Transparent Conductors and Printable Electronics Focus Topic
Room: Hall B - Session TC-TuP

Transparent Conductors and Printable Electronics Poster Session

TC-TuP2 A Universal Method of Producing Transparent Electrodes Using Wide-Bandgap Materials: Direct Ohmic Contact to *p*-AlGaN, *H.D. Kim, S.W. Kim,* ***K.H. Kim****, S.J. Kim,* Korea University, Republic of Korea, *M.D. Kim,* Chungnam National University, Republic of Korea, *T.G. Kim*, Korea University, Republic of Korea

Indium-doped tin oxide (ITO) is the most popular transparent conductive electrodes (TCEs) used in flat screen displays and lighting technologies for decades. However, due to indium's limited supply and increasing cost, there has been a big push for many years to find alternatives or replacements of ITO (i.e., indium-free TCEs); many scientist and engineers have been working with zinc oxide and other metal-oxide materials but this area still remains quite challenging. Here we worked towards something different, developing new ways to give a current path between the TCEs using ordinary wide-bandgap materials and p-(Al)GaN layers via conducting filaments (CFs), which can be formed using electrical breakdown (or forming) processes, for ultraviolet light-emitting diodes (UV LEDs).

UV LED is one of the eco-friendly optical sources for different wavelengths in the UV A to C regimes (200–400 nm), useful for various applications including sterilization and high color rendering index lighting. However, currently, the external quantum efficiency of the UV LED, particularly in UV-C bands, is extremely low (3-11%). One of the primary reasons for this low efficiency is a large absorption in narrow-bandgap contact layers for ohmic contact. To fundamentally solve this problem, we should obtain a direct ohmic contact to the p-AlGaN layers using UV-transparent conductive electrodes, as depicted in the right figure below. However, with conventional ohmic methods, it is almost impossible to make such contact and therefore no report has been made so far. In this article, we present a universal method of producing transparent electrodes with high conductivity and high optical transmittance in the UV A to C regimes (as well as visible-to-infrared regimes) using electrical breakdown to form CFs providing a current path between the TCEs and the semiconductor, which leads to a large reduction in their contact resistance. As a result, we found the contact resistance between the TCEs and the p-GaN layers (or p-AlGaN layers) to be on the order of 10^{-5} $\Omega\cdot cm^2$ (or 10^{-3} $\Omega\cdot cm^2$) while optical transmittance was maintained at up to 95% for the AlN-based TCEs at 250 nm.

TC-TuP4 Bending Properties of In and Ga Doped Zinc Oxide Films Deposited on Plastic Substrates by Magnetron Sputtering, ***K. Nagamoto****, K. Kondo,* LINTEC Corporation, Japan, *K. Ishii*, Utsunomiya University, Japan

Transparent conductive oxides (TCO) on polymer substrates are prospected as a key material for next-generation devices such as flexible displays and photovoltaics. The advantages of polymer substrates include light-weight, low cost, a multiplicity of materials with tailored properties, shock absorption and highly flexibility. However, polymer substrates also have disadvantages such as low heat resistance and large thermal expansion coefficient compared with glass substrates. A main challenge for an efficient TCO on polymer substrate is not only to choose conductive oxide materials having capability of growing at low substrate temperature, but also to develop a deposition processes in order to obtain good electrical characteristics. Thus, in this study structural, electrical and optical properties of highly transparent conductive polycrystalline Ga-doped ZnO (GZO) and In, Ga-doped ZnO (IGZO) films deposited on plastic substrates at below 100 °C by magnetron sputtering were investigated. The dependences of crystal structure, electrical and optical properties of the GZO and IGZO films on plastic substrates have been systematically studied. The surfaces of plastic substrates and optically properties were controlled by coating buffer layers (CBLs).

The aim of this study is to investigate the effect of surface roughness of plastic substrates on characteristics of GZO and IGZO films of less than 150 nm thickness, such as structural and electrical characteristics. Then optically properties of GZO and IGZO films, for example transmittance, reflectance, yellow index, haze, a* and b* value, were depend on GZO and IGZO films thickness and CBLs. The GZO and IGZO films in the thicknesses range from 20 to 120 nm were prepared by magnetron sputtering. The resistivity and average transmittance in the visible wavelength region of GZO films of 120 nm thickness on plastic substrates were 1.0 x 10^{-3} ohm·cm and more than 85 %, respectively.

TC-TuP5 Influence of Rapid Thermal Annealing Treatment on Various Properties of Texture-Etched Al- or Ga-Doped ZnO Thin Films Deposited by Magnetron Sputtering, *T. Minami, J. Nomoto,* ***T. Miyata****, T. Yamanaka*, Kanazawa Institute of Technology, Japan

This paper describes an investigation of the influence of a rapid thermal annealing (RTA) treatment on various properties of transparent conducting Al- or Ga-doped ZnO (AZO or GZO) thin films that was conducted in an effort to develop thin-film transparent electrodes suitable for thin-film solar cell applications. These doped ZnO thin films were deposited by an r.f. power superimposed d.c. magnetron sputtering deposition using AZO or GZO target : prepared with Al_2O_3 contents of 0.5-2 wt.% or Ga_2O_3 contents of 0.5-5.7 wt.%, respectively. The optical and electrical properties and texture-etched surface structures as well as the stability of electrical properties after use for long terms in moist environment in these thin films were found to be considerably influenced after heat treatment with RTA at 500°C for 5 min in air. In particular, the obtained electrical properties in these thin films were considerably dependent on the RTA treatment conditions as well as the kind and content of impurity doped into the films. For example, the heat treatment with RTA always decreased the carrier concentration in both the AZO and GZO films, irrespective of the doped impurity content, whereas the resulting carrier concentration in as-deposited AZO and GZO thin films increased as the impurity content doped into the films was increased. In addition, the Hall mobilities in both the AZO and GZO films doped with impurity contents up to approximately 1.25 at.% always decreased after heat treatment with RTA, which is in contrast to the slight increase of the Hall mobilities exhibited in films doped with an impurity content above approximately 1.5 at.%. The etch pit size developed in AZO and GZO films that were surface textured by wet-chemical etching in 0.2 mol./l HCl at 25°C tended to increase as the content of impurity doped in the films was increased up to approximately 2.5 at.%; however, the etch pit size obtained in GZO films decreased as this content was increased further. It should be noted that the heat treatment with RTA resulted in considerably enhanced etch pit size in these films, irrespective of the kind and content of doped impurity. As a result, in the films that were wet-chemically etched after being heat treated with RTA, the transmittance and the haze value in the near infrared range of 800-1200nm both increased as the size of the etch pits increased. It should be noted that the improvement in the transmittance and the haze value obtained in texture-etched AZO and GZO thin films heat treated with RTA is sufficient to enable the use of the surface textured these films described above for thin-film transparent electrode applications in thin-film solar cells.

Authors Index

Bold page numbers indicate the presenter