DISSERTATION SUMMARY

Structural and Electronic Properties of Solution-Processed Amorphous Indium-Silicon-Oxide for High Performance Thin Film Transistors

Endah Kinarya Palupi
Department of Nanotechnology for Sustainable Energy, Kwansei Gakuin University.

Amorphous oxide semiconductors (AOSs) gain high attention as the next-generation materials for TFT technology because of their transparent optical properties, robust electron transport properties to structure disorders, and robust structure properties. Recently doped indium oxides, such as In-Ga-Zn-O was proposed. However, most AOSs have a drawback due to the formation of oxygen vacancies. To eliminate oxygen vacancy, silicon (Si) was introduced as a dopant because of its high bond dissociation energy with oxygen (799 kJ/mol). From the viewpoint of fabrication methods, solution processing is a potential candidate as a cost-effective and environmentally-friendly method. In this study, structural and electronic properties of solution-processed In-Si-O (ISO) were investigated.

Stabilization of the amorphous phase by Si doping was investigated for ISO thin films with a wide variation of Si concentrations from 0 to 20 at.%. From XRD analysis, the crystallization temperature was determined, and the phase diagram was constructed. Crystallization temperature increased steeply with an increase of Si concentration for Si concentration less than 8.0 at.% and tended to saturate for Si concentration of more than 8.0 at.%. Correspondingly, the peak intensity of the crystalline phase decreased with an increase of Si concentration of more than 8.0 at.%. From the results, it is suggested that the SiO_4 tetrahedron deforms surrounding 12 InO_6 hexahedrons, and this deformed $SiO_4@(InO_6)_{12}$ forms a network and fills the whole region at around Si concentration of 8.0 at.%. Regarding the characteristics of the crystalline phase, the lattice parameter and the crystallite size were hardly affected by Si doping, suggesting that the crystalline phase mainly consists of an In-O network with a Bixbyite structure, and Si-O forms a non-crystalline network.

For the improvements of the device performance of ISO TFTs, the effects of many kinds of treatments were investigated. It was suggested that oxygen vacancy was easily produced even under low vacuum conditions at room temperature. The time constant of the elimination of oxygen vacancy in the air/oxygen atmosphere was about 1.6 days and did not strongly depend on the atmosphere (air/oxygen). In addition, from the results of the cycle response of temporal evolution and the absolute value of mobility, it was suggested that only oxygen weakly bonded to metal atoms can be removed again under vacuum, and the number of such oxygen ions decreases with storage time. Therefore, keeping ISO thin films in air for a long time can be a solution to eliminate oxygen vacancies.

This study clarifies that the presence of Si strongly contributes to the stabilization of amorphous phase ISO thin films and storage time on ISO TFT devices strongly influences the elimination of oxygen vacancy. The present series of findings give valuable information for further improvement of oxide-semiconductor-based TFTs.