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Fabrication of TiO$_2$ and Al$_2$O$_3$ High Aspect Ratio Nanostructured Gratings at Sub-Micrometer Scale

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Metal oxides such as TiO$_2$ and Al$_2$O$_3$ 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$_2$ nanopillars with the aspect ratio of 7.5 have been reported [2]. In this work we present a method of patterning TiO$_2$ and Al$_2$O$_3$ 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$^2$ 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$_2$ or Al$_2$O$_3$ at 150°C (figure 1b). The ALD coatings form nanostructured gratings but in order to isolate the TiO$_2$/Al$_2$O$_3$ trenches it is necessary to remove the silicon core (figure 1b). By introducing a chlorine plasma flow using inductively coupled plasma etching, it is possible to remove the top part of the TiO$_2$ coating; meanwhile the sidewalls and the bottom remain unharmed (figure 1c). For removal of the Al$_2$O$_3$ top part coating, the chlorine plasma was supported by a BCl$_3$ gas flow. The selective removal of the TiO$_2$/Al$_2$O$_3$, top part provides access to the silicon core between the ALD grown sidewalls. An SF$_6$ plasma removes selectively silicon without any observable influence on TiO$_2$ or Al$_2$O$_3$ thus revealing a high selectivity throughout the fabrication (figure 1d-e).

Using this procedure the TiO$_2$ and Al$_2$O$_3$ 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.