Fabrication of enhanced silver nanowire films via self-assembled gold nanoparticles without post-treatment

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Abstract

Transparent Silver nanowire (AgNW) electrodes have been widely explored in many applications as a promising alternative to relatively expensive indium tin oxide (ITO). For these applications, high contact resistance at the junctions of AgNWs is a main problem to be solved. In this paper, gold nanoparticles (AuNPs)-self-assembled method has been demonstrated to improve the optoelectronic performance of AgNW films. The sheet resistance of this novel AgNW film is measured as low as 13.2 Ω/sq, and the transmittance is high to 86.1 %. Self-assembled AuNPs can enrich the percolation paths between AgNWs with negligible loss of optical properties, thereby realizing the excellent optoelectronic performance of AgNW films. Moreover, no extra post-treatment procedures are needed for the fabrication process. All these advantages indicate this method has great potentials for achieving high performance transparent electrodes in emerging optoelectronic devices.

Parts of AgNW surface are attached with AuNPs after adding AuNPs solution into pristine AgNW solution. The schematic morphologies of both pristine AgNW and AuNPs-decorated AgNW solution are shown in Fig. 1a,b, respectively. The SEM image of pristine AgNW are shown in Fig. 1e,f, indicating a smooth surface. However, the AuNPs-decorated AgNWs show a rough surface in Fig. 1g,h. To verify that the AgNWs are decorated with AuNPs, Energy Dispersive X-Ray (EDX) mappings of Fig. 1g are illustrated in Figs. 1i,j. After each rod-coating process, the thin liquid (20 μm) films of ethanol, which is covering entire substrate, quickly break up into a large amount of small slices. These small slices of ethanol are more likely aggregate at nanowire junctions and nanogaps that acting as a certain kind of capillaries [1], as illustrated in Fig. 1c. Parts of the AuNPs decorated on the nanowire surface are gradually released into ethanol, while the moving range of AuNPs depends on the size of ethanol droplet. Most of the AuNPs in the ethanol droplet tend to move towards the center of droplet due to the surface tension gradient and this phenomenon is described as Marangoni effect [9]. After ethanol evaporation process completing, most of the AuNPs in the droplet are absorbed at junction and nanogaps, as illustrated in Fig. 1d and corresponding SEM image (Fig. 1k). The further evidence that AuNPs are self-assembled at the junctions and nanogaps are shown in Fig. 1l and its broader view Fig. S1. The two lines of AuNPs are parallel to each other and the blank space between them is the trace of AgNW, which is shifted to other place due to mechanical force in rod-coating process. It can be seen that most of AuNPs are aggregated in the region of two lines and few AuNPs are absorbed on the other substrate, indicating that AuNPs are self-assembled by capillary force.

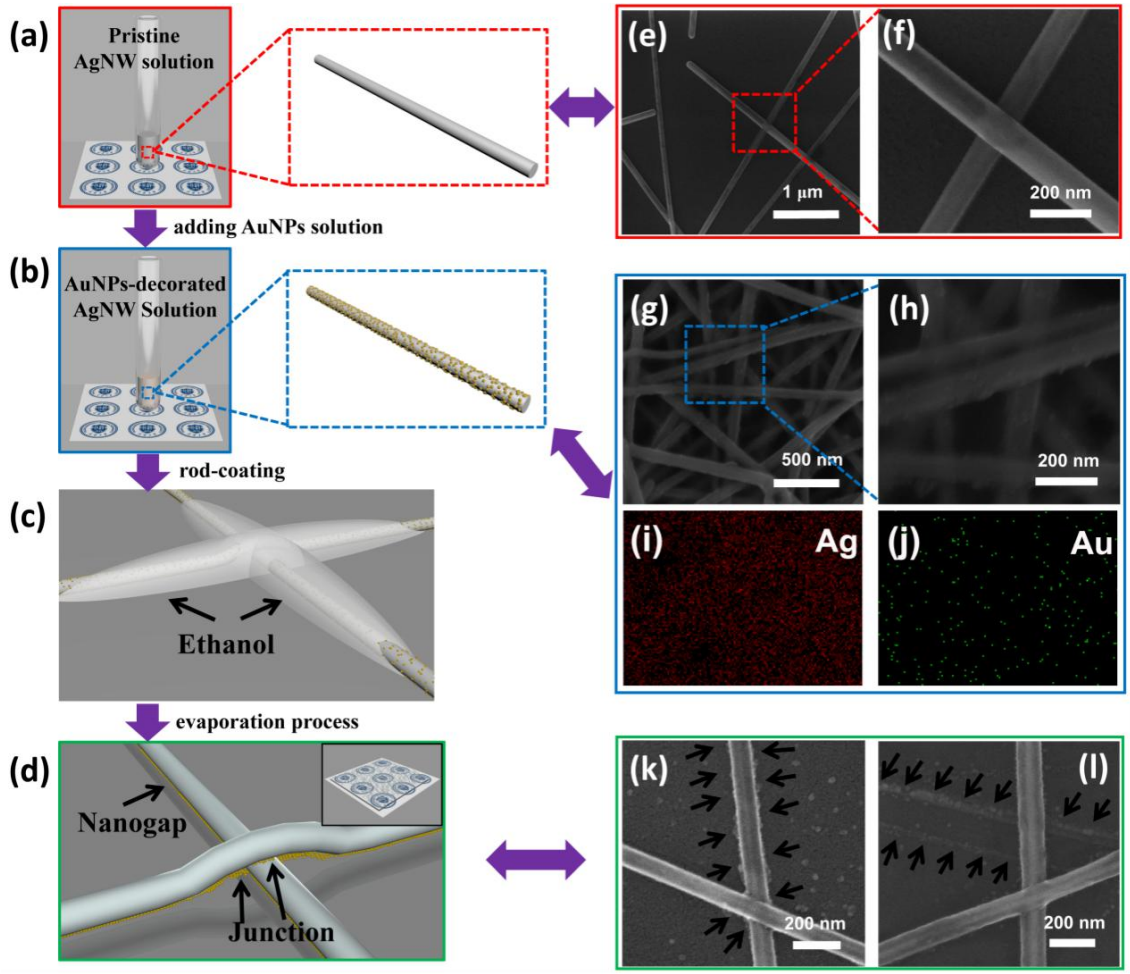

Figure 1: Schematic of fabrication procedures and corresponding SEM images of AgNW film. (a,b,c,d) Schematic of fabrication procedures, the insert of (d) is the schematic of entire AgNW film. SEM image of (e,f) pristine AgNW film, (g,h) AuNPs-decorated AgNWs. (i,j) EDX mapping of (g). (k) SEM image of self-assembled AuNPs on AgNW film and (l) the trace of self-assembled AuNPs.

References

[1] Su Q; Xue T; Zhang Y; et al.: Fabrication of enhanced silver nanowire films via self-assembled gold nanoparticles without post-treatment. Materials Letters, No. 236, pp. 218-221, 2019