Electron transport behavior in ZnO-based TCO films embedded with Ag nanoparticles

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In regime of highly-doped TCOs, their carrier (electron) concentration strongly depends on the shallow donor states created by the amount of extrinsic doping impurities. However, those impurities create equal amount of positively-charged point defects in the TCO lattice that tend to scatter electrons, resulting in the degradation of carrier mobility. Thus, this conundrum between carrier concentration and carrier mobility limits the development of highly-doped transparent conducting oxides (TCOs) films. In this study, we fabricated Ag nanoparticles (NPs) via a surfactant-free solution method, and pre-mix with Al-doped ZnO sol-gel (the Al-doping is approx. 0.1 at. %). We report that electrons can be donated from Ag nanoparticles (NPs) into this ZnO-based TCO matrix without deteriorating the carrier mobility significantly. An increasing Ag content (0.7 vol. %) results in rising electron concentration up to 4×1020 cm^{-3} while the mobility remains 10 to 20 cm^2/V.s, which is rarely seen in traditional TCO films prepared by solution methods that contain such high carrier concentration according to several electrical properties of TCO films reported historically. Furthermore, the Hall-effect measurements with function of temperature suggests us that the energetic barrier for this electron donation from Ag NPs at room temperature is synonymous with the Schottky barrier at the metal-oxide interface. Those evidence suggest us that electrons donated from Ag NPs can overcome this energetic barrier at the metal-oxide interface and further transport in the polycrystalline ZnO-based TCO matrix with relatively less positively-charged defects. Therefore, the carrier mobility remains as the same as that of oxide matrix and are eventually collected by our conductivity measurement tool. It is noted that the optical transmittance of such composite films in the visible wavelengths is above 85 % as the electrical resistivity is slightly less than 10^{-3} Ω.cm.

Speaker Biography

Dr. Po-Shun Huang studied metal oxide thin film depositions and low-dimensional nanomaterials via wet chemistry method during his PhD work with Prof. Jung-kun Lee in the Department of Mechanical Engineering and Materials Science at the University of Pittsburgh. Dr. Huang had in-depth knowledge and hangs-on experience in multi-functional oxides, nano-composites for the application of optoelectronics, and has develop several thin-film characterization skills. After PhD study, He worked as a R&D engineer in a startup company affiliated with Lawrence Berkeley National Laboratory at Berkeley, CA, mainly focusing on the polymeric conformal coating via CVD method on the AFM cantilevers for the application of liquid AFM. His interest includes low-dimensional nanomaterials for energy-harvesting devices, photovoltaic materials, and solution-based methods for electrically active thin-films.

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