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Improvement of conductivity of Ag nanowires-networked film using 1,8-diazabicyclo[5,4,0]undec-7-ene (DBU)

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ABSTRACT

This study proposes a chemical treatment using 1,8-diazabicyclo[5,4,0]undec-7-ene (DBU), a well-known catalyst and non-nucleophilic base, to improve the conductivity of Ag nanowires (NWs)-networked transparent conductive films by removing the surface oxide of the wires. Upon DBU treatment, the sheet resistance of the films drops immediately and significantly, confirming its effectiveness for surface oxide reduction. Scanning and transmission electron microscopy analyses disclose that the wires do not show any sign of damage even after 1 h-long exposure, an important benefit over other chemicals such as ammonia. We apply the method to excessively-oxidized Ag NWs via O_2 plasma and Cu NWs to further investigate the effectiveness of the method, confirming that the DBU treatment is an effective route to remove the surface oxide.

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1. Introduction

Transparent conductive electrodes (TCE) are an indispensable part used for devices which require transparent and electrically conductive panels such as touch panels, organic light-emitting diodes (OLED), organic photovoltaics (OPV) and thin-film heaters [1–6]. Indium tin oxide (ITO) is the conventional TCE material, which has good optoelectrical performance (high conductivity and high transmittance); however, the scarcity of indium and its poor flexibility have driven an urgent search for new TCE materials. Available candidates include metal mesh, conductive polymers, graphene, carbon nanotubes (CNT), and metal nanowires [7,8]. Among them, silver nanowires (Ag NWs) are promising owing to such advantages as good optoelectrical performance, high flexibility, and solution processability [9–13].

Research endeavor for last several years has brought this material close to commercialization; however, the extent of its employment largely depends on further improvement in performance, particularly, conductivity and transmittance. Several novel methods have been proposed for the improvement, including pressing with heating [14], light sintering [15], sol-gel treatment [16], conducting polymer treatment [17], and chemical treatment [18]. Among them, chemical treatment is an easy method by applying chemical solution on Ag NW networked films to remove the native oxide and thus improve the conductivity. Previously, we employed ammonia solution, disclosing that the method was effective in removing surface oxide. Nevertheless, a serious drawback also reported in the paper is that a prolonged exposure to the solution could damage the wires severely and degrade the conductivity.

In the present study, noting that aggressive chemicals are likely to damage Ag NWs, we employed 1,8-diazabicyclo[5,4,0]undec-7-ene (DBU), a well-known catalyst and non-nucleophilic base, to remove the surface oxide of Ag NWs without harming the wires and thus enhance the conductivity. The study confirms that DBU is quite effective in removing the oxide with little damage on the wires. We examined the films treated with DBU by measuring the sheet resistance and optical transmittance, and investigated the morphology of Ag NWs using scanning and transmission electron microscopy (SEM and TEM).

2. Experimental

We fabricated Ag NWs TCE films by coating Ag NWs solutions (Nanopixis, average diameter and length: ~35 nm and ~25 μm, respectively) of various solid contents (0.2, 0.5, and 0.8%) on the PET substrate with a Meyer rod, and drying at room temperature. We also used copper nanowires (Cu NWs)-networked films to examine the performance of the DBU treatment. We fabricated the Cu wire films by dropping Cu NWs solution (Novarials, average

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diameter and length: ~100 nm and 50–200 μm, respectively) on the glass substrate and drying at 150 °C. For the DBU treatment, we immersed the fabricated films into a DBU solution for a various period of time (30 s–1 h), followed by cleansing with dichloromethane, acetone, and water in succession. For comparison, some samples received an ammonia treatment. We immersed the sam-

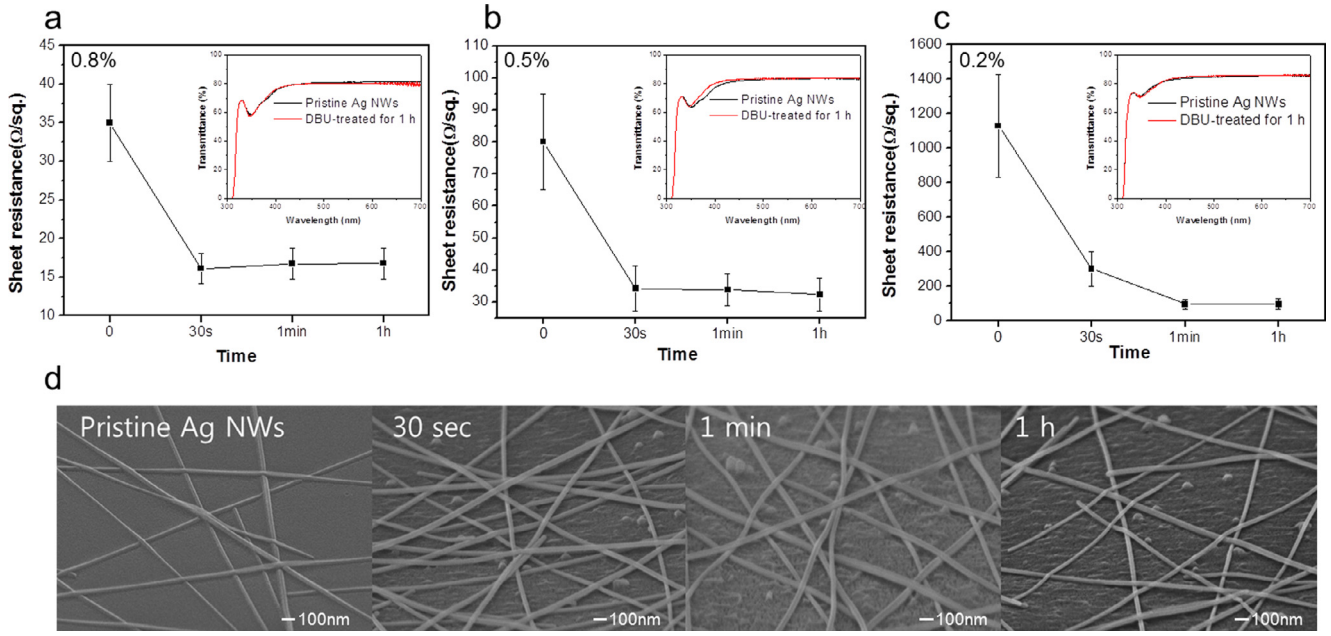

Fig. 1. Sheet resistance of Ag NW solutions with solid contents of (a) 0.8, (b) 0.5, and (c) 0.2% as a function of the treatment time. The insets show the UV–Vis transmittance spectra of pristine Ag NWs and DBU treated Ag NWs for 1 h. (d) SEM images of DBU treated Ag NWs for various treatment times.

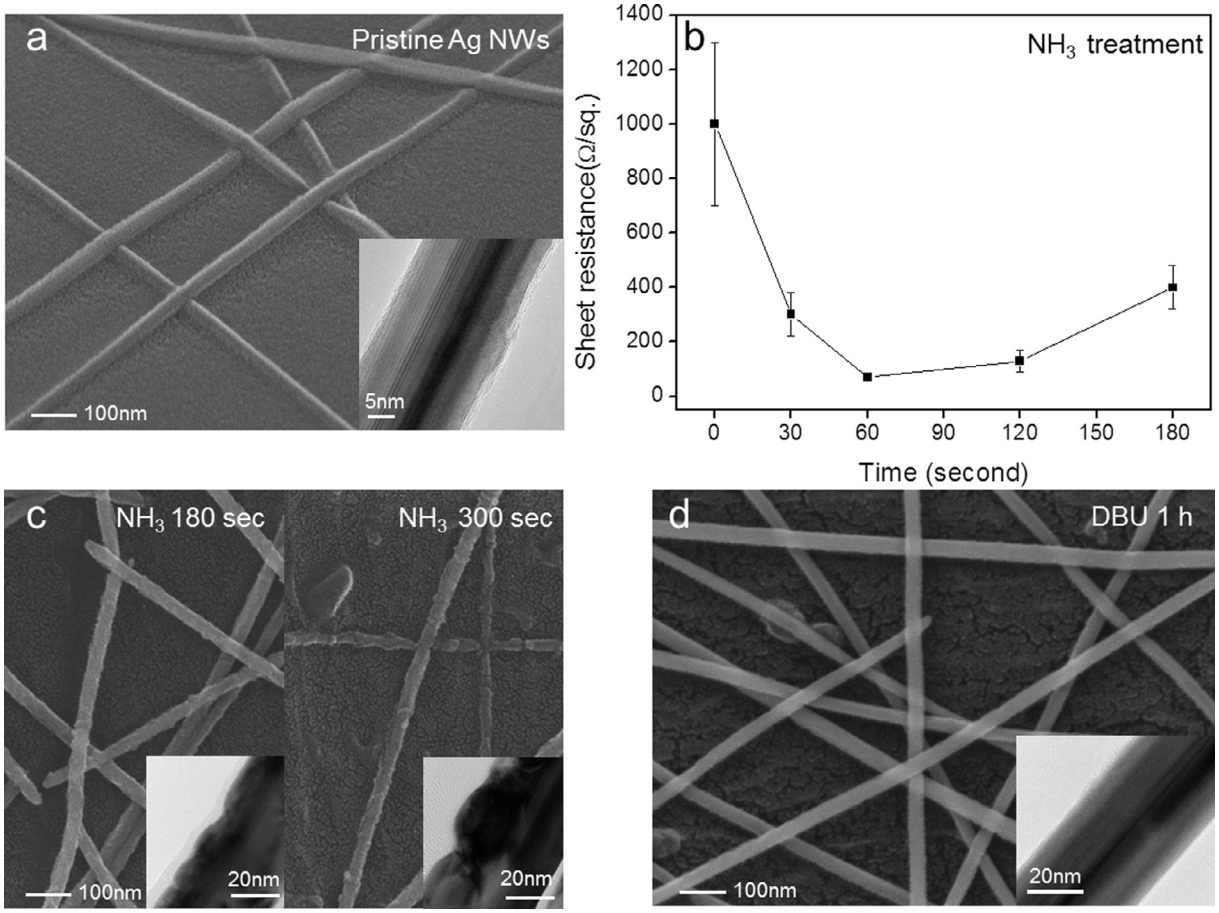

Fig. 2. (a) SEM image of pristine Ag NWs, (b) sheet resistance of ammonia-treated Ag NWs as a function of the treatment time, (c) SEM images of ammonia-treated Ag NWs, and (d) SEM image of DBU treated Ag NWs. The insets show TEM images taken around the surface of Ag NWs.

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