing suitable systems for nanoparticle coatings, continuous coating systems (e.g. for fibers), or convenient tools for low-temperature or ambient pressure processing, is still a challenge.

In summary, ALD is one method-of-choice for numerous applications in nanoscale manufacturing and functionalization. Instead of being just a tool for coating, it opens numerous possibilities for research and development in various fields, from optics to electronics and even fabrics. The possibility to upscale the processes allows for a direct transition from research to development or even production, especially if 3D structures are to be produced or functionalized.

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