Fabrication of ZnO Nano-Spring for Transparent Stretchable Conductor

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Conductive materials that are transparent and stretchable, essential to a variety of applications such as flexible displays, wearable electronics, conformable sensors and actuators, are difficult to achieve using conventional macroscale materials. One approach to enable stretchable conductors is to use rigid materials with micro-scale geometry on elastomeric substrate [1, 2]. Other approach is focused on making use of novel materials such as cracked ITO [3], graphene [4] and carbon nanotubes [5] to fabricate stretchable transparent conductors. Al-doped ZnO has also been demonstrated to work as transparent conducting oxide [6], however they are brittle in nature and cannot be stretched.

In this work, we present an alternative approach to fabricate transparent, stretchable conductor based on Al-doped ZnO nano-springs using interference lithography and atomic layer deposition (ALD). The fabrication process is outlined in Figure 1 (a), where a one-dimensional periodic grating structure is pattern in photoresist using interference lithography on silicon substrate. During lithography, the sample is underexposed to facilitate ZnO thin film lift-off on polydimethylsiloxane (PDMS). A conformal layer of 50 nm Al-doped ZnO is coated on the sample using ALD process, resulting in a nano-spring structure. Aluminum dopants are introduced during the ALD process to improve n-type conductivity of the deposited film. The sample is then treated with UV ozone and bonded to a PDMS substrate. The PDMS substrate is then immersed in NMP (1-Methyl-2-pyrrolidon) to dissolve the photoresist template to form a freestanding thin film 1D spring structure of Al-doped ZnO on PDMS. The micrographs of the fabricated ZnO nano-spring structure before and after lift-off on PDMS are shown in Figure 1 (b)-(c).

We will study the mechanical, electrical and optical properties of the fabricated structures. For mechanical characterization, tensile load is applied on the PDMS sample in the nano-grating direction. The behavior of spring under strain is shown in Figure 2 (a)-(c), and no systematic failure of the 1D spring structure can be observed for strain up to 34%. The resistivity of the 1D spring structure is measured and it increases with applied strain, as shown in Figure 2 (d). We will study the effect of cyclic loading on resistivity, and examine the optical transmission of the proposed nano-spring structure.

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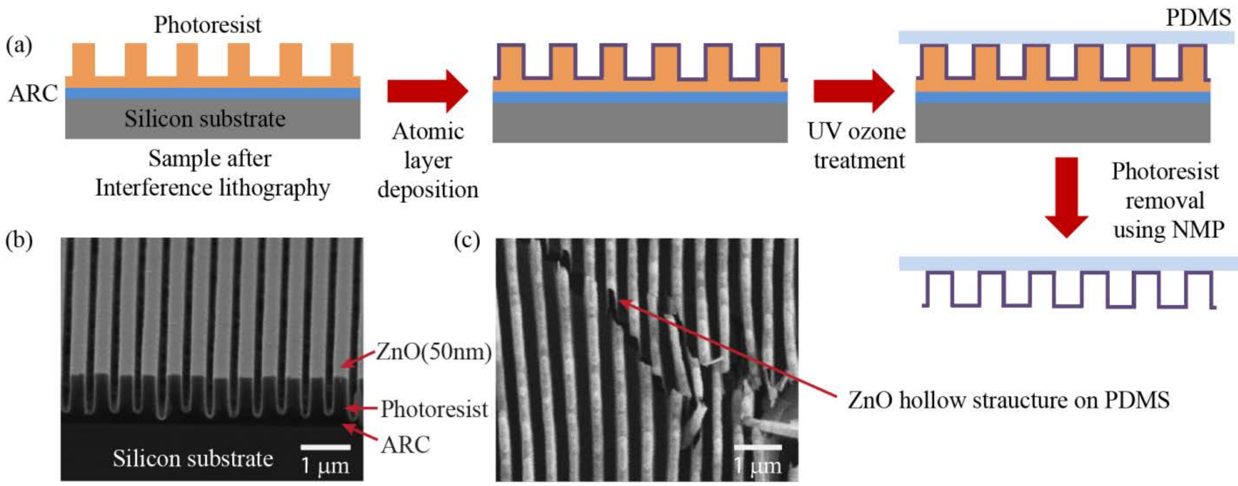

Figure 1 (a) Fabrication process for transparent, stretchable conductor. (b) Conformal Al-doped ZnO layer coated on underexposed photoresist using ALD. (c) Hollow 1D Al-doped ZnO spring structure after lift-off on PDMS substrate.

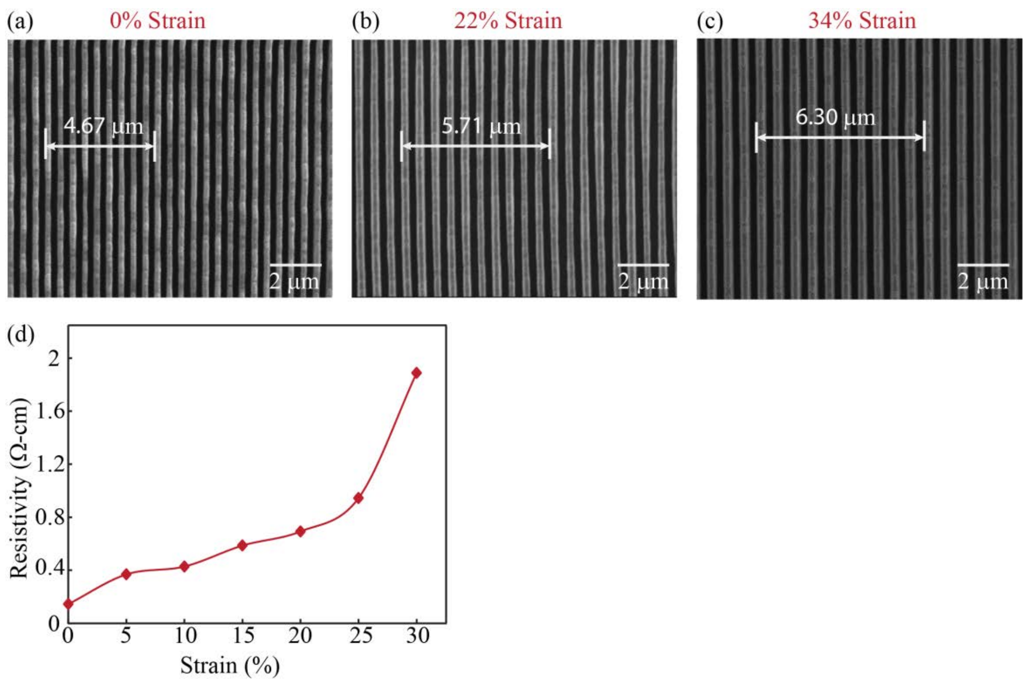

Figure 2 (a) Al-doped ZnO 1D spring on PDMS before stretching. (b) 1D spring under 22% strain. (c) 1D spring under 34% strain (d) Strain vs Resistivity for 50nm Al-doped ZnO 1D spring.

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