Transport properties and trap states density in sputter-deposited amorphous In-Ga-Zn-O

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Transparent amorphous oxide semiconductors (TAOSs) such as In-Ga-Zn-O (IGZO) are the subject of intensive experimental and theoretical research aimed at applications in functional devices for transparent electronics [1].

Unlike conventional covalent semiconductors (Si, Ge) with sp^3 anisotropic bonds, conduction band minimum (CBM) of TAOS materials is composed of heavy metal cations with $(n-1)d^{10}s^0$ electronic configuration, bonded by s-orbitals. Thanks to the spherical symmetry of the s-orbital, the neighboring orbitals overlap despite the degree of disorder of the material, which contributes to improved electron transport in IGZO. Among many deposition techniques reactive magnetron sputtering is the most commonly utilized for fabrication of thin amorphous IGZO films and thin-film transistor (TFT) structures. It is acknowledged that deposition conditions strongly affect In-Ga-Zn-O properties [2]. In the following study we examine the effect of one of the main parameters of sputtering, namely magnetron cathode current, on composition, microstructure, transport and optical properties. To evaluate density of states (DoS) in IGZO bandgap we employed computer simulations.

Amorphous 100 nm thick In-Ga-Zn-O films were deposited by means of RF reactive magnetron sputtering of $InGaZnO_4$ target in Ar/O_2 plasma on quartz and silicon. The use of compositional and microstructural analysis methods, such as Rutherford Backscattering Spectrometry, X-Ray Diffraction, as well as Hall-effect measurements made it possible to obtain a relationship between atomic composition, structure and transport properties of IGZO films. In order to extract DoS versus energy curve by means of method presented by Abe et. al. [3] and Silvaco ATLAS Simulation Package, we fabricated bottom-gate TFTs with IGZO channel.

Results of our experiments show that increasing cathode current caused carrier concentration of IGZO thin films to increase from 2×10^{18} to 5×10^{19} cm^{-3} for 0.2% of O_2 in sputtering plasma. Simultaneously, carrier mobility was increased from 9.0 to 12.0 cm^2/Vs. Independently of cathode current the chemical composition is $InGaZn_{0.7}O_6$ and presents zinc deficiency in comparison to $InGaZnO_4$ target. The origin of this behavior seems to be related to multiphase ceramic composition of the target and incongruent sputtering yields of each phase. We also evaluated influence of magnetron cathode current on DoS versus energy curve and total number of trap states below CBM in IGZO TFT channel.

The research was partially supported by the European Union within European Regional Development Fund, through grant Innovative Economy (POIG.01.03.01-00-159/08, "InTechFun")

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