Electrochemical Fabrication and Optical Properties of Gold Nanocavities

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Electrochemical deposition of metals through templates made by assembly of polystyrene latex spheres at electrode surfaces followed by subsequent removal of the template is a very effective way to produced thin nanostructured metal films containing voids between 20 and 1000 nm in diameter [1-3].

In the present work we report the fabrication of nanostructured gold films by this technique and we describe some of their unique optical properties. The gold films were prepared by electrochemical deposition from a commercial gold plating bath through templates assembled from 750 nm diameter polystyrene latex spheres. After deposition the template was dissolved away in toluene to leave the nanostructured gold film. By growing the films with a gradient of thickness across the sample we are able to examine in detail the evolution of the surface topography and the optical properties with film thickness, figures 1 and 2.

The local optical reflectivity of the macroporous metal films was measured using a white-light laser focused to a 10 μm diameter spot [4, 5]. Typical reflectivity spectra are shown in figure 2. These spectra show strong dips that are not generated by patterned Pt films of the same type or by planar gold films. As the angle of incidence is altered the resonant dips vary in strength and TE/TM ratio but show minimal shifts in energy. Extinction ratios in excess of 20 dB are found and up to 3 resonances can be seen simultaneously. Figure 2 also shows the extracted energies of the modes as a function of the film thickness. Three separate regions are apparent depending on the thickness of the film relative to the template sphere diameter. In particular, for a range of film thicknesses corresponding to between one half and nearly a full template sphere in thickness the TE and TM resonances are sharp (< 20 nm halfwidth) and coincident. The correlation of the microstructure with these resonant energies confirms that the modes arise from zero-dimensional plasmon-polaritons trapped inside the gold nanocavities.

The ability to control the optical reflectivity of the gold surface by patterning at the sub-micron level promises applicability in diverse areas from biotechnology to optoelectronics.

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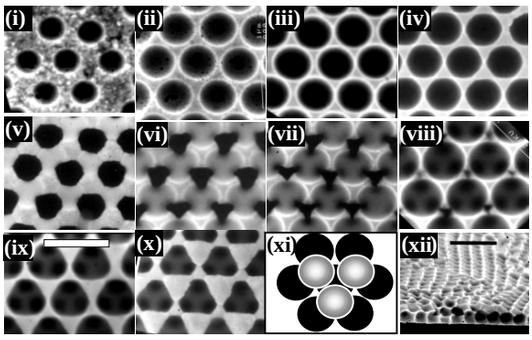

Fig. 1. Scanning electron micrographs of the photonic gold nanostructures fabricated with *d*=750 nm latex spheres. The thickness varies continuously across the sample: (i) 50 nm, (iv) 350 nm, (vii) 700 nm, (x) 1100 nm (scale bar is 1μm). (xi) The lowest void layer (black) and second layer (grey). (xii) Cross section (scale bar is 5μm).

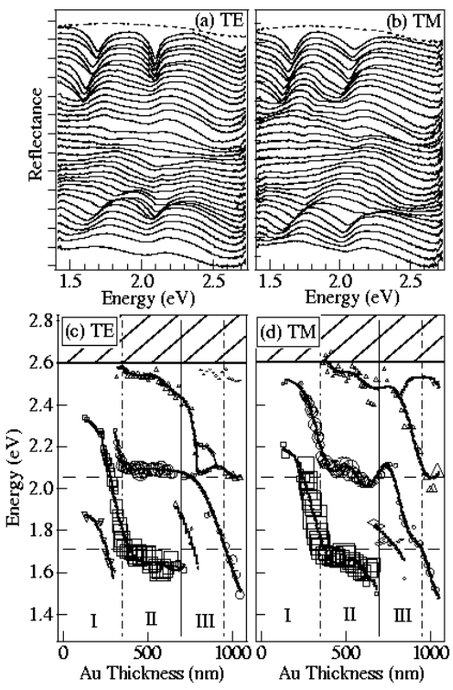

Fig. 2. a,b) Reflectivity spectra on the same sample at different locations (thicknesses 500-1100nm from top to bottom) for both TE and TM polarised incident light at 45°. The scale is logarithmic, each tick is a factor of 10, and the curves have been offset for clarity. The dotted curve is an unpatterned film electrodeposited under the same conditions. c,d) Extracted mode energies for TM,TE polarisations at 45°. The symbol size indicates the mode sharpness (depth/linewidth). The vertical lines mark the heights of ½,1, 1½ spheres, and above 2.6eV planar surface plasmon absorption occurs. The dashed horizontal lines are from a theory of idealised spherical voids.