Thin Film
Room 2022 - Session TF-TuM
Materials for Flexible Substrates, Displays, and Optoelectronics

Moderator: S. Gupta, University of Alabama

8:00am **TF-TuM1 Rapid Thermal Annealing of Indium Tin Oxide (ITO) Films on Flexible Substrates*, R. Thunuguntla,*** University of Alabama*; D. Bottesch,* ASU Flexible Display Center*; S. Gupta,* University of Alabama

Indium tin oxide (ITO) films are widely used for transparent electrodes in various optoelectronic device and display applications, for instance, organic light emitting diodes (OLEDs), and solar cells. Typically, optimization processes for ITO films include either an in-situ or post-deposition annealing step at temperatures ranging from 200-500°C to improve the sheet resistance and transmission properties, achieving resistivities as low as 250 µ@ohm@-cm and close to 100% transmittance. However, for flexible substrates, processing temperatures must be restricted to about 180 °C, resulting in as-deposited films with higher resistivity and lower transmittance. We report the optimization of ITO film properties on flexible substrates by rapid thermal annealing (RTA). ITO films were deposited on flexible substrates by reactive DC magnetron sputtering over a range of processing conditions. Resistivity and transmission was measured before and after atmospheric rapid thermal annealing with tungsten-halogen lamps at temperatures below 180 °C. Atomic force microscopy and X-ray diffraction studies were also carried out before and after annealing to study the effect of the RTA step on crystal growth and orientation as well as on surface morphology and grain size. These results were compared with those on glass substrates where in-situ annealing at high temperatures during deposition was carried out. Rapid thermal annealing shows great promise as a production-compatible technique for ITO on flexible substrates, with more than 50% reduction of resistivity being achieved in several instances. A detailed RTA optimization study for ITO films on flexible substrates by varying annealing parameters such as time, temperature, thermal profiles and ambient gas is presented.

8:20am **TF-TuM2 Gate Dielectric Development for Flexible Electronics*, P.C. Joshi,*** *A.T. Voutsas, J.W. Hartzell,* SHARP Labs of America, Inc.

TFTs integrated on flexible substrates are becoming increasingly attractive for low cost displays, sensors, and rf communication applications. The successful development of high performance flexible devices will be dictated by the enhancement in the thermal stability of the substrates and the low temperature (< 300 °C) processing of the high quality gate dielectric. The PECVD technique has successfully met the demands of the gate dielectric for display devices at processing temperatures lower than 600 °C. However, a further reduction in the processing temperatures below 300 °C is essential to realize low cost, highly functional devices on flexible substrates. The low temperatures processing of gate dielectric films necessitates the development of processes and techniques with plasma controlled reaction kinetics dominating the thin film growth rather then the thermal state of the substrate. At the same time, the gate dielectric reliability need to be maintained or enhanced. In the present work, we report on the low temperature processing of high quality gate dielectric films by high-density PECVD technique at process temperatures lower than 300 °C. The bulk and interfacial electrical quality and reliability of the MOS capacitors as a function of process temperature are discussed in this report. A comparison with the high temperature gate oxide films deposited by PECVD technique employing CCP source has been made to establish the film quality and reliability. The films processed at low temperatures in the range of 150-300 °C showed high electrical performance and reliability as evaluated in terms of the leakage current, flat band voltage, mid-gap interface trap concentration, and BTS characteristics. The observed results are promising and suggest the suitability of HDP technique for novel device development on low temperature flexible substrates.

8:40am **TF-TuM3 Thin-Film Amorphous Silicon Transistors on Flexible Substrates*, D. Loy,*** U.S. Army Flexible Display Center **INVITED**

The Flexible Display Center (FDC) at Arizona State University is focused on developing thin film transistor (TFT) devices on flexible substrates, for use in a variety of reflective and emissive display technologies. We are currently fabricating amorphous silicon TFT backplanes on a 6” Wafer-Scale Pilot Line linked to a Manufacturing Execution System and supported by a comprehensive suite of in-Fab metrology tools. We are simultaneously installing a GEN II (370 x 470 mm) Display-Scale Pilot Line, with qualified operation slated for late 2006. This talk overviews the critical steps in our backplane technology evolution, from qualification of our baseline low temperature a-Si process on the 6” line with rigid substrates, to transferring the process to flexible plastic and metal foil substrates, to form factor scale-up of the TFT arrays, and finally Pilot Line scale-up to GEN II. Keywords: Flexible displays, backplane electronics, Thin Film Transistors (TFTs), electrophoretic ink, OLEDs

9:20am **TF-TuM5 DC Magnetron Sputtered ITO Thin Film on Plastic Substrate with Hard Coating*, H.-P. Cheng,*** *C.-W. Sun,* National Taipei University of Technology, Taiwan, R.O.C.*; T.-H. Chen,* National Chiao Tung University, Taiwan, R.O.C.

The conventional substrates used on monitor are mostly made of glass. Glass has disadvantages of inconvenience in transporting, heavy, fragile, low impact tolerance. The thickness of the glass substrate is facing bottleneck in technical development. Thus, the development of plastic substrate is the growing application. This study focused on the application of DC magnetic sputtering on plastic substrate for sputtering ITO transparent conducting films, and discussed the relationship between the structure and photoelectric properties. The results showed that due to the heat-resistance problem of the plastic substrate, when the substrate temperature is over 60 degree C, ITO film would fracture due to heat stress. Thus, using sputtering under room temperature and lower power could prevent the fracture. Also, the thin film has low adhesiveness due to the characteristics of the plastic substrate, thus, the plastic substrate treated with hard coat could improve the adhesiveness. In terms of the electric properties, the conductivity of ITO film improves as the sputtering time increases, the oxygen pressure decreases, and the proper working pressure is selected. In terms of photoelectric properties, the transmission of light for the ITO film increases as the sputtering time increases, the oxygen pressure increases, and the proper working pressure is selected. After four-point probe test on the electric properties and spectrometer used to measure the transmission of light, the results showed the best resistivity to be 6.96E-4 Ohm.cm, whereas the transmission of light on the test sample is as high as 80%.

10:40am **TF-TuM9 The Surface States of MgO Thin Films Deposited with a Flow of Gases by e-beam Evaporation*, T.W. Heo,*** *S.H. Moon, S.Y. Park, J.H. Kim, H.J. Kim,* Seoul National University, South Korea

MgO thin film plays important roles in AC-Plasma Display Panels: the emission of the secondary electrons and protecting the dielectric layer against the ionized ions. Especially the secondary electron emission coefficient becomes more important recently.@footnote 1,2@ However, the secondary electron emission coefficient should be strongly related to the surface state of MgO thin film: only several nanometers of the surface might be the important part to determine the secondary electron emission coefficient. In addition, the density of states (DOS) of the valence band is one of key parameters, which can explain the mechanism of the secondary electron emission. Because, the two electrons involved have energies initially at two levels in the valence band.@footnote 3@ It is known that during e-beam evaporation the addition of gas improved the electrical property of MgO thin film depending on the kind of the gas. But the reasons for that are not clearly understood. MgO thin films were deposited with a flow of O@sub 2@, N@sub 2@ and H@sub 2@ gases by e-beam evaporator. The deposited MgO thin films were investigated by XPS and SEM. Discharging characteristics was also determined. To evaluate the discharging characteristics, 2-inch test panels were fabricated. MgO film deposited with O@sub 2@ flow shows the most dense microstructure(on the SEM image) and the highest density of states of the valence band(on the XPS spectra) as well as the lowest discharging voltage. The discharging voltages of panel that have MgO film deposited with O@sub 2@ flow are lower than those of panels with other gases flows by 4~5 V. The discussion about the reason for the improvement will be discussed in the presentation. @FootnoteText@ @footnote 1@H. Uchiike et al., IEEE Trans. Elec. Dev., ED-23 1211 (1976). @footnote 2@ T. J. Vink et al., Appl. Phy. Lett., 80 (12), 2216 (2002). @footnote 3@Homer D. Hagstrum, Phy. Rev., vol.122, no.1, 83 (1961) .

11:00am **TF-TuM10 Local Bonding Arrangements in Ge-Sb-Te Alloys for Optical Memory Applications: Correlations between Device Performance and Te and Sb Bonding*, D.A. Baker,*** *M.A. Paesler, G. Lucovsky,* NC State University*; P.C. Taylor,* Colorado School of Mines

EXAFS studies of as-deposited Ge@sub 2@Sb@sub 2@Te@sub 5@ films yield Ge K@sub 1@ spectra essentially the same as previously reported. The earlier studies assumed only Te nearest neighbors, but the more comprehensive analysis of this paper indicates significant concentrations of both Ge-Ge and Ge-Te bonds. Bond-lengths and coordinations determined from EXAFS, combined with relative bond enthalpies yield the following molecular structure: G@sub 2@Sb@sub 2@Te@sub 5@ = Ge@sub 2@Te@sub 3@ + Sb@sub 2@Te@sub 3@ with 17% of the Te-atoms 3-, rather than 2-fold coordinated. The average bond coordination, , and number of valence bonding constraints/atom, , have been determined from an extension of bond-constraint theory (BCT) that includes broken bond-bending constraints for Ge-Ge bonds. This paper addresses additional compositions to better understand the role of broken bond-bending constraints for Sb-Sb bonds that are present in alloys with Sb@sub 2@Te@sub 2@ molecular structures. Broken constraints reduce for Ge from 7 to 4.33, and Ge@sub 2@Sb@sub 2@Te@sub 5@, and optical memory alloys on the Sb@sub 2@Te@sub 3@-GeTe tie-line have ideal values of ~3.05Â±0.05. Similar decreases in occur for Sb-Sb bonds, and are important in identifying network idealicity in other GST alloys. The fraction of 3-fold coordinated Te increases from 7.1 to 25% along the Sb@sub 2@Te@sub 3@-GeTe tie-line, and the amorphous to crystalline optical transmittivity transition occurs over a narrow temperature range, 30°C, and with a different bond scaling relationship.

11:40am **TF-TuM12 Sputter Deposition of Al Doped ZnO Films with Various Incident Angles***, **Y. Sato**, K. Yanagisawa, A. Miyamura, Y. Shigesato,* Aoyama Gakuin University, Japan

Film structures or properties are heavily affected by varying incident angle of depositing particles. When sputtered particles are incident on a substrate perpendicularly, columnar structures normal to substrate surface are usually observed. However, when sputtered particles are incident on a substrate obliquely, columnar structures could be grown toward the incident angle of sputtered particles. In this study, we studied how film structure and some properties of Al doped ZnO (AZO) affected by the various incident angles of sputtered particles. AZO films were deposited on alkali-free glass heated at 200@super o@C by dc magnetron sputtering using an AZO ceramic target with substrate angles from 0 to 80@super o@. The substrate angle of 0@super o@ was defined that the direction of incident sputtered particles was normal to the substrate surface, whereas the substrate angle of 90@super o@ was defined that the one was parallel to the substrate. Film structures, electrical and optical properties of AZO films were analyzed by XRD, Hall-effect measurement and NIR-UV spectrometer. Especially, distributions of crystallographic orientations for the crystallites in the films were analyzed by using X pert-MRD (PANalytical) in details. AZO films deposited with the substrate angle at 0@super o@ showed a strong preferred orientation of c-axis normal to the substrate surface. On the other hand, AZO films deposited with the substrate angle at 80@super o@ possessed c-axis inclined corresponding to the incident angle of sputtered particles. As one of the explanations, such c-axis inclined could be caused by shadowing effect. Resistivity of AZO films decreased with increasing the substrate angle up to 60@super o@ and remained almost constant with the further increase in substrate angle up to 80@super o@. This work was partially supported by a Grant-in-Aid for the 21st COE program from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of the Japanese Government.

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