NANOFABRICATION OF SILICON METASURFACES FOR THIRD HARMONIC GENERATION

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We realized high quality silicon metasurfaces by e-beam lithography for controlling the spatial intensity distribution, polarization, and wavelength dependence of light beams generated by third-order nonlinearities.
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Nonlinear optical processes have been studied in different materials and structures [1-2]. These processes, such as second and third harmonic generation, can find numerous applications in photonics, material science and biomedical sensing [3-4]. In this frame, metasurfaces offer promising possibilities for the miniaturization of optical devices working at visible and infrared wavelengths. Recently, dielectric and semiconductor metasurfaces with a high refractive index have emerged as a new class of engineered nanostructures for nonlinear applications, thanks to their low dissipative losses and high nonlinear susceptibilities [5-6]. In this work, we demonstrate the nanofabrication of high quality silicon metasurfaces, exploiting the easy integration of this material in nanophotonic platforms, for controlling the spatial intensity distribution, polarization, and wavelength dependence of light beams generated by third-order nonlinearities. Periodic metasurfaces will emit THG signal in the grating modes, which are very narrow in the k space. The design of the semiconductor metasurfaces has been guided by numerical simulations to obtain the desired nonlinear optical response. The metasurfaces are realized by combining electron-beam lithography and reactive ion etching, using a silicon on insulator substrate with a device layer of 125 nm on 2 μm of buried oxide. Similar structures have been optimized also on a device layer of 145 nm. The process parameters have been optimized to obtain the desired gap and periodicity of the silicon nanostructures, as reported in Fig. 1, for either 125 nm or 145 nm devices over 100 x 100 μm^2 areas.

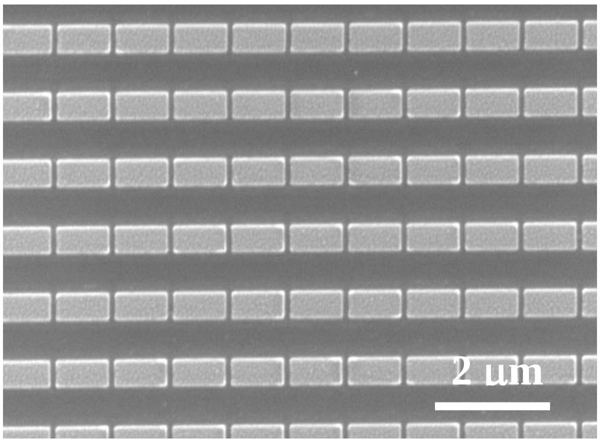

Fig. 1 Scanning elettronic micrograph of a silicon metasurface

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References

1. Timpu,F. et al., *ACS Photonics* **4**, 76–84 (2017).
2. Zhang,R. et al., *ACS Photonics* **3**, 371–377 (2016).
3. Krasnok, A., Tymchenko, M., Alú, A., *Mater. Today* **21,** 8−21A (2018).
4. Chen, S., Li, G., Zeuner, F. et al., *Phys. Rev. Lett.* **113 (3),** (2014).
5. Shcherbakov,M. R. et al., *Nano Lett.* **14**, 6488–6492 (2014).
6. Camacho-Morales, R. et al., *Nano Lett.* **16**, 7191–7197 (2016).