Nanorippled dielectric thin films as templates for self-organized silver nanoparticles using a dual ion-beam sputtering system

Elliot Vandenhecke*[1], David Babonneau[1], Sophie Camelio[1], Sophie Rousselet[1], and Philippe Guérin[1]

[1]Institut Pprime (PPRIME) – CNRS : UPR3346, Université de Poitiers, ENSMA – France

Abstract

The realization of metallic nanoparticles (NPs) with well-controlled composition, size, shape, and distribution remains a significant challenge, especially for the large-scale production of regular arrays on substrates in a short time. An effective and low-cost bottom-up approach consists in combining prepatterning of dielectric thin films (DTFs) by broad beam-ion sputtering with subsequent growth of NPs by physical vapour deposition at glancing incidence. In this work, we demonstrate the possibility to use a dual ion-beam sputtering system to produce unidirectional and periodic nanoripples on amorphous alumina DTFs, which can be utilized as templates to control both the morphology and the 2D organization of silver NPs.

Amorphous alumina DTFs were first grown by ion-assisted sputter deposition on flat substrates, and then sputtered with Xe ions varying parameters such as incidence angle (50-65∘), exposure time (90-1200 s), energy (0.25-1.5 keV), and temperature (20-600∘C). The ion-eroded surfaces were characterized by ex-situ atomic force microscopy and grazing incidence small-angle x-ray scattering, thus demonstrating the formation of periodic ripples with tunable wavelength, amplitude, and lateral correlation length.

Glancing-angle deposition of silver was performed on such nanorippled DTFs with the metallic flux being oriented perpendicularly to the ripples. Then, the resulting deposits were covered with an additional alumina capping layer to preserve silver from the external environment and characterized by high-angle annular dark-field scanning transmission electron microscopy. Because part of the metallic flux is shadowed by the surface topography during the glancing-angle deposition, preferential growth of silver occurs on the illuminated slopes of the rippled surface, thus leading to the formation of chains consisting of NPs elongated along the ripples and with gap between the NPs less than 10 nm. Optical transmittance spectra measured at normal incidence in the visible range evidence a strong dependence of the plasmonic response on the light polarization, which can be interpreted as the consequence of both the anisotropic spatial organization of the NPs and their shape anisotropy [1]. Moreover, our experiments show that such a plasmonic dichroism can be tuned by adjusting the amount of deposited metal, the angle of incidence during silver deposition, as well as the period and the lateral correlation length of the ripples.

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*Speaker

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