Conformal Coating of Gold on Nanostructured Surface using Thermal Evaporation

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Physical vapor deposition (PVD) has been one of the most widely used technologies for metallization of structures and devises in many areas, including integrated circuit (IC) production and thin film coating, due to its process versatility and material purity [1]. However, its poor step coverage and limited conformality on structures with high aspect ratio (AR) has been a long time challenge to overcome. Figure 1 shows a general result after thermal evaporation of gold on nanostructured polymer surfaces. The deposited gold has sat only on trenches and valleys of polymer structures, and the uncoated sidewalls revealed the poor step coverage and directionality of anisotropic PVD process. To mitigate this problem, several approaches without changing the main concept of PVD, including oblique angle PVD and ionized PVD, have been suggested, but still have limitations when deposited on complex nanostructured geometry [1-3]. Also, more advanced and progressive deposition techniques with perfect conformality, such as metal atomic layer deposition (ALD), have been introduced to replace the conventional PVD process. However the limited selection of depositing materials, long reaction time, and complex process are the disadvantages to be considered.

In this work, we demonstrate a novel approach to enhance the step coverage of gold metal layers by thermal evaporation process on nanostructured polymer surface using a thin ALD-deposited oxide layer. To confirm the improvement on conformality and morphology of our gold layer, the coating was analyzed using scanning electron microscope (SEM), energy-dispersive x-ray spectroscopy (EDS), and electrical conductivity measurement. Titanium (Ti) or chromium (Cr) are commonly used as an adhesion layer for gold evaporation. However, it only alleviates the poor migration of gold on target surface and cannot change the step coverage. Here we suggested an ultra-thin metal oxide interlayer, as aluminum oxide (Al_2O_3) layer is frequently used to enhance surface reaction for metal atom formation during ALD process [4-5].

Preliminary experiment results of gold deposition on 5 nm of Al_2O_3 interlayer between nanostructured polymer with aspect ratio (AR) of 0.67, 1.0, and 1.5 showed an improved conformality of metal film, as depicted in Figure 2. Compared to the sample without any adhesion layer (Figure 1), the oxide interlayer has even improved the morphology of gold layer as well as the step coverage. More deposition tests on structures with various AR from 0.5 to 2.0 will be tested to demonstrate the predominance of metal oxide layer as an intermediate layer. Other oxide layers, such as TiO_2 and ZnO, will be examined as candidate materials. For more detailed investigation, STEM images and high-resolution EDS mapping data of deposited gold film on nanostructures will be evaluated as in Figure 3. Also, electrical characterizations of the metal films will be performed to confirm the superiority of our process for conformal coating of metal film on nanostructured surfaces.

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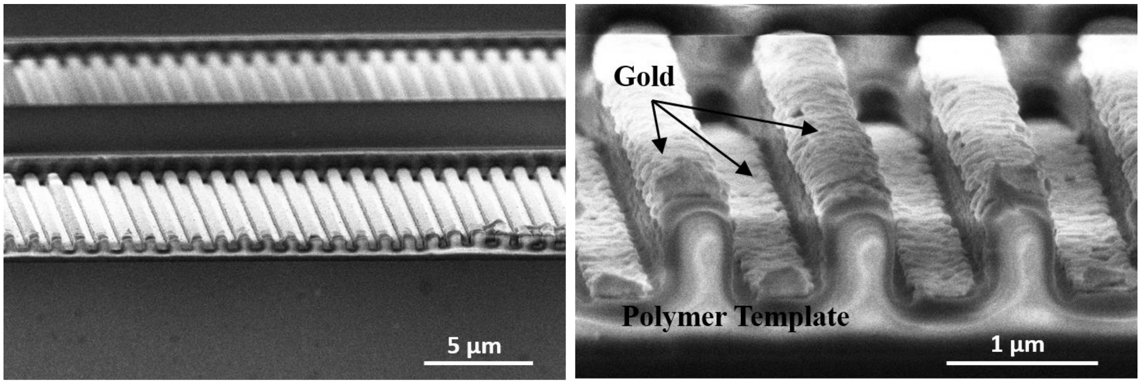

Figure 1. SEM images of thermally evaporated gold layer on top of the nanostructured polymer surface.

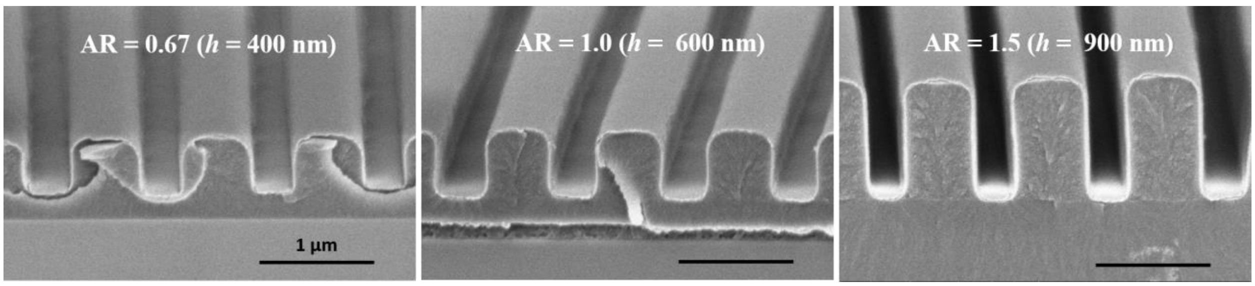

Figure 2. SEM images of conformal gold layers deposited on the nanostructured polymer surface with different aspect ratios: (a) AR = 0.67, (b) AR =1.0, and (c) AR = 1.5.

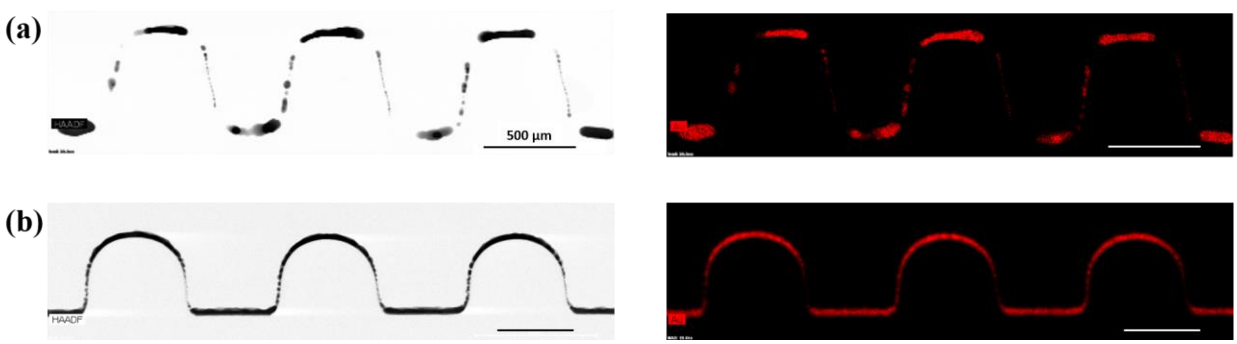

Figure 3. STEM images and corresponding high-resolution EDS mapping images of gold layers on nanostructured surfaces (a) without any surface treatment, and (b) with Al_2O_3 interlayer by ALD process.

References

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