Recent Advances in TAOS-TFT

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A transparent amorphous oxide semiconductor (TAOS)[1,2] exhibits large electron-mobility (>10cm^{2}V^{-1}) comparable to that in the crystalline phase and no p/n-sign anomaly in Hall voltage. Fermi-level is controllable from the mid of the gap state to above the mobility gap by electron-doping via the formation of oxygen vacancy or cation-implantation (chemical doping)[1]. In 1996 we proposed a material design concept for exploring TAOS materials, i.e.,"ionic oxides composed of heavy metal cations with (n-1)d^{10}ns^0 electronic configuration (where principal quantum number n>4)"[1,2] .

Amorphous oxide thin films in the system In_2O_3-Ga_2O_3-ZnO (IGZO) have appropriate properties as the active semiconductor layer in the TFT [3] with respect to .mobility and stability [4].

In this work we studied which metal cation is most important in high performance a-IGZO-TFT. The structure of a-IGZO thin films was examined by XAFS combined with *ab initio* calculation. The local structure around each action is similar to that in crystalline $InGaZnO_4$, i.e., Zn occupies tetrahedral coordination, while Ga and In take 5-6 fold coordination. Noteworthy is the presence of edge-sharing $InO_{5\text{-}6}$-$InO_{5\text{-}6}$. Such an edge-sharing cation-polyhedron is not seen in conventional oxide glasses and is the characteristic of ionic AOSs. *Ab initio* calculation reveals that the bottom of conduction band is primarily composed of

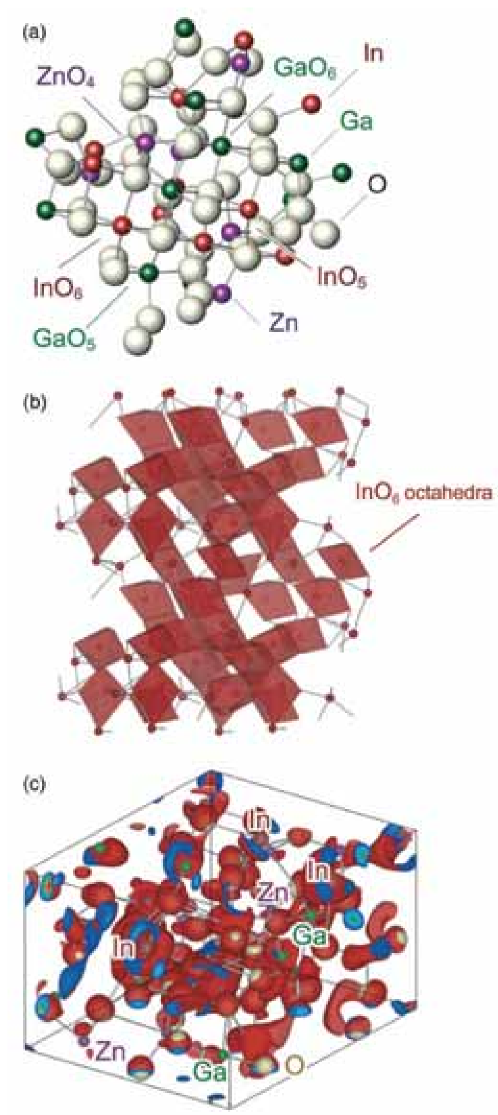

Fig.1 (Color) (a) LDA-relaxed a-IGZO structure containing $(InGaZnO_4)_{12}$ atoms. MO_n (M = metal cation, n = integer) indicates a specific coordination structure with MO_n polyhedra. (b) Polyhedral view of (a). In ions are shown by the red spheres and InO_n polyhedra by the red polyhedra. (b) was drawn with the VENUS system developed by Dilanian and Izumi. (c) Red surfaces show isosurfaces of the norm of the conduction band bottom wave function $|\psi|^2$. The blue-to-red planes show cross sections of the $|\psi|^2$ on the edge planes of the cell.

3d-mensionally percolated In 5s-orbitals along the edge-sharing In-O polyhedra as shown in Fig.1[5]. This finding substantiates the validity of our materials design concept (In with $4d^{10}5s^0$ configuration plays an essential role[1]). Another factor affecting the electron-transport properties is tail state density. We examined relation between the tail state, structure, and electron transport in a-IGZO, finding that thermal annealing is effective to improve the performance. The annealing induced shortening in In-In separation as well as reduction in tail state.

Application of TAOS-TFT is rapidly emerging. Ofuji et al.[6] fabricated five-stage ring oscillators (ROs) composed of amorphous In/Ga/Zn/O (*a*-IGZO) channel thin-film transistors (TFTs) with the channel lengths of 10 μm on a glass substrate. The *a*-IGZO layer was deposited by RF magnetron sputtering onto the unheated substrate. The RO operated at 410 kHz (the propagation delay of 0.24 μs/stage), when supplied with an external voltage of +18 V. This is the fastest integrated circuit based on oxide–semiconductor channel TFTs to date that operates faster than the ROs using conventional hydrogenated amorphous silicon TFTs and organic TFTs.

Ito et al.[7] of Toppan Printing demonstrated b novel display structure for a color electronic paper. .TAOS-TFT array was directly deposited on color filter array at RT and combined with E-Ink imaging film. This structure is nicely utilized the TAOS-TFT; the color filter and TFT array are positioned at the view side of the display, facilitating the alignment of the color filter and TFT remarkably.

A TAOS-driven OLED was reported by Gorren et al [8] and Kumomi [9] in 2006 . Lee et al of LG Electronics [10] reported the fabrication 3.5 inch diagonal AM-OLED driven by IGZO TFTS at IDW, which was held at last IDW (Dec.8,2006).

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