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Modification of Nanoparticle Arrays by Laser-Induced Self Assembly (MONA-LISA)

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Abstract: Large scale nano-structuring of metals is one of the challenges for the future of plasmonic and photonic devices. Such a technology calls for the development of ultra-fast, high-throughput and low cost fabrication techniques. Laser processing, accounts for the aforementioned properties, representing an unrivalled tool towards the anticipated arrival of modules based in metallic nano-structures, with an extra advantage: the ease of scalability. Specifically, laser nano-structuring of ultra-thin metal film or an alternative ceramic/metal film on a substrate results respectively on surface [1] (MNPs on the surface of the substrate) or subsurface [2] (MNPs embedded in a dielectric matrix) plasmonic patterns with many applications. In this work we investigate theoretically the photo-thermal processes involved in surface and sub-surface plasmonic nano-structuring and compare to experiments. To this end, we present a design process and develop functional plasmonic nano-structures with pre-determined morphology by tuning the annealing parameters like the laser's fluence and wavelength and/or the structure parameters like the thickness of the metallic film and the volume ratio of the ceramic metal composite. For the surface plasmonic nano-structuring we utilize the ability to tune the laser's wavelength to either mach the absorption spectral profile of the metal or to be resonant with the plasma oscillation frequency (LSPR), i.e. we utilize different optical absorption mechanisms that are size-selective. Thus, we overcome a great challenge of Laser Induced Self Assembly by combining simultaneously large-scale character with nanometer scale precision. For subsurface plasmonic nano-structuring, on the other hand, we utilize the temperature gradients that are developed spatially across the metal/dielectric nano-composite structure during the laser treatment. We find that the developed temperature gradients are strongly depended on the nanocrystalline character of the dielectric host which determines its thermal conductivity, the composition of the ceramic/metal and the total thickness of the nano-composite film. The aforementioned material parameters combined with the laser annealing parameters can be used to pre-design the final morphology of the sub-surface plasmonic structure. The proposed processes can serve as a platform that will stimulate further progress towards the engineering of plasmonic devices.

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[2] A. Siozios et al., Nanotechnology 26, 155301 (2015).