Templated Self-assembly of Nanoporous Alumina - Technique and its Applications

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Metallic nano-wires, rods, and dots can be used in a number of applications in micro- and nano-systems, such as nano-wire interconnects (wires), on-chip magnetic storage devices (rods), on-chip Peltier cooling devices (wires and rods), and plasmonic waveguides (dots). [Ref. 1, 2]. In this paper, we will discuss templated self-assembly methods that combine top-down (lithography) and bottom-up (self-assembly) approaches for fabricating and assembling metallic nano-wires, rods, and dots, for new applications including nano-contacts for devices and interconnects for mixed-material and multifunctional micro- and nano-systems.

Anodic porous alumina is an excellent example of a self-ordered nano-structured material that is well-suited as a template for growing metallic nanowires for applications in magnetic, electronic and opto-electronic devices [Ref. 3, 4]. The pores form a hexagonally ordered structure with short-range order and vertical orientation. Pore size can be varied from 4nm-300nm by controlling the conditions during electrochemical oxidation of aluminum [Ref. 5, 6, 7]. Although there has been considerable work done in the past to obtain porous alumina with well-defined pore diameter and spacing over a short range, little has been done to integrate it with wafer-level processes and achieve long range ordering of pores [Ref. 8].

Highly ordered alumina nano-pores with controlled symmetry have been grown by anodization of aluminum evaporated on nanoscale corrugated silicon surfaces (Fig. 1, Ref. 9). The silicon surface was patterned using interference lithography and a periodic inverted pyramid structure was obtained by chemical wet etching of the silicon. Thin aluminum films were then evaporated and electrochemically etched to obtain nano-porous alumina. By this technique, we have achieved both ordering of pores at the lithographic length scale as well as at the sub-lithographic length scale (Fig. 2). We are also combining this technique with micro-scale patterning of aluminum (Fig. 3) shown by Brevnov et al (Ref. 10) to control exact location of the pores. We have also used ordered alumina templates to fabricate metallic nanodots (Fig. 4) and nanorods by electrochemical routes as well as metal evaporation.

We will also discuss other techniques for achieving perfect ordering of porous alumina on silicon with sub-100nm spacing over an entire wafer.

References

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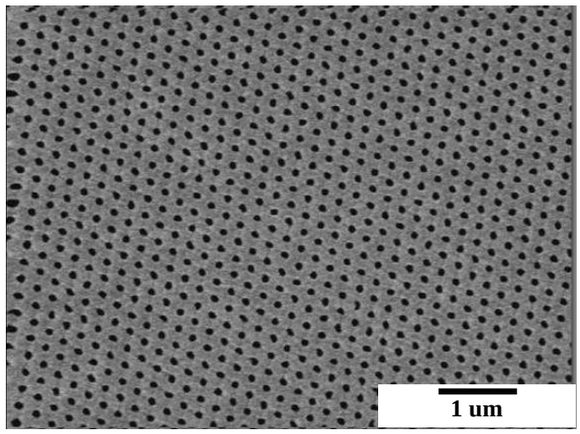

Fig. 1 Anodized alumina template on a Si wafer containing ordered nanopores. (spacing = 180nm, diameter =80nm)

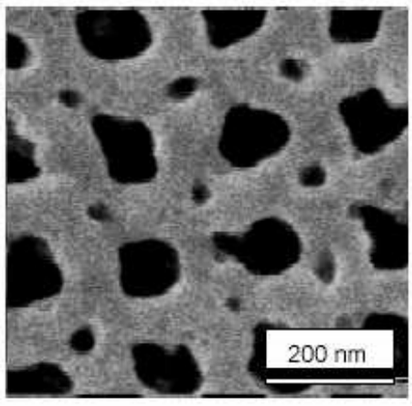

Fig. 2 By changing anodization conditions, additional pores are nucleated on a sub-lithographic length scale

Fig. 3 Formation of porous alumina on patterned substrates. Pores form only on the patterned letters "MIT". The figure on the bottom right shows an inset of the pores

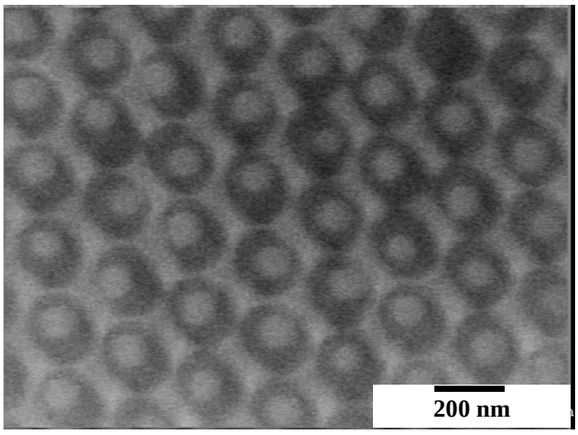

Fig. 4 Nickel nanodots deposited by evaporation using ordered alumina template as mask