NANOSTRUCTURED NOBLE METALS DEPOSITED ONTO SiO_2/Si WITH METAMATERIALS CHARACTERISTICS

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The small size of nanostructured layers is essential in applications of miniaturized optical systems. We obtained a multilayer of Ag/SiO_2/Si and Au/SiO_2/Si, exhibiting excellent qualities when silver was 7 nm thick and gold 5 nm thick, respectively; with plasmonic properties useful in obtaining structures with negative refractive index. Silicon dioxide has 200 nm thickness and high-performance dielectric properties, which improves the properties of metamaterial structures. The deposition conditions were optimized and led to layers with a good morphology of surface, consisting of nanoparticles with dimensions between 7 nm to 15 nm and a surface roughness between 0.5 nm to 1.3 nm. The analyzed XPS general scans showed the presence of Ag 3d3 and Ag 3d5 in the silver nanostructures and the presence of Au 4f5 and Au 4f7 in the gold nanostructures. The XRD diffractograms also indicated that both Ag and Au samples are crystalline. In the case of these noble samples the orientation was clearly after the main planes perpendicular to the substrate for the (111) planes. Good structural properties of the Ag/SiO_2/Si and Au/SiO_2/Si multilayers were highlighted by the crystallographic quality, resulting from XRD analysis and a high spectral transmission in the visible and infrared range. Therefore, the obtained noble films have a controlled morphology suitable in future applications of structures with metamaterials.

Depositions conditions

- Au, Ag and SiO_2 thin films were deposited on Si substrate;
- All these thin films were prepared by *RF magnetron sputtering*;
- distance from substrate to target: 9 cm;
- 4 inch diameter target;
- 99.95% purity.

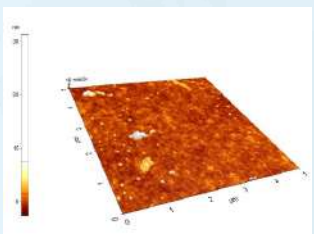
+ for Au, Ag thin films

- mass flow controller: 20 sccm Ar;
- pressure during deposition: 5×10^{-3} Torr;
- intensity of the electrical current: 0.1A;
- forward power/reflected power: 20W/0W;
- deposition rate: 1.1 Å/s.

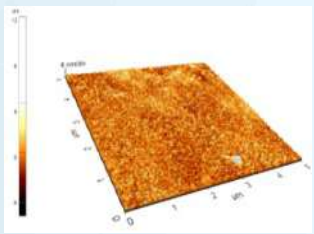
Table 1 The optimized deposition conditions used to obtain Ag and Au thin films with nanostructured surfaces.

substrate	target	Purity (%)	P (W)	d (sccm) Ar	D (nm)	r (Å/s)	I (A)
SiO_2/Si(100)	Au	99.99	20	15	5nm, 7 nm	1.1	0.1
SiO_2/Si(100)	Ag	99.99	25	17	5nm, 7nm	1.0	0.1

AFM analysis of a) SiO_2 thin film, b), c) gold deposited films, d), e) silver deposited films

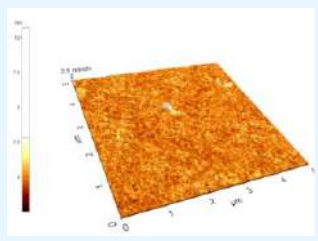


R_{rms} = 1.3 nm
d_1SiO_2 = 200 nm

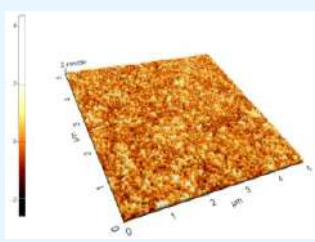


R_{rms} = 0.5 nm
d_2 Au = 5 nm

R_{rms} = 0.8 nm
d_3 Au = 7 nm

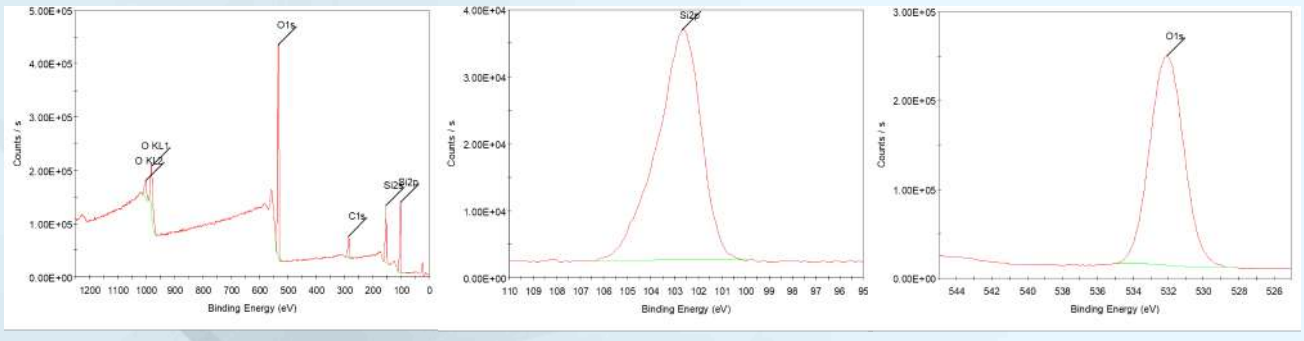


R_{rms} = 0.6 nm
d_4 Ag = 5 nm



R_{rms} = 1.1 nm
d_5 Ag = 7 nm

a) General spectra of SiO_2 thin films, b) HR-XPS analysis of Si c) HR-XPS analysis of O_2

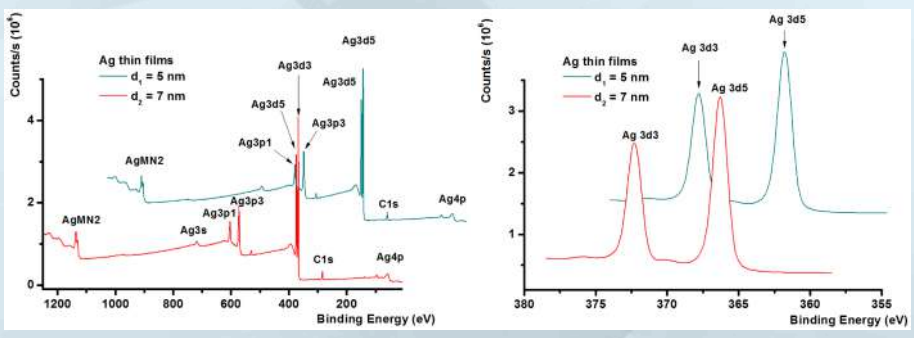


a) b) c)

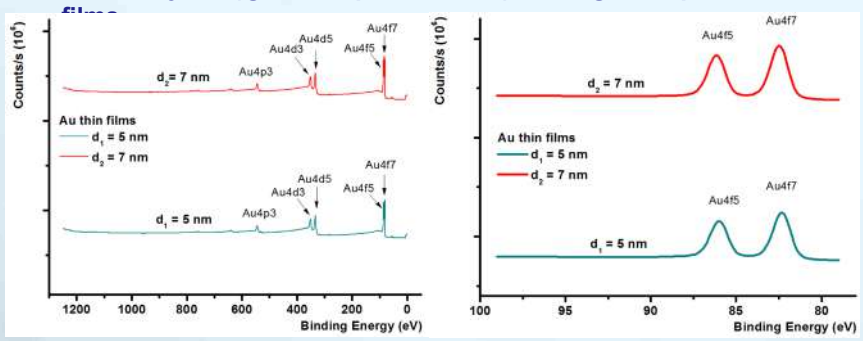
Table 2 The chemical composition of SiO_2 thin films by HR-XPS measurements.

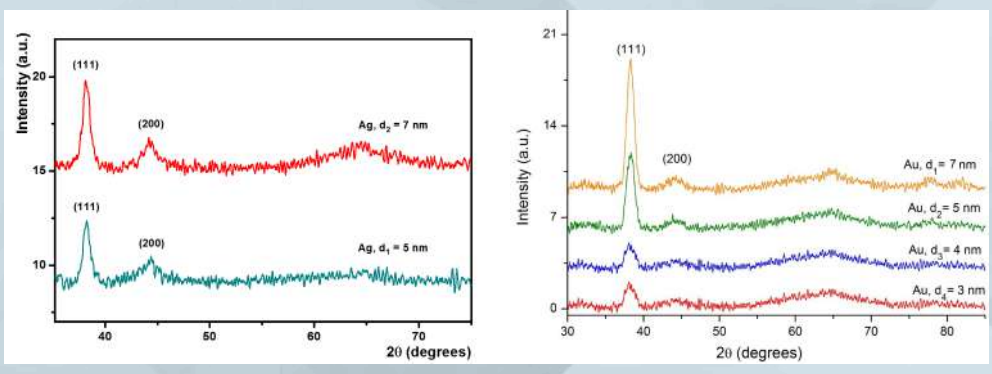
Name	Peak BE	FWHM (eV)	Atomic %
O1s	532.24	3.53	65.37
Si2p	102.92	3.34	34.63

XPS analysis a)general spectra and b) HR of silver deposited films



XPS analysis a)general spectra and b) HR of gold deposited films





In the mentioned experimental conditions, silver and gold films with uniform and reproducible nanoscale structure, were obtained. AFM images showed that our samples have a grain like surface morphology. Films made with smaller thicknesses are less crystalline, with smaller crystalline grains. The crystallites orientation, the granulation and columnar growth are more evident in the Au samples. Increasing the thickness of the thin film greatly improved the crystallinity of the film.

In the case of thin Au and thin Ag layers deposited on the SiO_2 /Si substrate, it has been observed the presence of chemical elements on the surface, such as: Au 4f5, Au4f7, Ag3d3 and Ag3d5. The XRD patterns indicated the Ag and Au films are crystalline and polycrystalline. Also, the Ag and Au thin films have a strong orientation after the main planes perpendicular to the substrate, e.g. (111) for Au films.

The present investigation of ultra thin films with small dimensions are useful for integration in the micro- and nanosatellites manufacturing.

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