Transparent Amorphous p-type Semiconductor with High Mobility (~9 cm^2/Vs), Cu-Sn-I: Utilization of I 5p orbital as Pseudo Extended s-orbital

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Transparent amorphous semiconductors (TAS) have received much attention owing to their low-temperature process, high transparency, large carrier mobility, and so on. However, TAS reported to date is restricted to only n-type material. Although several p-type semiconductors including $CuAlO_2$ and SnO have been reported, none of their amorphous thin films work as a p-type semiconductor. Therefore, the realization of p-type TAS is a challenging subject and will contribute to a variety of new optoelectronic applications.

Conventional n-type TAS was achieved utilizing the nature of large overlap between spatially spread vacant metal s-orbitals constituting conduction band minimum [1]. Similarly, p-type TAS would be realized if large s-orbitals constitute valence band maximum. However, it is quite difficult to employ cation's occupied s-orbital in amorphous materials. Therefore, we propose a different material design concept for p-type TAS that large p-orbital plays a role of pseudo extended s-orbital like conventional n-type TAS **(see Figure 1)**. As an example, we focused on CuI because iodine (I) has 5p-orbital large enough to realize the pseudo extended s-orbital. The amorphous Cu-Sn-I (a-CuSnI) thin films were successfully fabricated by spin-coating method. Here, Sn was employed to facilitate the amorphous CuI formation; the solution was prepared by dissolving CuI and SnI_4 in 2-methoxy ethanol. XRD and TEM results revealed the amorphous nature of the resulting CuSnI thin films. The chemical composition and electronic structure were evaluated using XPS and UV photoemission spectroscopy (UPS). Electrical properties were examined by Hall effect measurements with the van der Pauw configuration, and a very large Hall mobility of ~9cm^{2}V^{-1}s^{-1}, which is comparable to that in polycrystalline CuI thin films, was obtained for a-CuSnI thin films. On the other hand, a-CuSnI thin films have very smooth surface and pin hole free morphology, as shown in **Figure 2**.

This work demonstrates a new approach to the p-type TAS with high performance. It is expected that this result will contribute to new p-type TASs and their applications with conventional n-type TAS, e.g. flexible complementary circuits. More details including electrical properties and electronic structures is presented at the meeting.

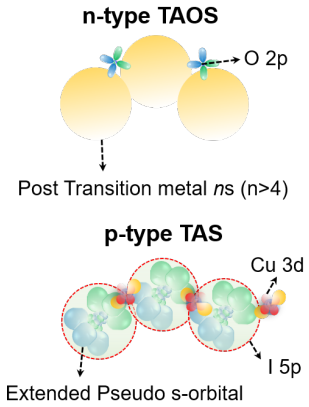

Fig 1. Schematic orbital drawing for CBM and VBM in n-type TAOS and p-type TAS (CuI), respectively.

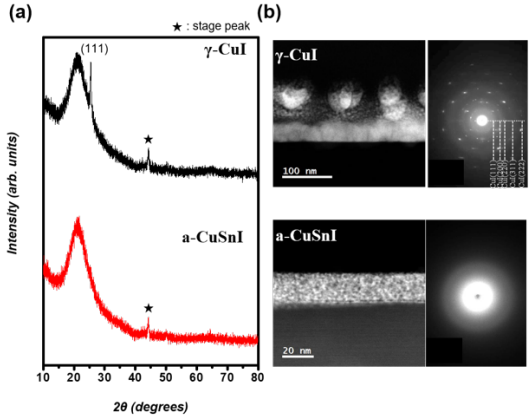

Fig 2. (a) XRD patterns of polycrystalline and amorphous CuI and Cross-sectional TEM image and selected area electron diffraction pattern.

[1] H.Hosono, M.Yasukawa,,H Kawazoe, Journal of non-crystalline solids, **203**, 334(1996); K. Nomura, H. Ohta, A. Takagi, T. Kamiya, M. Hirano, H. Hosono, *Nature (London)* **2004**, 432, 488.