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Study of Optical Response of Gold Nanoclusters Deposited on Polymer Substrates: Influence of in Situ Mechanical Deformation

S. ElJoumani[a*], M. Idiri[b*], M. Alhajjaji[c*], A. Tahiri[d*], B. Boubeker[e*]

[a,b,c,d,e]*Laboratory of Engineering and Materials (LIMAT), Faculty of Sciences Ben M'Sik Hassan II University Of Casablanca, Morocco*

[a]*Email: Safia.eljoumani2@gmail.com*

Abstract

Nanomaterials are the building blocks of today's nanoscience and nanotechnology. Due to the distinct features of the nanomaterials, their utilization in the application sectors has increased. The field of metal nanocluster has been studied with increasing interest in the past few years. In this context, we study the influence of mechanical deformation on the optical transmittance of gold nanoclusters deposited on polymer substrate the polyurethane Clear Flex® 50 during in situ tensile test.

Keywords: Nanomaterials; gold nanoclusters; polymer substrate; transmittance; in situ tensile test.

1. Introduction

Nanoparticles have remained the focus of many research mainly due to their strong size- and their properties[1,2]. It has further been realized that the formation of nanoparticle assemblies may conceive new properties unattainable using individual nanoparticles through collective effects such as interparticle coupling and structural ordering [3,4]. It is well known that, as we move from "bulk" to "nanoscale" dimensions, the material properties change [5]. Optical properties of the materials are not an exception to this fact. Applications based on the optical properties of nanomaterials span domains such as, optical detectors, lasers, optical sensors, imaging technologies, screen displays, solar cells, photocatalysis, biomedicine, also many studies were focused on the influence of the nanostructure of the metal nanoclusters on their optical properties[6,7,8].

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* Corresponding author.

2. Experimental section

2.1. Strain measurements

Before deposition we obtain the elastic limit of our polyurethane substrate using a uniaxial tensile testing and strain measurement technique DIC (Digital image correlation) [9,10]. Image acquisition was performed using an optical microscope connected to a CCD camera. We used a CCD camera type Pixel fly (Figure 1):

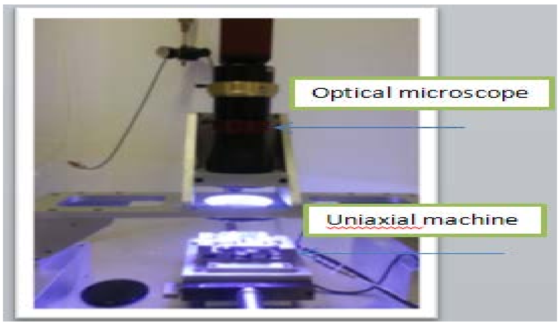

Figure 1: Optical microscope installed on tensile machine

2.2. Results of strain measurements

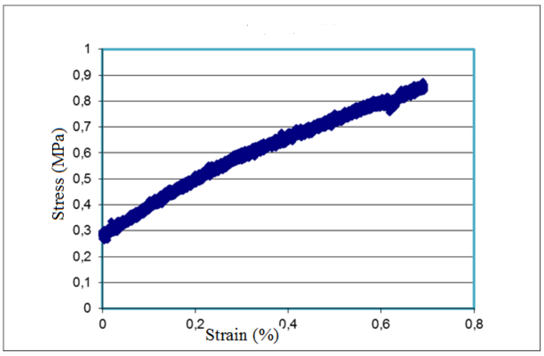

Figure 2: Uniaxial tensile test of polyurethane substrate

As we can see from the graph, the substrate breaking is achieved after having around 65% of deformation. This shows that our material is sufficiently elastic to be used as a substrate and to allow us to have a new Au / polyurethane material having a very good transmittance.

2.3. Nanoclusters thin films: fabrication method

The gold nanoclusters thin films were synthesized at room temperature (RT) by sputtering Au on polyurethane substrate. Sputtering deposition [11] was achieved with an argon-ion-gun sputtering beam at 1.2 keV, where the pressure in the chamber was 10-4 mbar. In our study we deposited 3nm gold nanoclusters. After gold deposition for 29 s (corresponding to an effective thickness of 3 nm), no action was taken for about 3 hours in order to give the nanoclusters sufficient time to stabilize on the surface. The ion sputtering principle is presented in Figure 3:

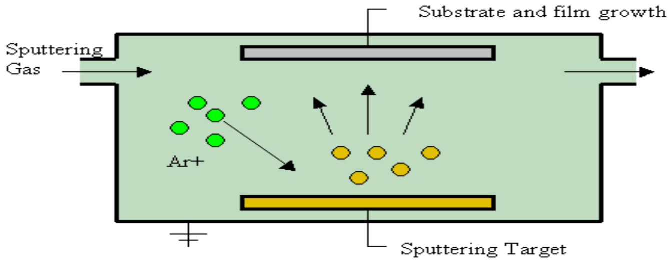

Figure 3: Ion sputtering principle [12].

2.4. In situ Optical measurement

In this part we study the optical response of our samples during in situ tensile tests. The spectral transmittance of gold clusters deposited on Polyurethane substrate was determined for the wavelength range from 250nm to 1500nm by Ultraviolet−Visible Spectrophotometer coupled with tensile Deben machine [13]. The transmission measurements were performed coupled to tensile tests at different strengths 0N, 2N, and 4N, with polarization of 0 ° and 90°. First we have studied the transmission measurements of polyurethane substrate, at the visible-infrared range (~ 400-1400nm) the obtained results are reported in figure 4 and figure 5:

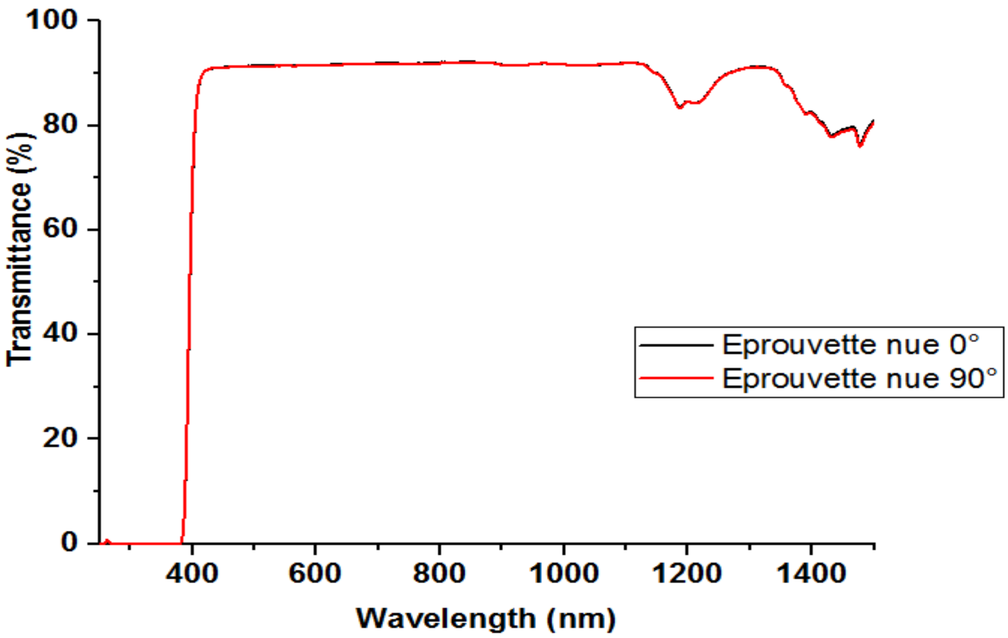

Figure 4: transmission measurements of polyurethane substrate

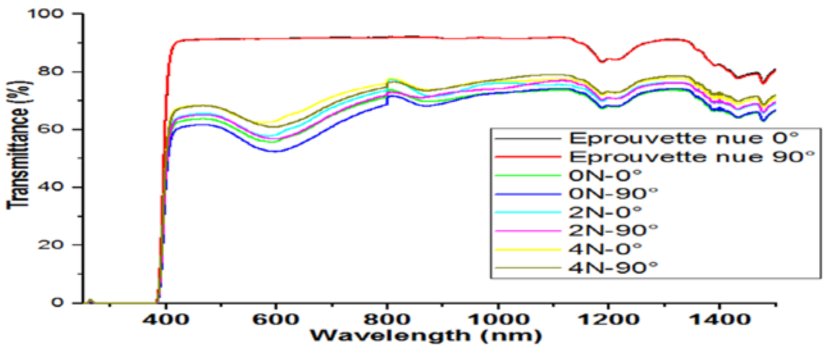

Figure 5: transmission measurements of Au/ polyurethane substrate

As we can see from the graph the transmission of polyurethane substrate is around 90%. This result shows that our substrate is a good transparent material. This will allow having after the deposition of gold a good optical response of the system gold on polyurethane. Also we observe the presence of a marked resonance band centered around 610 nm. This confirms the presence of gold nanoparticles which generally give resonances bands transitions lie in the visible range around 500nm and 600nm [13, 14, 15, 16]. In the other hand the tensile test induce an increase in transmittance from 53% without uniaxial tensile test (0N) to around 63% with application of 4N load, combined with a light blue-shift in position of the resonance as a function of the increase of the applied strength, which is due to the increased distance separating the gold nanoparticles. Such observation was noted by Yu-Lun Chiang and his colleagues (17), on the Au / PDMS system or they noticed an absorption peak locates at around 560 nm in wavelength when the external stress is not applied. When the PDMS membrane is stretched, the absorption peak shows a blueshift.

3. Conclusion

In this work, we have first studied the mechanical properties of polyurethane substrate. That allows determining the limit of elasticity of this substrate. We have deposited an effective thickness of 3 nm of Au on substrate using physical vapor deposition technique (ion sputtering). We have studied the optical behavior of this film with in situ application of load range from 0N to 4N tensile by means of spectrophotometer. This study concluded that the Au / polyurethane system exhibits a blue-shift of the transmittance peak due to the distance of the gold nanoparticle under the effect of the tensile stress.

4. Perspectives

As perspectives we plan to study the influence of the thickness of gold deposited on the optical properties. We will also study the effect of Au / polyurethane heat treatments, especially the annealing effect on these properties.

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