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A Carbon-black Soft Photo-mask for Patterning Metallic Microstructures with Application on Localized Surface Plasma Resonance

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Extended Abstract

Arrayed metallic nano-structures have recently drawn a lot of attention for the possibility of manipulating their optical characteristics. For example, a two-dimensional (2D) array of nano-structures deployed on a substrate can interact with an incident electromagnetic wave and induce localized surface plasma resonance (LSPR) as described by Hutter and Fendler (2004). Significant enhancement of absorption and scattering of optical energy can occur and directly affect the transmission spectrum. The resonant frequencies and the resonance behaviors depend on the nano-structures' material properties, sizes, shapes, array period, and geometrical arrangements…etc., and hence are tunable.

Nano-fabrication methods are critical to the application of arrayed metallic nano-structures. Conventional photolithography methods are still the most mature and widely used method. However, for localized surface plasma resonance, the feature sizes of metallic nanostructures have to be in the order sub-micrometer or nanometer, which requires advanced and expensive photolithography equipments.

In this paper, we propose a new method which is suitable for patterning arrayed metallic nano-structures. It starts from applying the silicon bulk machining method suggested by Kovacs et al. (1998) to create an array of inverted pyramidal micro-cavities on the surface of a (100) silicon wafer. A soft mold, which is negatively replicated from this master silicon mold by a mold process, will contain arrayed micro-pyramids on its surface. A black photo-resist (Web-1), which is opaque to UV light, is spin-coated on the surface micro-pyramids of the soft mold. By carefully adjusting the spin-coating parameters, the black-PR can fully cover the whole mold surface except around the tips of micro-pyramids. When using this black-PR coated soft mold as a photo-mask in conventional photolithography, arrayed metallic nano-structures over large-area can be obtained in a simple and straightforward manner.

This work successfully demonstrates a new method for fabricating arrayed metallic mano-structures with small line-width, high density, and large patterning area size. It follows conventional method of photolithography but using a black-PR-coated soft mold with arrayed pyramidal 3D surface micro-structures as the photo-mask. This approach requires only relatively simple equipments and processes at a must lower cost, and therefore opens up a new way and possibilities of applying LSPR for real and industrial applications in optical and optoelectronic engineering.

The smallest feature size obtained in this paper is 400 nm, and hence the LSPR is in the near infrared spectrum. However, with some refinements and adjustments in the fabrication processes, it is possible for further reducing the feature sizes down to the order of 100 nm and therefore can be directly applied to LSPR in optical visible regions. The obtained metallic nano-structures obtained in this work are arrayed dots, which after subjecting to thermal annealing can turn into arrayed nano-particles as been described before by Chen and Lee (2010). This will further improve and enhance the LSPR effects.

References

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