Itinerant and localized surface plasmons in annealed Au films

A.Serrano[1,2], O. Rodríguez de la Fuente[1], M. A. García[2]

[1]Dpto. de Física de Materiales, Universidad Complutense de Madrid, 28040, Madrid, Spain
[2] Instituto de Cerámica y Vidrio, Consejo Superior de Investigaciones Científicas, 28049 Madrid, Spain

aida@fis.ucm.es

Surface plasmon resonance (SPR) is probably the most outstanding property of noble metal nanostructures in the form of nanoparticles or thin films. It consists in a collective oscillation of conduction electrons leading to a huge absorption cross section with applications in many fields [1-4]. The incorporation of plasmonic nanostructures over surfaces can be used to enhance functionalities and improve their properties. For instance, gold nanoparticles can increase the efficiency of photovoltaic panels, photocatalytic surfaces or biological entities labeling devices. However, incorporation of metallic nanostructures over large area surfaces is not straightforward. Dispersion of chemically synthesized nanoparticles is complex and expensive and lithography can hardly achieve areas of hundred of microns.

Metallic thin films deposited over substrates with poor adhesion are known to exhibit substantial modifications when annealed in air or vacuum, including the formation of hillocks, subsequent hole growing and island agglomeration leading to a discrete structure [5-7]. While these kind of modifications represent a serial problem for thin film processing in microelectronics, they can provide a method to engineer their optical properties as surface plasmons are extremely sensitive to the morphology of the nanostructure. Both itinerant and localized surface plasmons exhibit important changes in the resonant conditions when the size and shape of the nanostructure are modified, thus providing a method to tune the optical properties of the system.

We deposited Au films with different thicknesses onto sodalime glass substrates by thermal evaporation. The films were subsequently annealed in air at temperatures up to 500 ºC. The thermal treatment promotes morphological modifications of the films (see figure 1) switching from a continuous to a discrete structure. The size and shape of the islands depend on the film initial thickness and annealing temperature.

Morphological modification of the films upon annealing are reflected in the optical properties of the films. The as-grown films exhibit itinerant SPR measured in the Kretschmann-Raether configuration (figure 2). After annealing and island formation, the films exhibit the absorption band characteristic of localized SPR in nanoparticles (figure 2). The features of the SRP can be tuned through the control of the film initial thickness and annealing parameters.

Therefore annealing Au films deposited onto glass provides a method to tune the plasmonic properties of the films in a wide a range and over large areas not easily achievable by other methods.

References

[1] U. Kreibig and M. Vollmer, Optical properties of metal clusters, Ed. Springer-Verlag, Springer Series in Materials Science 25 (1995).
[2] M. L. Brongersma and P. G. Kik, Surface Plasmon Nanophotonics, Ed. Springer-Verlag 1988.
[3] S. A. Maier, Plasmonics, Ed. Springer-Verlag 2006.
[4] H. Raether, Surface Plasmons on smooth and rough surfaces and on gratings, Ed. Springer-Verlag 1988.
[5] A. E. B. Presland, G.L. Price, D.L. Trimm, Surf. Sci. 29 (1972) 424.
[6] S. K. Sharma, J. Spitz, Thin Solid Films 65 (1980) 339.
[7] M. S. Rahman Khan, Bull. Mater. 9 (1987) 55.

Figures

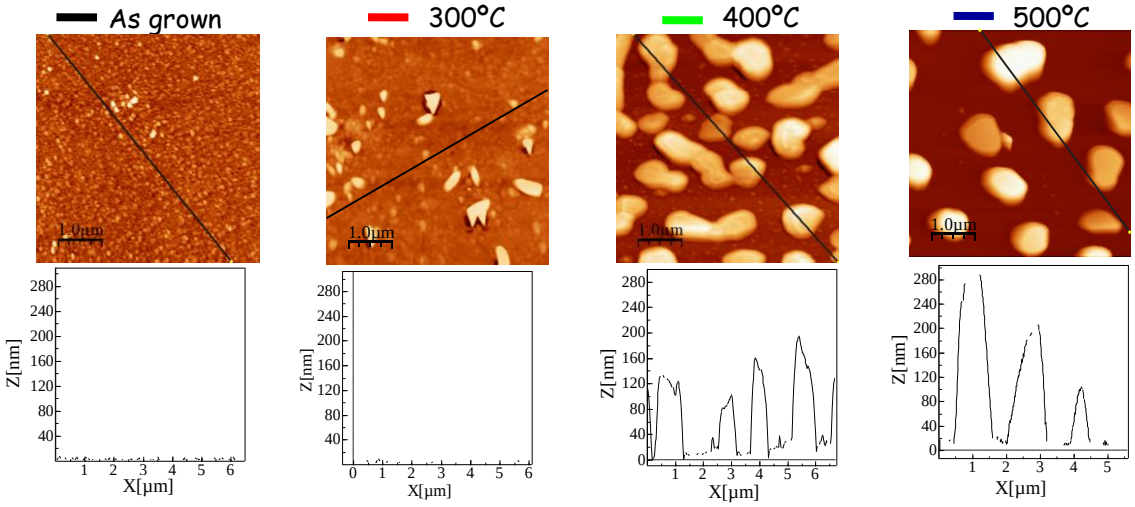

Figure 1 AFM images of Au films, with a thickness of 45 nm, deposited onto sodalime substrates and annealed at different temperatures in air. Bottom panels present the height profiles measured along the lines indicated in the figure.

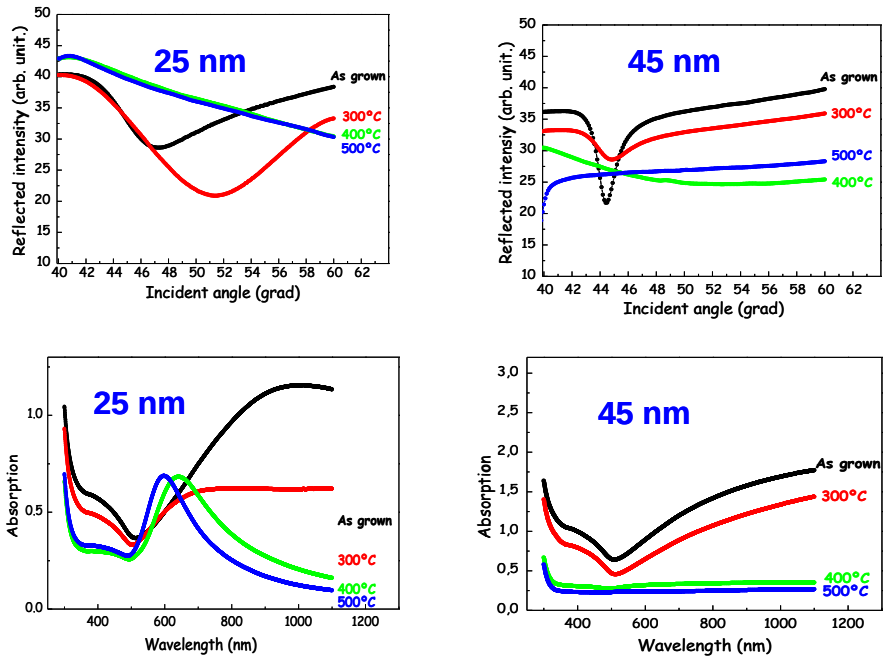

Figure 2. Measurements of the itinerant (top) and localized (bottom) surface plasmon resonance of the 25 and 45 nm films, as grown and upon annealing at different temperatures.

Acknowledgments

Authors acknowledge C. Romero for assistance with the experiments. This work was supported by the Spanish Ministry of Science and Education through the project FIS-2008-06249.