Advanced Applications of Wide Bandgap Semiconductors with Hybrid Structures

Seohan Kima,b, \*, Pungkeun Songa, J. Monterob, L. Österlundb

aDepartment of materials science and engineering, Pusan National University

b\*Departmentof materials science and engineering, The Ångström Laboratory, Uppsala university

(E-mail:seohan.kim@angstrom.uu.se),

**Abstract:**

Most transparent conducting materials are based on Sn:In2O3 (ITO). However, when deposited on flexible substrate, a single ITO coating present mechanical brittleness and poor electrical stability. A solution is enhancing amorphous structure and give them mechanical stability or using an oxide-metal-oxide (OMO) structure, typically ITO/Ag/ITO, instead of a single ITO layer. The micro quantity of hydrogen doping on ITO can stabilize amorphous structure without any deterioration in optical and electrical properties. The positive effect of hydrogen incorporated ITO has been proved with various applications which needs transparency and electrical conductivity mean time. At early stage, the hydrogen incorporated with single ITO and IZO layer, so we found that the hydrogen can suppress sub-gap level effect near 3.1 eV, and this dramatically can improve mechanical stability of amorphous thin film. Therefore, hydrogen incorporated ITO have attempted to various application, such as ITO/metal/ITO hybrid structure and surface amorphized ITO, and as a result, all of them shows improved device performances. Furthermore, we have tried to enhance thermoelectric (TE) performance using TCO thin film. The TCO as TE materials are not much interested due to thermal and electrical transport properties are deeply intertwined. Here, we demonstrate approach allows independent optimization of optical transparency, electrical conductivity and thermal conductivity. An embedded nanopattern structure is filled with ITO and sandwiched between two ITO layers. The resulting triple-layered structure exhibits reduced thermal conductivity and excellent electrical conductivity. This is made possible by electron channels in the embedded Ito nanopattern that electrically connect top and bottom layers, while at the same time limiting phonon-mediated heat conduction. The filling fraction and thickness of the nanopattern are adjusted to improve optical transmission, achieving transparency higher than bare ITO film. The results is a transparent TCO triple layer film with simultaneous high TCO and TE figure of merits.

Figure. Continuous single layer of APC:O thin film with thickness of 5 nm

And the other way to overcome limitation of single ITO is hybrid structure using an OMO structure. The ductility of the metal layer (e.g. Ag) provides mechanical stability. Ideally, the metal layer has to be as thin as possible, ensuring high transparency, but at the same time retain a continuous structure, ensuring good electrical properties. This has been proven to be difficult when using Ag, which needs a critical thickness 10 nm to guarantee the formation of a continuous single layer film. In this talk, we demonstrate that OMO coatings exhibiting excellent optical and electrical properties can be achieved by using an AgPdCu alloy of variable oxygen content (APC:O), instead of Ag, in an ITO/APC:O/ITO configuration entirely fabricated by magnetron sputtering. The APC:O layer results in a smooth continuous film comprising interconnected grains even for thickness as low as 5 nm, whereas Ag films of equivalent thickness exhibit a particulate structure consisting of isolated agglomerates. As a result, APC:O-based OMO structures exhibit superior optical and electrical properties than their Ag-based OMO counterparts. Additionally, ITO/APC:O/ITO coatings show excellent stability in high humidity/temperature environments.