Nanofabrication of deterministic aperiodic structures for radiative engineering in nanoplasmonics

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In this work, we demonstrate controlled nanofabrication of novel optical devices based on the engineering of deterministic aperiodic nanostructures (DANS) for nanoscale electromagnetic localization and enhancement[1,2]. These devices consist of aperiodic arrays[1] of metal nano-particles fabricated by electron-beam lithography on non-conductive silicon nitride substrates containing light-emitting silicon quantum dots. Silicon-rich nitride films are deposited by reactive magnetron sputtering and Si quantum dots with 2nm diameter are obrtained after rapid thermal annealing at 700C for 10min. The Si quantum dots efficiently emit near infrared radiation with a broad spectrum centered at 750nm[3]. Electron-beam nanofabrication is performed on the active silicon-based films and provides 100x100 microns-size arrays of 30nm-thick Au nano-cylinders with diameters ranging between 50nm-200nm and controlled separations between 20nm and 500nm. Semi-analytical, multi-particle scattering simulations based on the Generalized Mie Theory (GMT) enabled the rigorous understanding of the complex electromagnetic scattering response of metal-nanoparticles DANS. Our GMT calculations combined with experimental dark-field microscopy measurements reveal characteristic electromagnetic resonances in DANS due to the excitation of characteristic plasmon modes with strong field enhancement.
We demonstrate that the resonant coupling of light-emitting quantum dots with plasmonic modes in aperiodic arrays provides significant enhancement in the photoluminescence intensity over a broad spectral range. In addition, we investigate radiative enhancement in aperiodic arrays of metal nanoparticles with elliptical and triangular shapes, and we discuss the engineering design rules for the optimization and control of broadband emission from Si nanostructures.
The combination of top-down nano-patterning of metal-dielectric aperiodic surfaces with light emitting quantum dots in a Si-based platform can open new pathways for the engineering of radiative processes in nanomaterials.

1. A. Gopinath, S.V. Boriskina, N.N. Feng, B.M. Reinhard, L. Dal Negro, Nano Lett. **8**, 2423 (2008).
2. S. V. Boriskina, A. Gopinath, L.D. Negro, Opt. Express **16**, 18813-18826
3. R. Li, J. Schneck, J. Warga, L. Ziegler, L. Dal Negro, Appl. Phys. Lett., **93**, 091119 (2008).

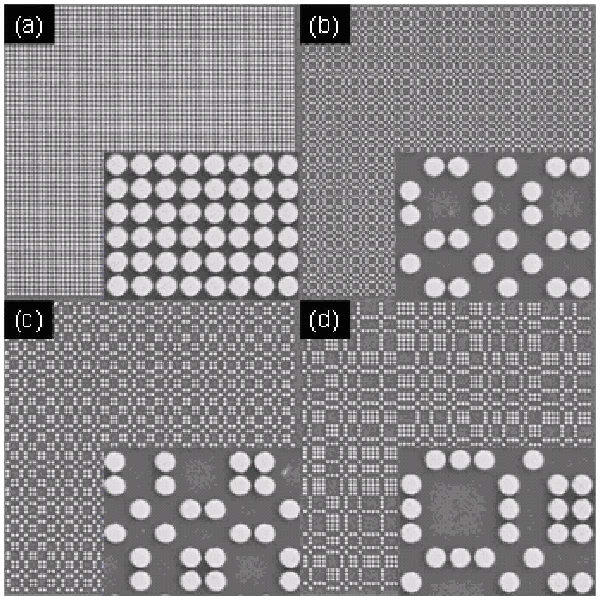

Fig 1: Nanofabricated periodic (a), Fibonacci (b), Thue-Morse (c) and Rudin-Shapiro (d) arrays of Au nano-cylinders with 100 nm radii and 25 nm minimum edge-to-edge inter-particle separation.

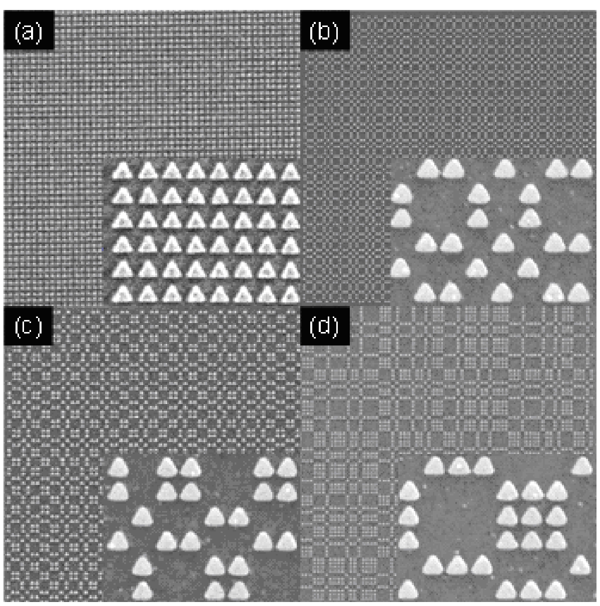

Fig 2: Nanofabricated periodic (a), Fibonacci (b), Thue-Morse (c) and Rudin-Shapiro (d) arrays of Au equilateral nano-triangles with 200 nm side length and 25 nm minimum inter-particle separations.