Keynote

SYNTHESIS OF COMPLEX NANOSTRUCTURES BY ATOMIC LAYER DEPOSITION

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Atomic layer deposition (ALD) has recently become the method of choice for the semiconductor industry to conformally process extremely thin insulating layers (high-k oxides) onto large-area silicon substrates. ALD is also a key technology for the surface modification of complex nanostructured materials. After briefly introducing ALD, this talk will focus on the various aspects of nanomaterials and their processing by ALD, including nanopores, nanowires and -tubes, nanopatterning and nanolaminates as well as low-temperature ALD for organic nanostructures and biomaterials [1]. The following application area will be emphasised during this presentation:

1) **Low-Temperature ALD and Biomaterials [2]**: In this work we show the application of atomic layer deposition, a gas-phase thin film deposition process, to biological macromolecules, which are frequently used as templates in nanoscale science, and the possibility to fabricate metal oxide nanotubes and thin films with embedded biomolecules.

2) **Ferromagnetic Nanotubes in Ordered Alumina Membranes [3,4]:** Iron oxide nanotubes of 50-150 nm outer diameter and 2-20 nm wall thickness are prepared in ordered arrays. Atomic layer deposition (ALD) of Fe_2O_3 from the precursor iron(III) *tert*-butoxide at 130-180 °C yields very smooth coverage of the pore walls of anodic alumina templates, with thickness growth of 0.26(±0.04) Å per cycle. The reduced Fe_3O_4 tubes are hard ferromagnets, and variations of the wall thickness d_w have marked consequences on the magnetic response of the tube arrays. For 50 nm outer diameter, tubes of $d_w = 13$ nm yield the largest coercive field ($H_c > 750$ Oe), whereas lower coercivities are observed on both the thinner and thicker sides of this optimum. For the ALD of Ni and Co nanotubes metal oxide is initially deposited by a conventional two step ALD process. The precursors were nickelocene or cobaltocene, and H_2O or O_3. Subsequently, the sample is reduced under hydrogen atmosphere.

3) **Atomic Layer Deposition of SiO_2 thin films and nanotubes [5]:** Molecular self-attack: According to mythology, a scorpion may sting itself to death; similarly, 3-aminopropyltriethoxysilane catalyzes its own hydrolysis in the atomic layer deposition (ALD) of SiO_2 thin films and nanostructures. Between 120 and 200 °C, the growth rate is constant at 0.06 nm per ALD cycle. The SiO_2 films are chemically and optically pure. SiO_2 nanotubes of aspect ratio 500 exhibit smooth walls of accurately controlled thickness.

4) **Large-scale arrays of nanorings with sub-30 nm feature:** The approach is based on templates with periodic polymer holes structures on silicon substrate generated by laser interference lithography (LIL). A homogeneous TiO_2 layer was deposited on the relief of the substrate by atomic layer deposition (ALD) (ref) at room temperature. The unwanted parts of the TiO_2 layer were removed by anisotropic etching.

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References:

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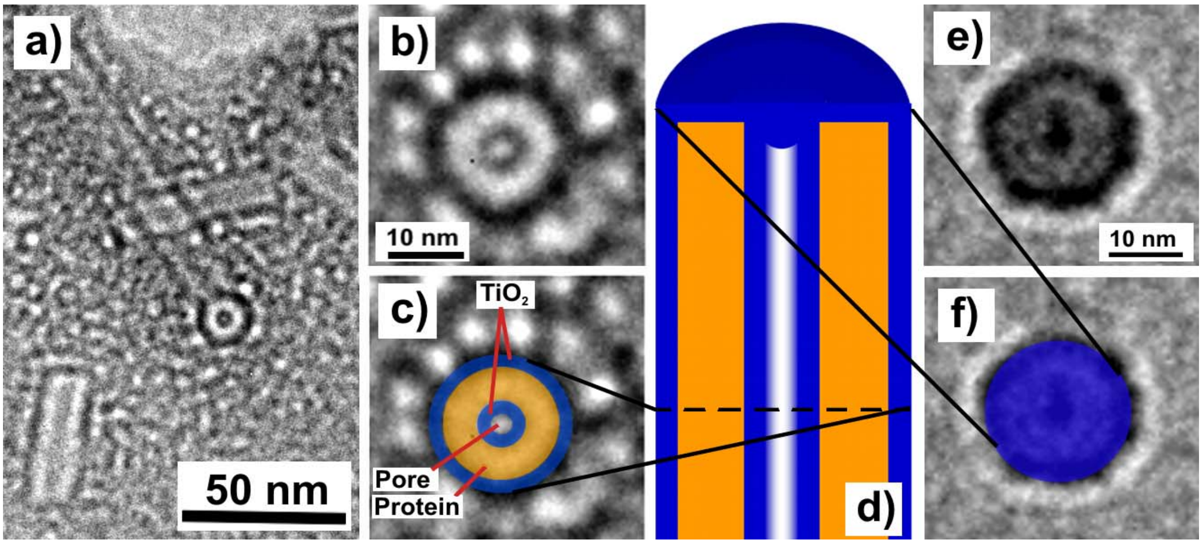

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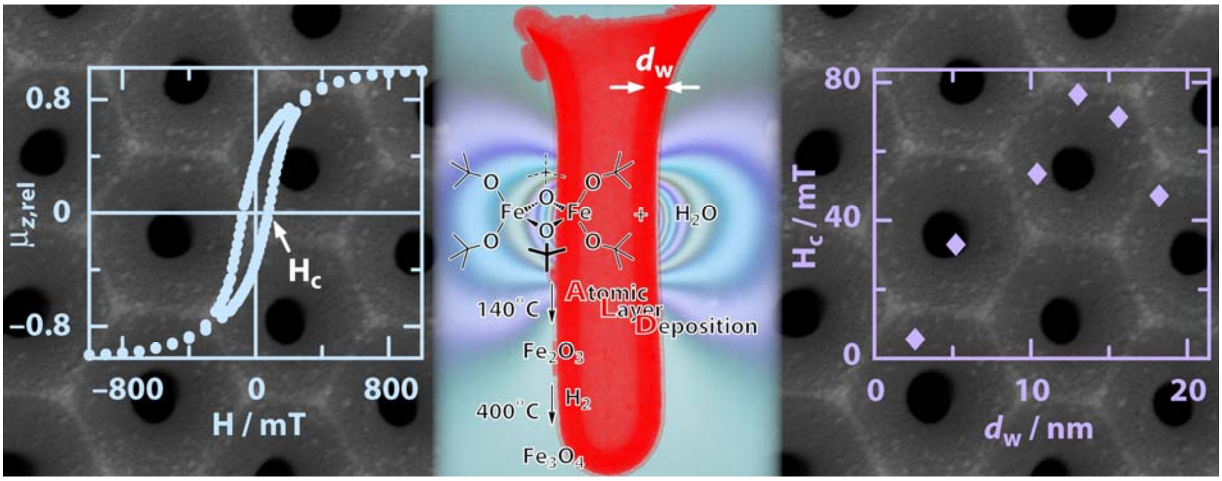

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