Using focused ion beam to fabricate anodic aluminum oxide arrays arranged in custom-designed geometry for manufacturing metamaterials

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Anodic aluminum oxide (AAO) contains arrays of high-aspect-ratio nanochannels have been wide used as templates for the synthesis of nanocomposites and as mask for nanolithography and device fabrication. The AAO nanochannels can be laterally self-organized into domains of hexagonally closed-packed (hcp) ordered arrays under certain anodization conditions.[1,2] Furthermore, FIB irradiation can employed to close the nanochannels in a selective area by a capping layer of desired thickness, which is determined primarily by the energy of the FIB.[3] The successful fabrication of these long-range-ordered nanochannel arrays, later, referred to easily as ordered arrays, have not only broadened the possible applications of AAO films but also opened possibilities for the manufacturing of nanostructure arrays arranged with a custom-designed geometry. For example, one can design an array with some part of it covered by nanodots or nanowires with specific materials while other part of surface remains empty. Depending on its geometry and material property, such an array with designed electrical and/or optical properties could be used as a waveguide or a photonic crystal. Here, we report a novel technique of using FIB to build a custom-designed template for plasmonic metamaterials. The fabrication process is shown in Fig.1. First of all, we carefully use FIB to pattern the guiding lattice pits with designed spacing on the surface of a finely polished aluminum specimen. An AAO film then growth with ordered hcp array which being with designed pore size and spacing by well-controlled eletrolyte and anodization voltage. For this work, we set the spacing of the ordered Array to be 75nm. After that, we use 30keV gallium FIB with a 10pA beam current and a diameter of about 25nm to close the nanochannel. Using the bitmap controlled beam-blanking function of the FIB, partial nanochannels would be closed by scanning over the desired area under controlled incident ion dose. The results are shown in Fig.2(a) and Fig.2(b). AAO array templates with single (75nm) and double (150nm) pore wide and 3μm in length are manufactured with this method. The single and double pore wide nanostructures are designed for waveguide application as an metamaterials. With this technique, we can also fabricate custom-designed pattern with different bitmap pattern, which were shown in Fig.2(c) and Fig.2(d). Size and shape of the pore array can be well controlled by the resist-free FIB lithography method. Afterwards, the template can be transformed into plasmonic metamaterials with specifically chosen materials. The unique technique facilitates the creation of novel type template with custom-designed geometries for fabricating metamaterials and nanophotonic/nanoelectronic devices.

Reference:

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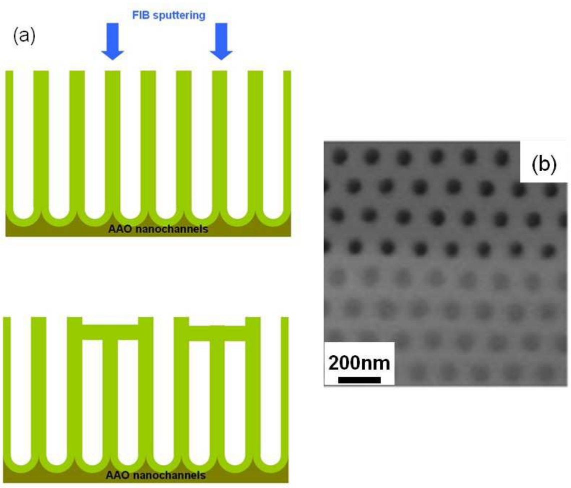

Figure 1. (a) Schematic picture showing the process of selective closing AAO nanochannels in an array. (b) Array before (upper) and after (lower) FIB closing.

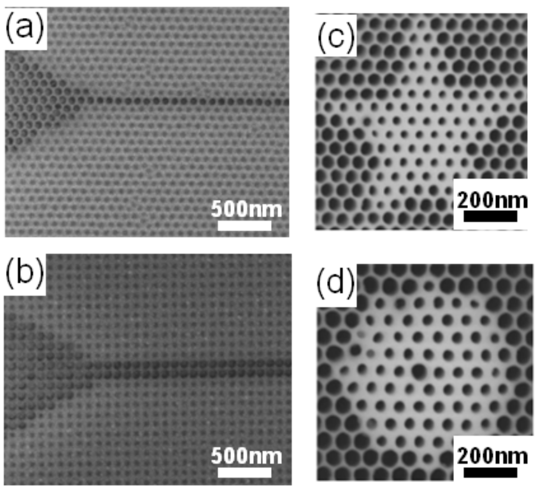

Figure 2. (a) Nanostructures with one pore wide, (b) two pore wide, (c) custom-designed star shape, and (d) hexagonal shape.