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Dense nanoparticles arrays for plasmonic solar cells and sensors

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Nobel metal nanoparticles exhibit distinct optical properties due to localized surface plasmon resonance (LSPR). Potential applications of these structures can be found in thin film solar cells, nonlinear optical devices, or sensors [1]. Plasmonic field coupling in aligned equidistant chains of metal nanoparticles is higher compared to randomly distributed particles [2]. Recently it proposed that field enhancement in the surrounding of nanoparticles can be used to improve the solar cell efficiency, since they can generate more electron-hole pair or couple the light field more strongly. All the experimentally reported works about inter-particle coupling are in the range of several tens or hundreds of nanometer due to lithography limitations. When nano-gaps are small 1-20 nm the electron beam lithographic approach is not scalable for actual solar cell applications, where 1 x 1 cm^2 areas have to be fabricated for reliable benchmarking of quantum efficiency, also proximity effects start dominating. Therefore an approach is needed that can be implemented on a large surface area. In this work we propose a bottom up approach to make large area nicely ordered nanoparticles chain with interparticle gap down to 5 nm over larger areas and can be implemented on industrial scale [2].

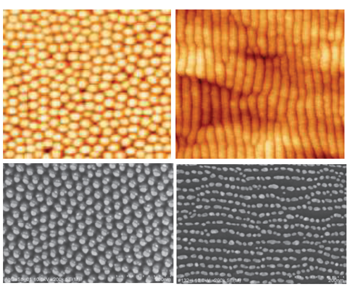

Figure 1: In the top images, AFM images of Nanodot and Nano ripple like structures produced by low energy ion irradiations are shown. In the bottom, SEM images of silver nanoparticles grown on such dot and ripple patterns are shown. Typical dot and ripple size is in the range of 30 nm

Low energy ion beam produced ripple and dot templates (Figure 1) are under investigation for tailoring the plasmonic properties [3]. Possibility of tuning the ripple wavelength with ion energy and fluence gives the additional parameters for modifying the growth mechanism of materials.

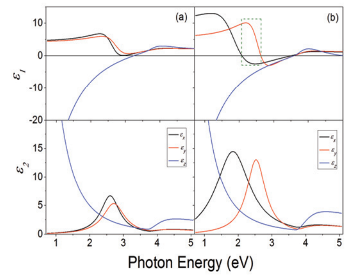

Figure 2: Dielectric coefficient calculated for the nanoparticles arrays, showing the biaxial optical anisotropy

Self-assembled nanoparticles/nanowires on these rippled surfaces are optically anisotropic, i.e. they exhibit a direction dependent shift in LSPR. The reason for the observed anisotropy is a direction dependent plasmonic coupling [4]. Different in plane and out of plane dielectric coefficients calculated by modelling Jones matrix elements (Figure 2) confirm that nanoparticle/nanowire arrays are biaxial anisotropic ($\varepsilon_x \neq \varepsilon_y \neq \varepsilon_z$) [1, 5, 6]. Authors will demonstrate the capabilities of silver nanoparticles arrays produced on rippled templates as the Surface Enhanced Raman Scattering active surface [7]. Lager field enhancement in silver nanoparticles arranged along the ripple is responsible for the higher observed SERS intensity compared to randomly distributed nanoparticles. Hexagonally arranged silver nanoparticles grown on GaSb dots surface are highly light absorbing and can be used as top layer of plasmonic solar cell [8].

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