Large-area Plasmonic Substrates Based on Ordered Metallic Nanostructures

L. Duempelmann, F. Lütolf, D. Casari, A. Luu-Dinh, G. Basset, B. Gallinet

We present the fabrication of large-scale plasmonic substrates based on UV casting or hot embossing. Such plasmonic structures are very promising in the field of structural color, sensor, solar cell or light harvesting applications.

Plasmonics is the field of light interaction with metallic nanostructures mainly in the visible and NIR. Specifically sub-wavelength light confinement enables such interactions, leading to strong field enhancement in close vicinity. This results in a resonant spectral interaction, which is strongly dependent on the surrounding media. These properties make plasmonics very promising for optical security, color filter, sensing or light harvesting applications respectively.

Recent examples show the potential of plasmonic substrates, but to date fabrication of such plasmonic structures is very challenging or requires expensive and serial fabrication techniques. Our aim is to develop plasmonic structures in industrially relevant dimensions and with cost-effective processes.

For fabrication of ordered sub-wavelength structures we utilize laser interference lithography, capable of creating a large-area (5cm x 5cm) master structure. With the use of an in-house step-and-repeat robot we can upscale this master manifold, reaching up to 20x the original area (1m x 1m), see Figure 1. This area is fully roll-to-roll compatible and can be utilized for rapid and cost-effective mass-production.

Replication of the structures is done either with UV casting in UV curable sol-gel or via hot embossing into plastic both by using the master structure. Subsequently a variety of metals at distinct angles can be deposited. Finally the structures are embedded in e.g. UV curable sol-gel for protection in ambient conditions.

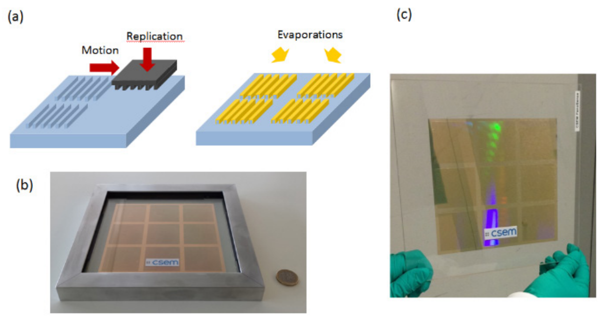

Figure 1: Plasmonic nanostructures fabricated with a step-and-repeat UV casting process. a) Replication and evaporation process; b & c) 15 cm x 15 cm sample.

The ordered metallic nanowires (range of the visible wavelength) interact with the light in such that a resonant condition leads to appearance of a color. Figure 2 shows how this resonance not only depends on the kind of metal used, but also whether the structure is embedded or not. Moreover the resonance depends on the polarization and the incidence angle of the impinging light, but more importantly on the structure of the nanowire themselves.

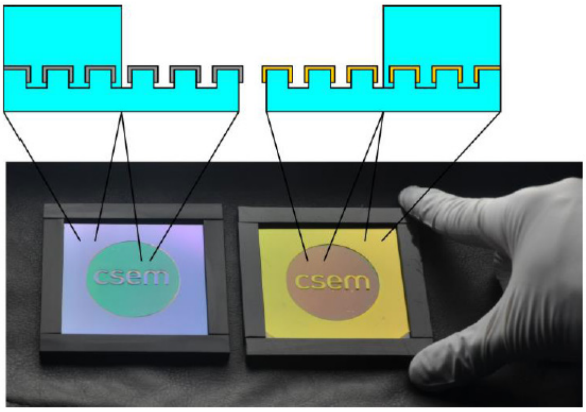

Figure 2: Photograph of aluminum (left) and gold (right) evaporated samples containing plasmonic structures. The image also shows the contrast between embedded (border and letters) and air interfaced parts (circular area) of the structure.

Figure 3 shows a stretch sensor, which changes the appearance upon elongation. Replication of the mold master was done in polyurethane allowing high elasticity of the substrate, provided with metallic nanostructures and subsequently embedded PDMS. The color change is caused by the increased distance of the metallic nanowires, resulting in a shift of the plasmon resonance.

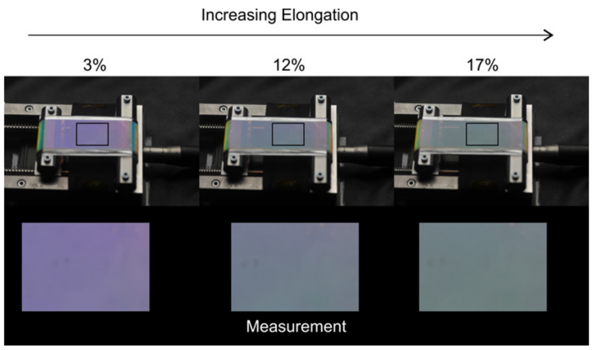

Figure 3: Visible response of the stretch sensor for elongations of up to 17%.

Overall we demonstrate a fabrication process of large-scale plasmonic substrates compatible with industrial roll-to-roll process. Adaptability of the substrates to different applications such as color filters or sensors is granted by modification of the fabrication process. This paves the way for industrialization of plasmonic substrates with great potential in future applications.