Trial of the Ga doping to the Sprayed ZnO Nano-Particle Layers by mixing and annealing with Ga_2O_3

Islam Md Maruful[1]*, Atsuya Tabuchi[1], Toshiyuki Yoshida[1] and Yasuhisa Fujita[1]
[1]Interdisciplinary Graduate School of Science and Engineering, Shimane University
*s179005@matsu.shimane-u.ac.jp

Sprayed semiconducting nanoparticle (NP) layer is one of attracting techniques for low-cost and simple processes, widening the LSI application field, and so on. Zinc Oxide (ZnO) is one of suitable materials for it [1], since its surfaces will not be covered with insulator by exposing to the air and/or to the water, which provide easiness for handling. Previously, nitrogen-doped ZnO-NPs were successfully synthesized and p-n junction type near-UV-LEDs [2] and n- and p-channel thin-film-transistor (TFT) operations [3] had been achieved in our laboratory. However, the resistivity of sprayed NP-layers is extremely high; the order of GΩ and more, drastic improvement of current conduction is required. Several groups have recently suggested Ga-doping as one of the most effective method [4]. In this paper, the trials to dope Ga atoms in the n-ZnO NP-layers to reduce the resistivity for the practical use are presented.

ZnO-NPs were synthesized by arc-discharge-mediated gas evaporation using dry air with a chamber pressure of 610 Torr and an arc current of 20 A. The dispersions with median size of 240 nm were prepared by mixing and dispersing 0.2 g of ZnO-NPs and 0.06 g of Ga_2O_3-NPs with 10 g of water using an ultrasonic homogenizer (150 W, 3 min), and by centrifuging (3000 G, 1 min). In spraying, a 30 ml of dispersion fluid was sprayed to heated quartz substrate with 5 s intervals for 15 min, as shown in **Fig. 1**. The setting value of the hot plate temperatures was 500 °C. After spraying, annealing process was carried out in the air with the temperature of 800 °C for 60 min.

SEM image for the surface of sprayed ZnO-NP layer (only ZnO) are shown in **Fig 2**, confirming the formation of NP-layer on the quartz substrate with less aggregation. The resistivity variations are summarized in **Fig. 3**. The resistivity of only ZnO-NP layers showed extremely high value in the order of GΩ. By mixing and annealing with Ga_2O_3 NPs, the resistivity drastically reduced to the order of 10kΩ. As a reference, in the only Ga_2O_3-NP layers, resistivity of sub-GΩ was observed. From these results, it is expected that the Ga atoms doped into the ZnO-NPs and acted as n-type dopant.

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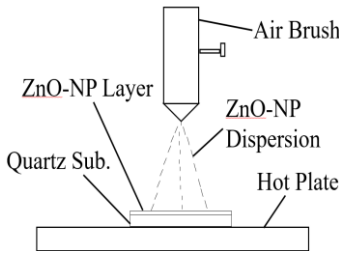

Fig. 1 spray method for NP-layer formation process.

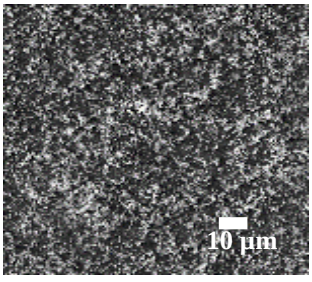

Fig. 2 SEM image for n-type ZnO NPs layer.

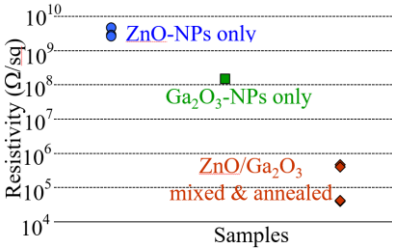

Fig. 3 variations of resistivity obtained from two probe measurement