# Nanoporous alumina template assisted growth of nanotubes and nanowires

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**Abstract**

Precise engineering of shape and physico-chemical properties of materials at the nanometer scale is a central issue of current nanotechnology. In order to enable practical applications of nanometer materials, structures constituted by nanoelements with precise and uniform shape and size should be synthesized, positioned at a desired location, and organized into two- or three-dimensional architectures. In addition, it is of great importance to develop structurally and dimensionally well-controlled nanostructured materials, whose physical properties are easier to interpret and more amenable to theoretical treatment, because a broad range of material properties depend critically on the size, shape, and regularity of their substructure.
Particularly, nanoporous materials have gained much importance in the last years due to their potential industrial and technological applications for nanometric device fabrication (Jones, Osberg, Macfarlane, Langille, & Mirkin, 2011). The existent nano-lithographic techniques like e-beam, X-ray or focused ion beam are expensive and have a low throughput so that new assembling methods are needed. Porous Anodic Alumina (PAA) templates, and pattern aluminum foils having self-organized hierarchical structure have been shown suitable not only as a templates for preparing structurally well-controlled nanostructured materials but also as a non-lithographic replication master for the preparation of two- or three-dimensional arrays of periodic nanostructures.
PAA templates are produced by anodic oxidation of Al substrates in an aqueous solution of acidic electrolytes, such as oxalic, sulfuric and phosphoric acids. The resulting membrane consists of closely packed hexagonal arrays of self-organized nanoporous. The pore diameter depends on the type of electrolyte used and the voltage; typical pore densities are of the order of $10^{11}$ pores/cm$^2$. Highly-ordered hexagonal lattices of PAA have been successfully prepared by a two-step anodization process and structures with pore diameters in the 25 - 200 nm range and interpore distances between 65-500 nm were obtained depending on the experimental conditions (Ono, Saito, & Asoh, 2005). An important characteristic feature of PAA templates is their ability to tune the aspect ratio (length divided by diameter) of the resulting nanoelements, which is not so easily accessible with conventional lithographic techniques. In this respect, applications of the hierarchically organized nanoporous structure of the anodic PAA film as a template or replication master might provide more realistic opportunities for creating nanostructured materials with tailored properties (Sousa et al., 2012).
Several types of high aspect ratio nanoparticles can be produced in PAA templates. A diversity of materials can be deposited on the templates, forming nanotubes (for example nanotubes of silica prepared with the sol-gel method) and nanowires (prepared by electrodeposition) that allow diverse biofunctionalization. These high aspect ratio nanoparticles are inorganic structures that have attracted great interest in several fields, like nanomedicine due to their generic transporting ability and a wide range of functionalities that arises from their unique physical properties. In fact, these particles present advantages over spherical ones as they exhibit anisotropic (shape dependent) collective properties (e.g. absorbance, photoluminescent, surface enhanced Raman cross-section, conductivity, magnetization). A wide variety of nanomaterials prepared by the PAA template method can be used for biotechnological applications, for example, for drug delivery, cell separations, hyperthermia and magnetic resonance imaging.

This work reports the work made on the synthesis and characterization of high aspect ratio nanoparticles in PAA templates aiming several applications, namely for biomedicine, solar cells and metamaterials.
The pathway of this work can be divided in three main steps: the first consists of the development and characterization of PAA templates; the following step consists on the synthesis and characterization of high aspect ratio nanoparticles (e.g. nanotubes and nanowires by sol-gel and electrodeposition, respectively) using PAA as template (Sousa et al., 2011); and also a coordinated effort to functionalize the surface of the developed nanoparticles for potential biotechnological applications. In addition, the synthesis and functionalization of high-aspect ratio nanoparticles were always complemented by morphological, structural and magnetic characterizations using techniques like: X-ray diffraction, ferromagnetic resonance, electron microscopy, Fourier-transformed infra-red, fluorescence spectroscopies and magnetometry. The part of the work concerning the functionalization of nanoparticles, drug loading and release studies for biotechnological.

**Figures**

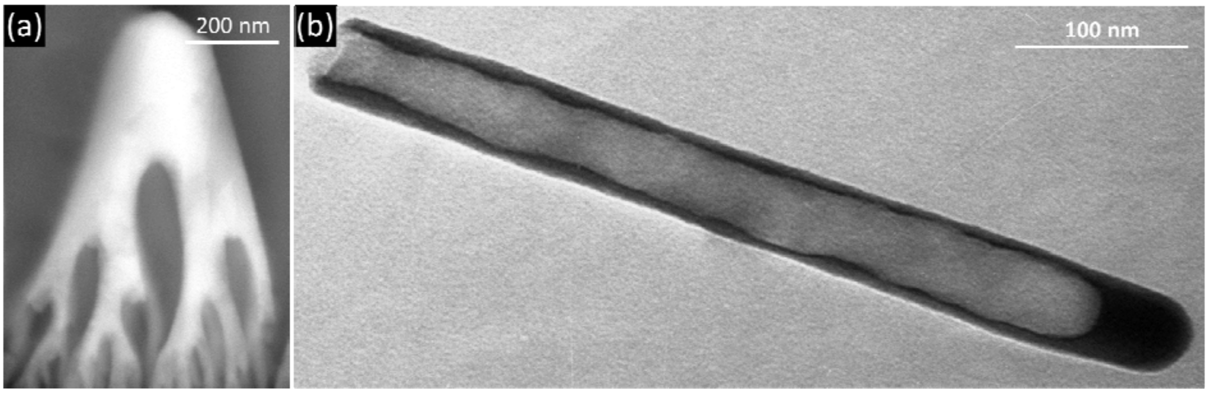


**Figure 1.** (a) Branched Ni nanowires; (b) Silica nanotube. Both obtained by PAA template assisted method.

**References**

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