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Microstructural Analysis of IGZO Thin Films and Its Thin-Film Transistor Application

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論 文 名　: Microstructural Analysis of IGZO Thin Films and Its Thin-Film Transistor Application
Title　　　（IGZO 薄膜の微細構造解析とその薄膜トランジスタへの応用）

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論 文 内 容 の 要 旨

Thesis Summary

Indium-Gallium-Zinc Oxide (IGZO) thin films have received great attention in Display technology because of their good electrical, electronic and optical properties. Their electronic device applications are being enhanced owing to their remarkable performance, e.g., high electron carrier mobility, better uniformity over a large area, and potential optical transparency. Moreover, IGZO can be a promising thermoelectric candidate for its good thermoelectric performance to other oxide candidates. The thermal conductivity of IGZO indicates its ability for heat conduction, which is subjected to various factors, and can be subdivided into electro- and phono-thermal conductivities revealed by phonon–phonon and electron–electron scattering. Most studies on IGZO thin films focused on electrical, electronic, and optical properties . The thermal properties of IGZO thin films are also of vital importance for heat dissipation and thermal management of devices. Although the atomic-scale structure of IGZO films has been lacked to reveal whether these are amorphous or crystalline, few fundamental studies have been performed on the relationship between the thermal conductivity and microstructure of IGZO thin films.

From the above perspective, this thesis emphases towards the development of the relationship between the temperature dependence of thermal conductivity of the Indium–Gallium–Zinc–Oxide (IGZO) thin films and microstructure analysis. The research strongly stress on two factors, firstly, Scanning transmission electron microscopy (STEM) observations were also carried out to characterize the nanometre-scale microstructure of the IGZO thin film. Secondly, the temperature dependence thermal conductivity of the Indium–Gallium–Zinc–Oxide (IGZO) thin films was investigated with the differential three-omega method (3ω) for the clear demonstration of nano-crystallinity. Electron microscopy observations revealed the presence of nanocrystals embedded in the amorphous matrix of the IGZO films. The typical size of the nanocrystals was approximately 2 to 5 nm with the lattice

distance of about 0.24 nm to 0.26 nm. These experimental results indicate that the nanocrystalline micro-structure controls the heat conduction in the IGZO films. To perform the differential three-omega (3ω) method experiment, the IGZO thin films were deposited on an alumina (α-Al_2O_3) substrate by direct current (DC) magnetron sputtering at different oxygen partial pressures ([PO_2] = 0 %, 10 %, and 65 %). Their thermal conductivities at room temperature were measured to be 1.65, 1.76, and 2.58 $Wm^{-1}K^{-1}$, respectively. The thermal conductivities decreased with increase in the ambient measurement temperature. This thermal property is similar to that of crystalline materials.

To analyse the IGZO thin-film transistor application, the back-channel etched Indium–Gallium–Zinc–Oxide (IGZO) thin-film transistors (TFTs) with copper (Cu) source and drain (S/D) which are patterned by a selective etchant was fabricated and investigated the electrical properties. The main challenge of this work strongly stress on two factors, firstly patterned the source and drain contact by photolithography process with special Cu etchant without damaging the IGZO layer. Secondly, to protect the Cu diffusion into the IGZO thin film. The fabrication process parameters are optimized and the electrical properties is discussed. The Cu S/D were fabricated on molybdenum (Mo) layer to prevent the Cu diffusion to the active layer (IGZO). In this work, the IGZO TFTs with Mo/Cu S/D exhibits good electrical properties as the linear region mobility is 12.3 cm^2/V-s, saturation region mobility is 11 cm^2/V-s, threshold voltage is 1.2 V and I_{ON} is 3.16 x 10^{-6} A. The results suggested an effective fabrication method for fabricating high mobility metal oxide TFT based on Cu S/D.