Fabrication of Metallic Microstructured Nano-Accordions for Transparent Electrodes

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There have been numerous interests on developing flexible conductors using various fabrication technologies, such as dispersing nanomaterials onto elastomeric substrates, or using pre-strained thin materials which can be stretched and compressed.[1-3] Another promising technique is atomic layer deposition (ALD), one of the most effective techniques to create those ultra-thin layers of new materials. In recent work, we have demonstrated a method to fabricate novel nano-accordion structures using ALD and interference lithography (IL), achieving precise control of the geometry and size of the flexible conductors.[4,5] An excellent electrical conductivity and a structural stability were achieved from its metallic nature, however limited optical transmission is one major drawback with metallic nanostructures.

Here we demonstrate a novel approach to fabricate transparent metallic electrodes using microstructured nano-accordion structures. A detailed fabrication process is proposed in Figure 1, which begins with IL on the first photoresist (PR) layer and ALD of conformal metal film on PR. To enhance transparency, another layer of PR is spin coated for patterning of microscale periodic openings that is parallel to the first accordion fold direction. A subsequent etching process results in a discontinuous metal layers, and the second PR layer is washed away by chemical process. Finally, a thermal process using a convection oven removes the sacrificial polymer template and leaves a group of free-standing nano-accordion structures only. Two different PR's, a negative-tone PR for first patterning before ALD and a positive-tone PR for second patterning after ALD, will be used for this two-step patterning process.

Preliminary experiment results for two important steps in aforementioned process are shown in Figure 2. First, a solid platinum (Pt) film was generated by ALD on a negative PR template, as in Figure 2(a)-(b). The film was 20 nm thick, and its wavy geometry has a period of 1 μm and a width and height of 500 nm. The measured sheet resistance of this film was about 10.5 Ω/square, which indicated an excellent conductivity as a metallic nanostructure. Second, to test the feasibility of selective metal etching process, a positive PR layer with 1 μm thickness was spin coated on a 10 nm thick planar Pt film, and patterned using a conventional photolithography. Figure 2(c)-(d) illustrate the patterned Pt film after wet etching process using aqua regia solution, and it has a period of 10 μm and a width of 3 μm. Further experiments including an etching process on nanostructured metallic layers, and thermal process to remove negative PR template will be conducted with optimization of patterning on metallic nanostructures by changing the ratio of open and closed areas for better transparency. Also electrical and mechanical characterizations of the transparent metallic nano-accordions will be performed to confirm the superiority of our structures as flexible conductors.

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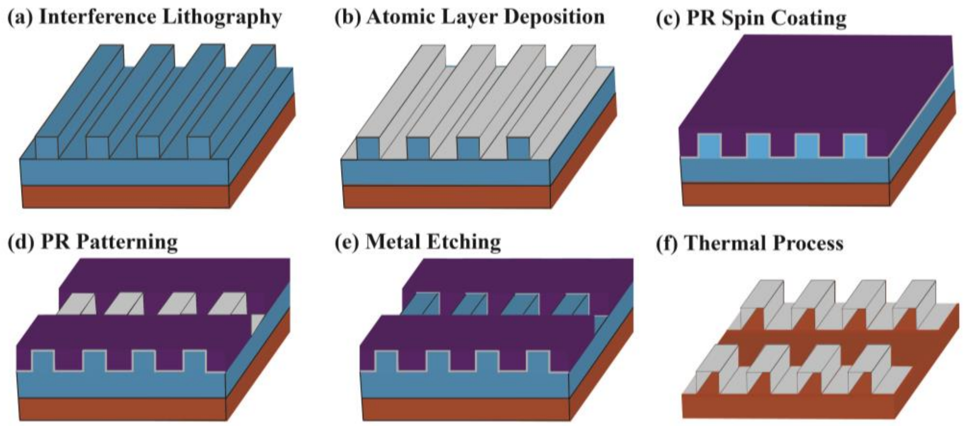

Figure 1. Fabrication process for transparent metal nano-accordion structures: (a) interference lithography of first polymer layer, (b) atomic layer deposition of metal, (c) spin coating of second polymer layer, (d) patterning of second polymer layer, (e) metal etching, and (f) thermal process to remove first polymer layer.

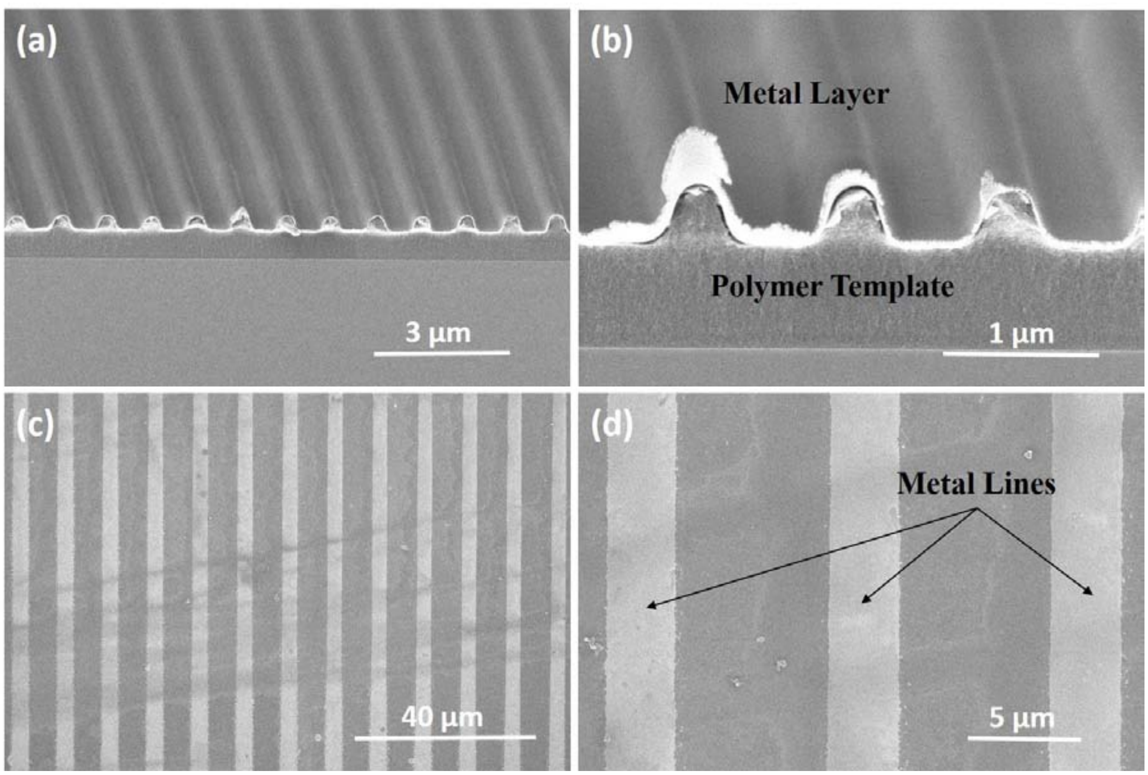

Figure 2. SEM images of (a)-(b) solid platinum film on wavy polymer template, and (c)-(d) discontinuous planar platinum film after second patterning and metal etching process

References

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