Smooth Au Film by Annealing for Enhanced Extraordinary Optical Transmission

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Transmission enhancement of incident light through nano-apertures in optically-thick noble metal films has been an active research area since extraordinary optical transmission (EOT) phenomenon in metal nano-hole array (NHA) was observed by Ebbesen et al in 1998[1]. Due to the high sensitivity of EOT devices to the variation of the refractive index in ambient medium, one of the most interesting applications of EOT phenomenon is chemical/bio-sensing[2]. However, the poor quality (e.g. surface roughness and film morphology) of deposited noble metal film is a serious limit in the sensing application, because of the random light scattering on the rough metal surface and the absorption/scattering within the polycrystalline metal film containing grains and its boundaries.

Here, nano-hole arrays (NHAs) in optically-thick Au film with the hole diameter of 150 nm and the period of 500 nm were fabricated by electron beam lithography (EBL) followed by double liftoff process developed by us previously[3-4]. Thermal annealing in Ar atmosphere was carried out to improve the film quality and thus the optical transmission. The sensitivity for both annealed and as-fabricated NHAs was compared using the 16-mercaptohexadecanoic acid (16-MHA, n=1.48) as the target molecule.

As can be seen in Fig.1 a-b, the RMS roughness of the Au film surface was reduced by ~72% (from 6.4 nm to 1.8 nm) after annealing the NHAs at 600^{o}C for one hour. To understand the effect of annealing on the optical behaviour of the fabricated NHAs, optical transmission of both annealed and as-fabricated NHAs with the hole diameter of ~150 nm are compared in Fig. 1c. As can be seen, the optical transmission of annealed NHAs was enhanced more than 50% than the as-fabricated one, and matches well the FDTD simulated result. The sensitivity, as defined by $\Delta\lambda/\Delta n$ after coating a self-assemble monolayer of 16-MHA, was derived as 16.8 nm/RIU for the annealed NHA (Fig. 2a) and 6.6 nm/RIU for the as-fabricated NHA (Fig. 2b). Therefore, as a result of annealing, the sensitivity of the NHAs for EOT sensor was improved significantly by ~1.5 times.

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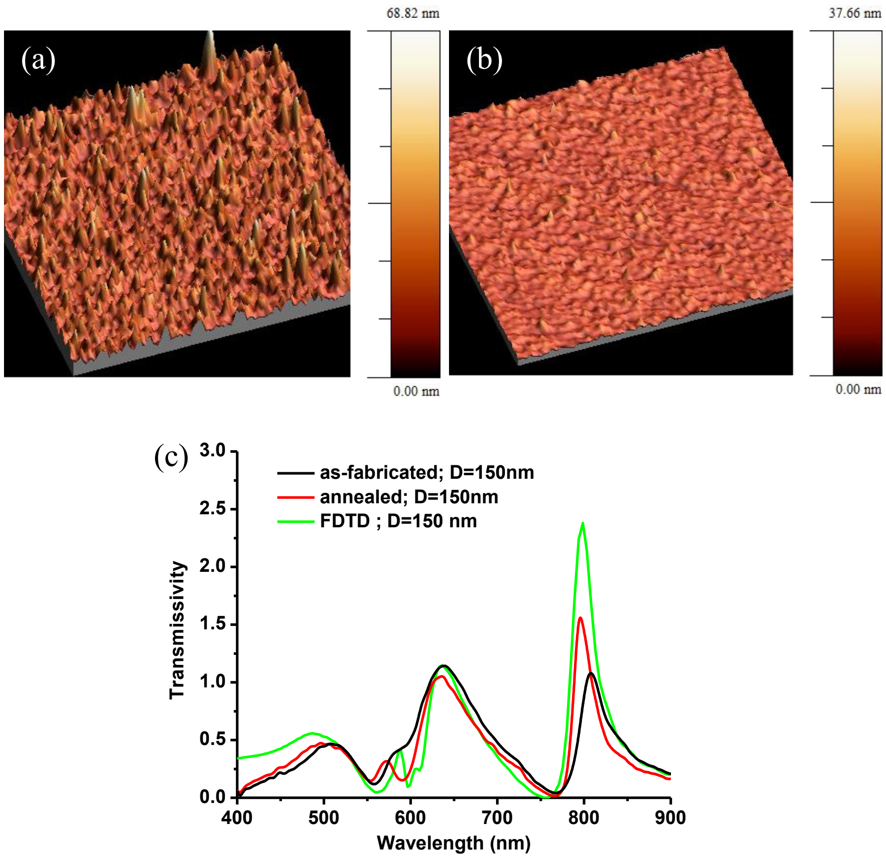

Figure 1: Comparison of the AFM images of (a) non-annealed Au film and (b) annealed Au film. (c) Comparison of optical transmission spectrum of NHAs with the diameter close to 150 nm: —NHA after annealing, —NHA as-fabricated, and —NHA FDTD simulated.

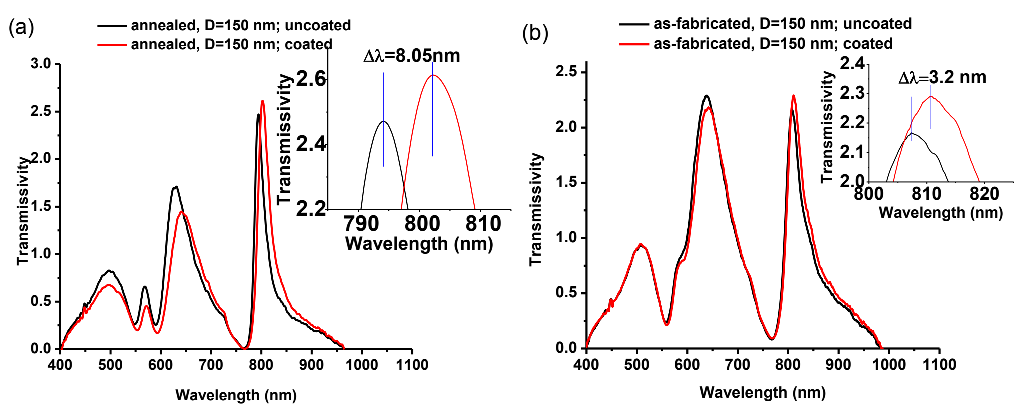

Figure 2: Measured transmission spectrum shift by coating 16-MHA on: a) annealed NHA; b) as-fabricated NHA.