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Fabrication par « Atomic Layer Deposition » de nanostructures de nitrure de bore pour des applications dans l'environnement

Atomic layer fabrication of boron nitride nanostructures for environmental applications

The scientific interest for hexagonal boron nitride (h-BN) material, especially as thin film and nano-/hetero-structures, is growing every year owing to its potential use in various domains such as microelectronic, energy and environment. Atomic Layer Deposition (ALD) is a technique of choice for fabrication of thin films and complex nanostructured materials.

Indeed, ALD is a unique technique for deposition of conformal and homogeneous thin films. Due to its simplicity, reproducibility and the high conformality of the as-deposited films, it appears to be a promising deposition technique.[1,2,3] Briefly, it is based on a reaction between precursor materials, which are separated into successive surface reactions. In this manner, the reactants are kept separated and react with surface species in a self-limiting process, i.e. without the presence of a gas phase reaction, differentiating it from the chemical vapor deposition technique. Each surface reaction is separated by a purge step to remove the unreacted precursor and the by-product. The succession of self-limited reaction and purge constitute a cycle (Figure 1). The growth per cycle is defined as the thickness of the film deposited in one full cycle. Due to the self-limited reactions, the thickness of the as-deposited film is simply controlled by the number of cycles, up to the atomic scale level. level.[4]

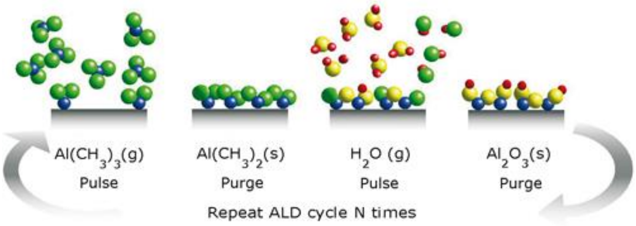

Figure 1. Schematic of an ALD cycle: example of Al_2O_3 deposition from $Al(CH_3)_3$ and H_2O. *Step 1:* pulse of the reactant 1, $Al(CH_3)_3$, leading to its absorption on the surface. *Step 2:* purge of the unreacted precursor and of the by-products. *Step 2:* pulse of the reactant 2, H_2O, which reacts with the surface species created by precursor 1. *Step 4:* purge of the unreacted precursor 2 and of the by-products. Taken from ref [5]

ALD is widely used for the deposition of thin films onto various supports.[1,4] It allows the coating of flat surfaces and complex nanostructures in a conformal and homogeneous manner with a precise control of the thickness of the deposited film in the range of a few angstroms. ALD has already proved to be suited for elaboration of functional structured material,[1,2,3,6] applied for instance in new energy and environment domains.[7,8,9]

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Few ALD processes of BN have been already reported so far; they are mostly based on ammonia and/or halide precursors. In all cases, the crystalline quality of the as-deposited layers remains insufficient and post-annealing treatments at high temperature are currently performed. Despite these limitations, ALD already demonstrates suited to fabricate BN layers that can successfully be integrated into electronic devices.

Recently, based on polymer derived ceramics chemistry, we developed a new low temperature ALD process of BN. It permits access to various h-BN complex nano-/hetero-structures such as unwoven BN nanotubes fabricated from low cost polymer template. The obtained boron nitride mat exhibit high crystallinity and outstanding super-hydrophobicity properties as well as exceptional stability over a long period. The obtained structure reveals to be a highly efficient and renewable filter for separating oils and organics from water

The PhD candidate will work on the development and use of this new process in order to fabricate high quality complex nanostructures from polymeric templates and carbon supports as graphene and carbon nanotubes in view of water treatment and catalysis applications.
One part of the work will also be dedicated to the understanding of reaction mechanism taking place during the ALD and crystallization process. In particular,

D'autre part, un effort important sera consacré à la compréhension des mécanismes réactionnels et de cristallisation du dépôt ALD. En particulier, en collaboration avec le laboratoire C2P2 (A. Quadrelli), le (la) candidat(e) s'intéressera à la nucléation du film ayant lieu lors des tous premiers cycles (1-5) en fonction des supports utilisés. L'étude de ces mécanismes servira de base pour développer de nouveaux matériaux à base d'allotropes de BN.

Techniques

Synthesis techniques: ALD, inert atmosphere lab work, inorganic synthesis

Characterizations: X-ray diffraction, ellipsometry, XR reflectrometry, spectroscopies (NMR, IR, UV-vis), microscopies (AFM, SEM, TEM), NMR, thermal analysis.

Skills

Le (la) candidat(e) doit être titulaire d'un master en chimie, de préférence en chimie inorganique ou organique et être motivé(e) par un travail interdisciplinaire alliant la synthèse de matériaux aux caractérisations physico-chimiques. De solides connaissances en chimie ainsi qu'une autonomie d'organisation au travail et une bonne maitrise de l'anglais sont aussi fortement souhaitables.

Contact

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