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Investigation the scattering properties of silver nanowires with different densities

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ABSTRACT

In this paper, the effect of spin-coating cycles with different densities on the light scattering properties of Ag nanowires (Ag NWs) transparent conductive films was investigated. The Ag NWs were characterized by scanning electron microscopy (SEM), and UV-Vis spectrophotometry. The results indicate that haze factor and the scattering in reflection and transmission directions increased with an increase in Ag NWs density. The resulting Ag NWs show cross point dropped down from ~800 nm to ~600 nm for spin coating 4–7 cycles. The ratio of back and forward scattering for Ag NWs exhibited a cross point that shifted to lower wavelengths with the increase in density. The controlling scattering properties of Ag NWs films may open a new avenue for Ag NWs application.

1. Introduction

Transparent conducting thin films have been extensively used as electrode materials in solar cells, touch-screen panels, and light emitting diodes [1–3]. Indium Tin Oxide (ITO) films have excellent electronic properties and are prepared through high vacuum deposition processes. However, ITO films are expensive as indium is a scarce element and these films also exhibit a brittleness that is a disadvantage in several applications [4,5]. Thus, several low-cost indium-free transparent conducting materials have been recently investigated, including silver nanowire (Ag NWs) films [6–11], carbon nanotubes [12–14], graphene [15–17], and conducting polymers [18–20].

Among the above-mentioned materials, Ag NWs based films are turning out to be promising replacements for ITO films and they have attracted wide attention owing to their low sheet resistance, high transmittance and high flexibility. However, scattering properties of Ag NWs dependent on the fabrication method, density, length and diameter of the nanowires and have not been quantitatively studied. In our previous report, optical properties of Ag NWs of different length and mesh size were studied and we found that the mesh size of nanowires can tailor the scattering ratio [21]. Another useful aspect is to control the scattering properties by changing the density of Ag NWs on substrate, which has also not been studied.

In this work, transmittance, scattering and electrical properties of Ag NW films relying on different nanowires densities were investigated. Ag NW films fabricated with different densities were controlled by the spin-coating cycles. Furthermore, back and forward scattering properties had an obvious decrease from 960 nm (1-layer NW) to 610 nm (7-layers NW) with increased Ag NWs films from 1 to 7 cycles. The observation of steerable scattering properties of Ag NW films implies a potentials avenue for controlling the Ag NWs films optical properties and application in Solar cells and OLED device.

2. Experimental methods

Silver nanowires were synthesized by reducing silver nitrate with ethylene glycol (EG) in the presence of $AgNO_3$, $FeCl_3{\cdot}9H_2O$ and poly(N-vinylpyrrolidone) (PVP) [19,20]. A 30 ml EG solution with PVP was vigorously stirred until dissolved, followed by the addition of $AgNO_3$ and $FeCl_3{\cdot}9H_2O$. The reaction was carried out at 150 °C for 1.5 h until silver nanowires were obtained. Silver nanowires were purified by washing with ethanol for two cycles. The prepared Ag NWs were dispersed in ethanol (0.25 g $AgNO_3$ precursor dispersed in 80 ml ethanol) and spin-coated at 300 rpm for 5 s on top of glass substrates. The Ag NWs film prepared by spin-coating was subject to 1–7 cycles to control silver nanowires density on the films. Finally, Ag NW film samples were dried at 150 °C for 10 min.

The morphology of the films was characterized using scanning electron microscopy (SEM) (SUPRA 550 VP). Electrical measurement of the sheet resistance (Rs) of silver nanowires films were carried out

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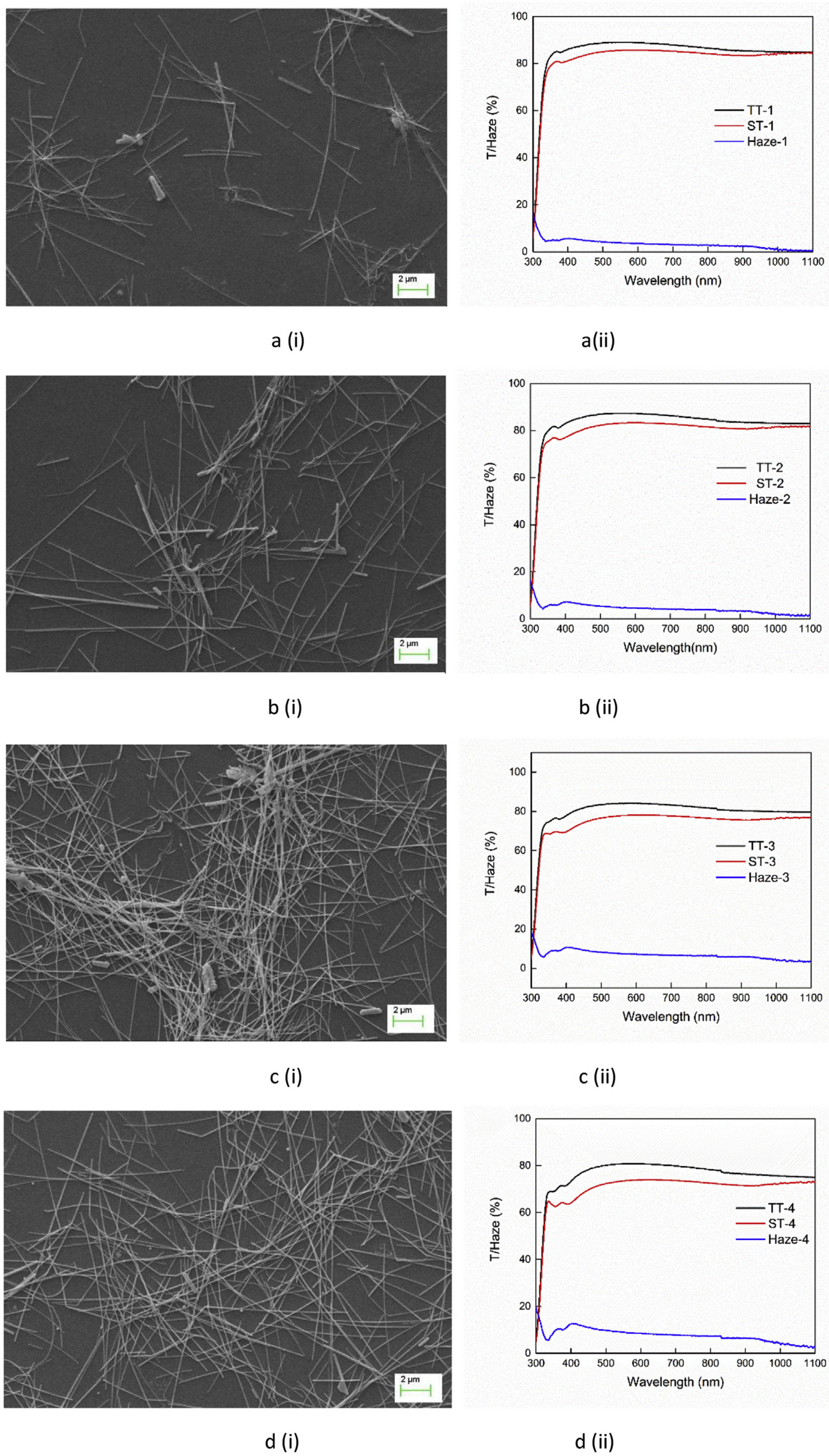

Fig. 1. SEM images of Ag NWs with 1–7 cycles (a–g) (i), ST, TT and haze (a–g) (ii) of Ag NWs with 1–7 cycles.