Carbon-nanotube dispersed Ga_2O_3 films for UV transparent electrodes fabricated by molecular precursor method

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Light extraction is a crucial issue for UV LEDs. For realization of their high efficiencies, absorption in electrode should be reduced. Transparent conductive oxide (TCO) is one of the candidates. In this case, very wide bandgap (VWBG) oxides are required for its realization. Generally, VWBG oxides are known as "insulator." Thus, these materials selection is limited. On the other hand, carbon nanotube (CNT) has a good electric conductivity and its diameter is several nanometers. This means that a transparency in CNTs depend on Rayleigh scattering and a high light transparency will be expected for CNT dispersed VWBG oxides. In this paper, the fabrication of CNT dispersed Ga_2O_3 films by molecular precursor method [1], which is one of the chemical solution methods, is reported. Their transparent properties and conductive properties are also discussed.

The Ga_2O_3 precursor solution was prepared as follows [1]. The 3.65 g (12.5 mmol) of ethylenediamine-N, N, N', N'-tetraacetic acid (EDTA) and 5.00 g (12.5 mmol) of $Ga(NO_3)_3 \cdot nH_2O$ (n = 7–9) [calculated as $Ga(NO_3)_3 \cdot 8H_2O$] were added to 30 mL of pure water at 80°C, and the solution was stirred for 1 hour, and then cooled to room temperature (RT). The white powder (abbreviated as Ga-edta complex) precipitated from the solution was collected on a paper filter under reduced pressure and air-dried. The precursor solution was prepared by a reaction of 1.34 g (3.55 mmol) of Ga-edta complex with 0.51 g (3.91 mmol) of dibutylamine in 10 g of ethanol. The solution was refluxed for 0.5 h, and then cooled to RT. The Ga concentration for the precursor solution was adjusted to 0.3 mmol g^{-1}. CNT solution of ethanol solvent (CNT; 0.0583 mmol g^{-1}). The solutions were then mixed with the CNT solution. The 100 μL of solution was coated on quartz glass substrate by spin-coating method, and the films were dried in air at RT for 10 min and were then thermally treated using a tubular furnace in an Ar gas flow of 1.0 L min^{-1} at 600°C for 30 min. Thickness of the resultant CNT doped Ga_2O_3 films were about 100 nm.

The transparencies of the films are over 80% in UV spectral regions longer than a wavelength of 300 nm. The typical resistivity of a CNT-dispersed Ga_2O_3 film is 2 x 10^{-2} Ω·cm. The results indicate that the CNT-dispersed VWBG oxides have a potential for the application of UV transparent oxides.

[1] H. Nagai and M. Sato, in *Heat Treatment— Conventional and Novel Applications, Heat Treatment in Molecular Precursor Method for Fabricating Metal Oxide Thin Films*, ed. Dr. F. Czerwinski (InTech, Rijeka, 2012).

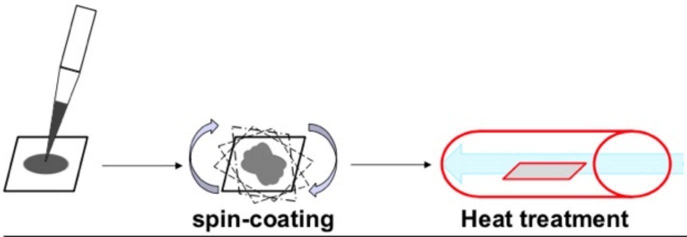

Fig. 1. Molecular precursor method (MPM).

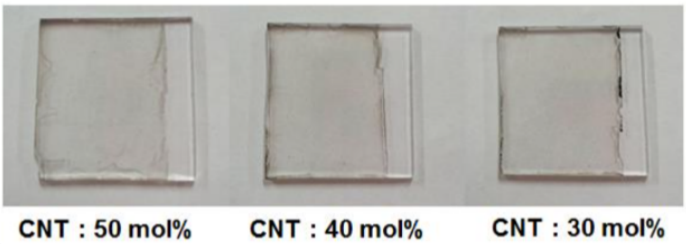

Fig. 2. CNT doped Ga_2O_3 thin films

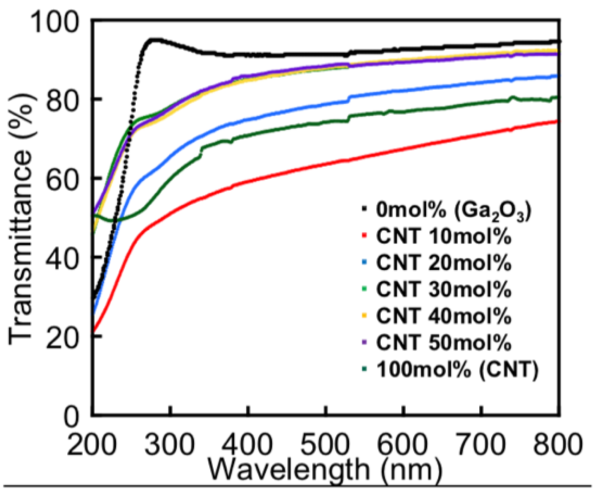

Fig. 3. Transmittance spectra of CNT doped Ga_2O_3 thin films at RT.