Deposition of CuI for Thin Film Transistors via Inkjet Printing

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Abstract

Since the late 1990's, a variety of Thin Film Transistors (TFT's) have been utilized in both commercial and academic applications. This work culminated in the emergence of transparent electronics around 2002 through use of ZnO as a negative carrier semiconductor (n-type). Since then, a large array of inorganic n-type semiconductors—including ZnO, In_2O_3, and SnO_2—have been applied, most notably in liquid-crystal displays (LCDs). While these have been successful, p-type semiconductors are required for expansion of transparent electronics. However, few examples of functioning inorganic p-type semiconductors have been developed. Of these, Cu_2O has shown promise with a relatively high band gap around 2.1-2.6 eV and a carrier mobility above 100 $cm^2/V*s$, however fabrication of quality thin films requires a high temperature synthesis above 500°C.

Of particular interest is Copper (i) Iodide, which has a high band gap in the range of 2.9-3.2 eV, giving it semiconductor properties useful for transistor applications. Importantly, the active crystal structure is formed at temperatures well below 300°C, allowing for the possibility of low-energy film synthesis. In this work we present a low-temperature fabrication method of CuI thin films with use of inkjet printing. Additionally, we study the film's properties as p-type semiconductor in thin film transistors. CuI was printed with an acetonitrile-based ink onto a SiO_2 substrates, forming thin films with thicknesses on the nanoscale. Inks were formulated at variable concentrations of CuI. The effect of adding the amine stabilizing agent TEMED to the ink was investigated. The printed films were annealed at variable temperatures ranging from 25 to 150°C. The electronic properties were then measured. Films were also analyzed with use of UV-Visible spectroscopy, X-ray diffraction, and scanning electron microscopy.

TFT performance was shown to be non-existent for prints contaminated with the stabilizing agent—indicating a possible breakdown in film formation in its presence. Additionally, XRD measurements showed an amorphous film, while UV-Vis spectroscopy revealed a material band gap much lower than the accepted value for CuI. Films made using no stabilizing agents, however, were shown to form a continuous film of CuI, which was verified using both XRD and UV-Vis spectroscopy. TFT performance was identified for films using voltage-current curves, which showed the low on/off ratio of around 2 with a V_{on} of 12V. The hole mobility for the film was found to be around .01 $cm^2/(V*s)$ The on/off ratio was lowered by a high film conductivity, caused by absorption of moisture.

Further work will focus on improving the TFT performance by fine-tuning film thickness, as well as lowering film conductivity.