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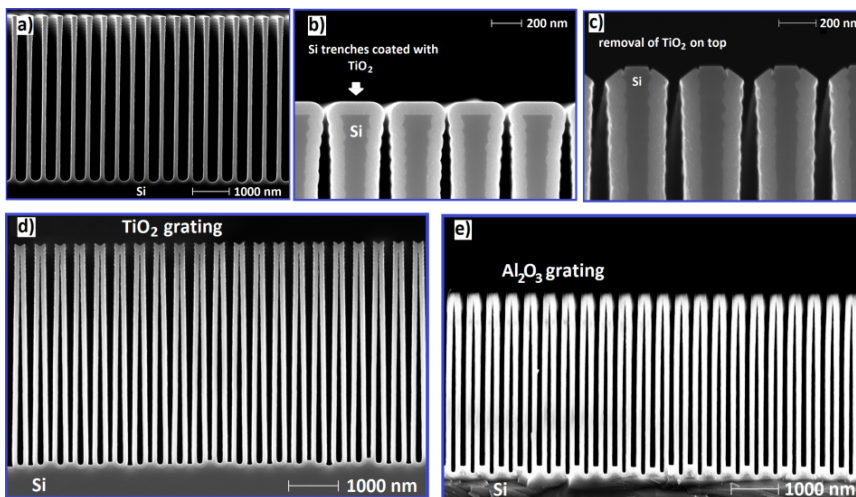
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# Fabrication of TiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> High Aspect Ratio Nanostructured Gratings at Sub-Micrometer Scale

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Metal oxides such as TiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> can be used for many different fields of applications including photovoltaics, MEMS technology, and high quality dielectrics for DRAM trench capacitors [1]. There is a great need to develop a reliable and reproducible way to pattern such materials on nanoscale. Successful attempts to fabricate and measure 2D photonic crystal based on hexagonal patterning of TiO<sub>2</sub> nanopillars with the aspect ratio of 7.5 have been reported [2]. In this work we present a method of patterning TiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> nanogratings with a high aspect ratio of up to 20 on a silicon substrate.



As a starting point deep UV lithography was used to pattern resist on 2 cm<sup>2</sup> scale chips. Thereafter deep reactive ion etching was used to fabricate 4.5 μm deep silicon trenches with a period of 400 nm (figure 1a). The silicon trenches have been coated using atomic layer deposition (ALD) with 100 nm thick TiO<sub>2</sub> or Al<sub>2</sub>O<sub>3</sub> at 150°C (figure 1b). The ALD coatings form nanostructured gratings but in order to isolate the TiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> trenches it is necessary to remove the silicon core (figure 1b). By introducing a chlorine plasma flow using inductively coupled plasma etching, it is

Figure 1. Fabrication of TiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> nanogratings. a) Silicon trenches. b) TiO<sub>2</sub> coverage using ALD. c) Selective opening of TiO<sub>2</sub> top part. d)-e) Isolating TiO<sub>2</sub> or Al<sub>2</sub>O<sub>3</sub> by removing the silicon core leads to the formation of nanostructured gratings.

possible to remove the top part of the TiO<sub>2</sub> coating; meanwhile the sidewalls and the bottom remain unharmed (figure 1c). For removal of the Al<sub>2</sub>O<sub>3</sub> top part coating, the chlorine plasma was supported by a BCl<sub>3</sub> gas flow. The selective removal of the TiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> top part provides access to the silicon core between the ALD grown sidewalls. An SF<sub>6</sub> plasma removes selectively silicon without any observable influence on TiO<sub>2</sub> or Al<sub>2</sub>O<sub>3</sub> thus revealing a high selectivity throughout the fabrication (figure 1d-e).

Using this procedure the TiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> gratings have been fabricated. We believe this approach opens the possibility to fabricate high quality epsilon-near-zero [3] and hyperbolic metamaterials [4], using this procedure.

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