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Fabrication of TiO_2 and Al_2O_3 High Aspect Ratio Nanostructured Gratings at Sub-Micrometer Scale

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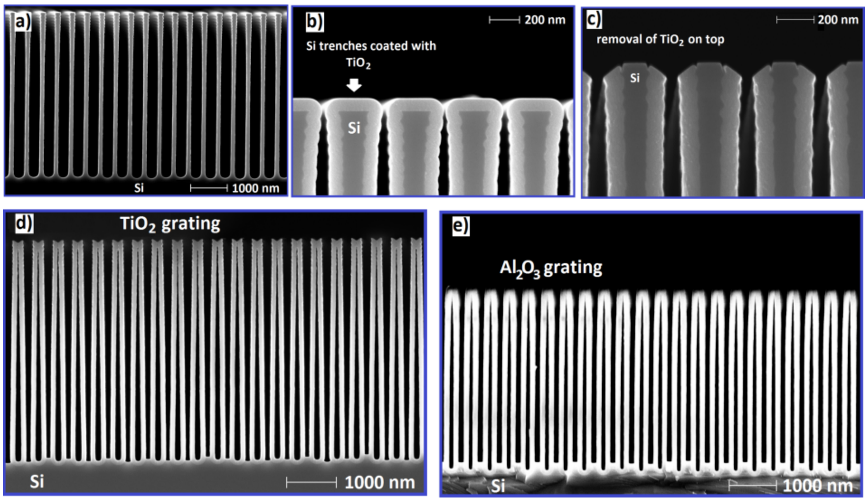
Metal oxides such as TiO_2 and Al_2O_3 can be used for many different fields of applications including photovoltaics, MEMS technology, and high quality dielectrics for DRAM trench capacitors [1]. There is a great need to develop a reliable and reproducible way to pattern such materials on nanoscale. Successful attempts to fabricate and measure 2D photonic crystal based on hexagonal pattering of TiO_2 nanopillars with the aspect ratio of 7.5 have been reported [2]. In this work we present a method of pattering TiO_2 and Al_2O_3 nanogratings with a high aspect ratio of up to 20 on a silicon substrate.



Figur 1. Fabrication of TiO_2 and Al_2O_3 nanogratings. a) Silicon trenches. b) TiO_2 coverage using ALD. c) Selective opening of TiO_2 top part. d)-e) Isolating TiO_2 or Al_2O_3 by removing the silicon core leads to the formation of nanostructured gratings.

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_2O_3 at 150°C (figure1b). The ALD coatings form nanostructured gratings but in order to isolate the TiO_2/Al_2O_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_2O_3 top part coating, the chlorine plasma was supported by a BCl_3 gas flow. The selective removal of the TiO_2/Al_2O_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_2O_3 thus revealing a high selectivity throughout the fabrication (figure 1d-e).

Using this procedure the TiO_2 and Al_2O_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.

[1] S.M. George, Chem. Rev. **110**, 111 (2010)

[2] Y. Huang, Nanotechnology **23**, 485306 (2012)

[3] R. W. Ziolkowski, Phys. Rev. E **70**, 046608 (2004)

[4] A. Poddubny, Nature Photonics **7** 958 (2013)