Doctoral thesis/dissertation Digest Form

Title of Doctoral Thesis: Structural functionalization of polysilsesquioxane for thin-film device applications (ポリシルセスキオキサン構造機能化および薄膜デバイス応用)

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(Summary)

Rapid development in display applications has been focused on improving pixel density with large scalability while maintaining low fabrication temperature. Amorphous oxide semiconductor (AOS) material has been considered as the best candidate for channel material for thin-film transistors (TFT) devices as it offers excellent mobility, remarkable scalability, with solution process compatibility. Numerous studies have been aiming to improve the AOS electrical properties by additional dopants, variety of heating and metal-oxide functional treatments, adoption of various gate insulator layers, and channel stoichiometry modification. Yet, AOS TFTs still experience severe degradation upon exposure to ambient atmosphere and substandard electrical performance specifically AOS channel deposited via solution-processed technique.

This dissertation aims to: (1) investigate hybrid polymer passivation layer to improve stability of AOS TFTs while maintaining low fabrication temperature; (2) explore the potential of solution-processed deposition method for formation of highly dense hybrid passivation layer; (3) study the effect of additional additives in hybrid polymer on electrical performance of AOS TFTs; and (4) elucidate the effect of additional high-*k* nanoparticles in hybrid polymer for AOS thin-film devices. High performance and better device stability of AOS TFTs were achieved through incorporation of inorganic-organic polysilsesquioxane (PSX) which acts as passivation and gate insulator layers. Various functionality of PSX polymer was studied by modifying the alkyl groups compositional ratio, insertion of additional additives, and incorporation of high-*k* nanoparticles.

Complete polymerization of PSX polymer was accomplished through polycondensation of silanol groups forming stable Si – O – Si network. Low-temperature cure PSX passivation was obtained through introduction of inorganic silica group in PSX polymer matrix which facilitates the silanol condensation reaction enables the polymer to cure at low temperature. However, introduction of high silica

ratio generates excessive water which trapped in passivation layer due to lower temperature applied. The existence of water affects the device performance by formation of hump phenomenon due to parasitic capacitance. Therefore, 10% inorganic silica composition led to the best AOS TFTs stability and performance when cured at low temperature.

Aside from that, fluorine doped PSX (PSX:F) was also investigated as passivation layer of AOS TFTs. Fluorine additives are widely known to potentially increase AOS carriers as well as passivating defect sites when introduced in the channel layer specifically. Therefore, fluorine additives were added in PSX polymer with the aim of improving device characteristics while preventing the back-channel interaction. PSX:F passivation deposited with spin coating (SC) and spray coating (SP) techniques reveals superior electrical performance with higher device mobility compared to unpassivated AOS TFTs due to fluorine diffusion to oxide channel confirms by SIMS analysis. Other than that, SP deposited PSX:F reveals remarkable barrier again humidity compared to SC PSX:F passivation manifested by minimal change in threshold voltage compared before and after humidity stress test. Excellent barrier was originated from high dense passivation layer through deposition of fine mist from SP technique.

This work also investigates the effects of additional high-*k* barium titanate (BTO) incorporation in PSX polymer forming nanocomposite (BTOPSX) gate insulator layer for AOS TFTs. Utilization of high-*k* gate insulator layer helps in having similar thin low-*k* gate insulator layer which potentially lowers the turn on voltage while maintaining acceptable leakage current. Different BTO nanoparticle sizes were introduced and the effects of BTO dimensions on electrical behavior were investigated through capacitor measurement. Different hysteresis measurement was observed by utilizing different BTO sizes which 20 nm exhibits clockwise hysteresis and 100 nm exhibits counterclockwise hysteresis. Different hysteresis directions are due to different in crystal forms confirmed through XRD analysis. Interestingly, 100 nm BTO shows different crystal structures at different subjected temperatures wherein tetragonal structure undergoes phase transition to cubic crystal structure above 100 °C. Meanwhile 20 nm BTO retains cubic crystal phase regardless of subjected temperature. Different in crystal structures demonstrated different

This research demonstrates various roles of PSX polymer material through structural functionalization approach for thin-film devices. By understanding the effect of different alkyl groups, additional dopants, and nanoparticles incorporation, different film properties could be achieved which valuable in tuning the functionality of PSX polymer in electronic applications.