Controlled Formation of Spike-Like Structures in Silicon by fs-Laser Processing for Enhanced Light Absorption

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Laser processing offers a powerful engineering solution for functionalizing the surface of materials. One specific case of interest is the fabrication of nano- and microstructured silicon by femtosecond laser irradiation, generating Laser Induced Periodic Surface Structures (LIPSS) [1]. In the case of silicon (Si), this functionalization may reduce the material's reflectivity due to multi-reflection processes [2].

In this work, an approach to improve the light absorption of silicon in the ultraviolet-to-near infrared spectral range via fs laser processing is described and discussed. The approach is based on the fast cost-effective fabrication of fs laser (1030 nm and 515 nm) -induced micro-spikes in silicon in air atmosphere. The impact of the irradiation conditions on the size, period and aspect ratio of the structures, as well as on the light absorption of the material has been studied. Varying pulse number and laser fluence up to 1.8 J/cm² we have been able to tune the size and period of the processed structures. Additional tuning of the laser repetition rate from 50 to 500 kHz has allowed the fabrication of spikes with high aspect ratio, leading to an extremely high absorption, above 95% from 250 nm to 1100 nm. In addition, a post-processing annealing has been performed in order to recover the crystallinity of the sample after irradiation, in order to overcome the induced factors that could compromise carrier lifetimes. Applications of the structures to the field of photovoltaics will be presented.

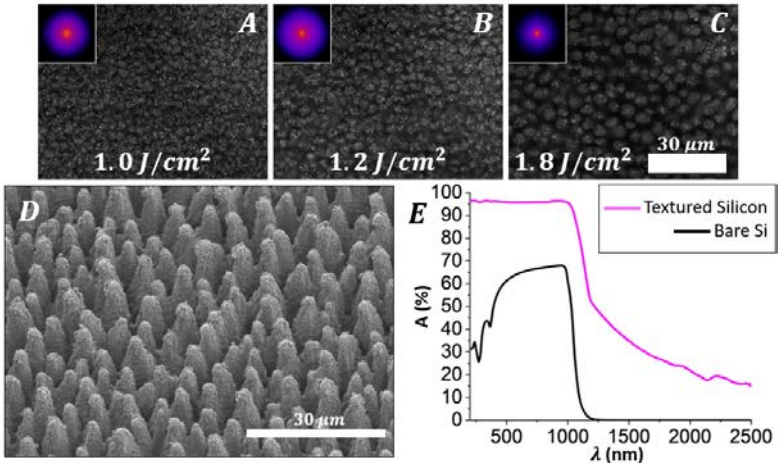

Figure 1. (A-C) Optical microscope images of the structures formed at different fluences (insets show the Fast Fourier Transforms of the images); (D) scanning electron microscopy of processed silicon with optimized spike-like texture; (E) optical absorbance of textured Si (repetition rate = 300 kHz) compared to bare Si.

Acknowledgements: This work has been funded by the research grant HyperSolar (TED2021-130894B-C22) from the Spanish Research Agency (AEI, Ministry of Research and Innovation), the European Regional Development Fund (ERDF) and NextGenerationEU.

References: [1] J. Bonse, A. Rosenfeld and J. Krüger, J. Appl. Phys. (2009), 106: 104910; [2] B. Franta, E. Mazur and S.K. Sundaram, Int. Mat. Rev. (2018) 63(4): 227-240.