Fundamentals and Technology of Multifunctional Materials and Devices
Room Sunrise - Session C2-2

Novel Oxide Films for Active Devices

Moderators: Marko Tadjer, Naval Research Laboratory, USA, Vanya Darakchieva, Linkoping University, Sweden

1:30pm **C2-2-1 Investigation of Negative Bias Temperature Instability under Illumination on P-type Low Temperature Poly-crystalline Silicon Thin Film Transistors***, **Shin-Ping Huang**, T Chang, A Chu, W Su, W Chen,* National Sun Yat-Sen University, Taiwan*; Y Chen, Y Shih,* National Taitung University, Taiwan*; Y Zheng, Y Wang,* National Sun Yat-Sen University, Taiwan

This work investigates the effect of the negative bias temperature instability (NBTI) (temperature range from room temperature to 100°C) under illumination in p-channel low temperature poly-crystalline silicon thin film transistors (LTPS TFT), employing back-faced 20000 lux white light.

Experimental results show an apparent Vt shift after NBTI with illumination during the stress time since the trapped charge in insulator layer causes the degradation.

Moreover, off current in both of the linear and saturation region shows that the degradation is affected by strong and weak field effect under illumination.

1:50pm **C2-2-2 Mechanism of Reset Process with Varying Compliance Current in High-k Spacer Resistance Random Access Memory***, **Yi-Ting Tseng**, T Chang, W Huang, Y Guo, T Chang, W Chen,* National Sun Yat-Sen University, Taiwan

In this study, a problem of forming voltage increased during device cell scale-down in resistance random access memory (RRAM) has been solved by adding high dielectric constant (high-k) material as a side-wall (spacer) structure. In contrast, a normal side wall material is used low dielectric constant material. Electric characteristic of high-k spacer RRAM shows a great electric behavior and is the same with a normal RRAM. High resistance state (HRS) of reset process of values obviously increased during varying compliance current of set process form 1mA to 10mA in high-k spacer RRAM. However, HRS didn’t clearly different change during controlled compliance current in normal RRAM. Varying compliance current of set process is as applying different energy to switch resistance. Then, AC pules was applied to switch resistance for verifying that relationship. AC pulse of rising time was controlled between 10μs to 90μs for applied reset process. As a result, value of HRS increases with increasing rising time. Mechanism of high-k spacer RRAM is dominated by Schottky emission. From intercept and slope of Schottky emission, HRS can be analyzed further for insulator of barrier and dielectric constant.

2:10pm **C2-2-3 Improve Reliability of Complementary Resistive Switching Induced by Carbon Dopant in Indium-Tin-Oxide as The Insulator in Resistive Random Access Memory***, **Chun-Chu Lin**, T Chang, W Chen, Y Tseng, S Huang, H Zheng,* National Sun Yat-Sen University, Taiwan

Among these possible candidates, resistance random access memory (RRAM) is recognized as the most capable of replacing flash memory due to its non-volatility, simple structure, and easy integration into CMOS fabrication. Previous experiments investigate the Complementary resistive switching (CRS) characteristic by co-sputtering indium–tin-oxide (ITO) with oxygen (O_2) gas as the insulator. However, Pt/ITO(O_2)/TiN RRAM device shows poor endurance of CRS I-V characteristic. In this work, double insulator layers are used by co-sputtering ITO with O_2 and carbon to improve endurance of CRS characteristic as the Self-Rectifying Cell (SRC) and also resistance switching (RS) properties of RRAM. The chemical bonds of this Pt/ITO(O_2)/ITO(C)/TiN device was also investigated with FTIR spectrum measurement.Moreover, endurance test was **also** carried out to confirm its RS stability and fast I-V measurement was applied to make sure its CRS I-V curve when giving the pulse. Finally, a conduction model was proposed to clarify the RS characteristics, and support the Pt/ITO(O_2)/ITO(C)/TiN device as appropriate for Self-Rectifying Cell (SRC).

2:30pm **C2-2-4 Study on the Characteristic of Cobalt Silicide Electrode Resistive Random Access Memory***, **Wen-Chung Chen**, T Chang, T Tsai, Y Zhang, S Huang, Y Lin, C Lin, H Zheng,* National Sun Yat-Sen University, Taiwan

Resistance random access memory (RRAM) is one of the promising next-generation nonvolatile memory devices due to its simple metal insulator-metal structure and its ability for high density integration. Furthermore, RRAM also has superior characteristics such as low operation voltage, fast operation speed, and nondestructive reading, and has attracted much interest by many academics and industries. On the other hand, colbalt silicide is popular to use on the semiconductor industry. It can use to reduce the contact resistance. In addition, the Self-alignment process can replace the lithography process by colbalt silicide. In this work, colbalt silicide was deposited as the top electrode, silicon oxide doped hafnium deposited as the translation layer, and the TiN was deposited as the bottom electrode. Though the device shows poor endurance, it has a large memory window by over reset. After reducing the thickness of colbalt silicide, the device shows a great improvement as compared to the device of thick colbalt silicide. Finally, we propose a model to explain the characteristic of cobalt silicide electrode on the resistive switching behaviors.

2:50pm **C2-2-5 Material and Device Engineering for Gallium Oxide Electronics***, **Siddharth Rajan**,* The Ohio State University, USA **INVITED**

The presentation will give an overview of our recent accomplishments and the future outlook for high-performance β-Ga_2O_3 based semiconductor materials and devices. The ultra-wide band gap semiconductor β-Ga_2O_3, is attractive for applications in next-generation high frequency and power switching devices due to availability of large area substrates, large breakdown field, and good electron transport properties. We will first discuss the main research opportunities and potential applications for these devices. This will be followed by an overview of our experimental results on molecular beam epitaxial (MBE) growth of β-Ga_2O_3, β-$(Al,Ga)_2O_3$, and Si doping. We will then discuss our work on growth and characterization of heterostructures based on β-$(Al,Ga)_2O_3$/ β-Ga_2O_3 and the demonstration of modulation-doping in β-$(Al,Ga)_2O_3/Ga_2O_3$ channels. We will then discuss recent our experimental device results on delta-doped and modulation-doped field effect transistors with high current density and transconductance, and discuss their DR, pulsed, and RF performance. We are grateful to Department of the Defense, Defense Threat Reduction Agency (Grant HDTRA11710034), ONR EXEDE MURI program, and the OSU Institute for Materials Research Seed Program for funding.

[1] Krishnamoorthy, S., Xia, Z., Bajaj, S., Brenner, M., & Rajan, S. (2017). Delta-doped β-gallium oxide field-effect transistor. *Applied Physics Express*, *10*(5), 051102.

[2] Krishnamoorthy, S., Xia, Z., Joishi, C., Zhang, Y., McGlone, J., Johnson, J., ... & Rajan, S. (2017). Modulation-doped β-(Al0. 2Ga0. 8) 2O3/Ga2O3 field-effect transistor. *Applied Physics Letters*, *111*(2), 023502.

3:30pm **C2-2-7 The Ultra-violet Light Effect on the Off-state Current of InGaZnO Thin Film Transistor with the Different Structure***, **Yu-Ching Tsao**, T Chang, Y Tsai, W Su, S Huang, Y Chien,* National Sun Yat-Sen University, Taiwan

In this work, we discuss the ultra-violet (UV) light effect in amorphous $InGaZnO_4$ (IGZO) thin film transistor with different drain metal capping area and different active layer thickness. An asymmetric off-state current of transistors in forward and reverse sweep due to different ultra-violet light exposure region and length. An obvious off-state current can be found as a result of a source barrier lowing causing by UV light exposure near the source side. Different off-state current can also be found in different thickness of IGZO active layers. A model is also introduced to interpret this phenomenon.

3:50pm **C2-2-8 Study on the Characteristics of Device in Copper Ion Movement during Operation Process in Conductive-Bridging Random Access Memory***, **Ming-Hui Wang**, T Chang, Y Tseng, H Zheng, C Wu, S Huang,* National Sun Yat-Sen University, Taiwan

In this experiment, Materials commonly used in semiconductor processes hafnium oxide as the insulating layer, The top electrode is copper, bottom electrode use titanium nitride, Conductive-Bridging Random Access Memory is metal-insulator-metal structure. The divice operational process happen abnormal phenomenon, In the resistance decrease process (SET) will first decrease after increase and then decrease until Low Resistance State similar to the negative differential resistance,and this feature is closely related to CBRAM conduction mechanism,because copper ion diffusion to the insulation lead to dielectric constant change,and then condition similar negative differential resistance phenomenon.

4:10pm **C2-2-9 The Degradation Mechanism of Tungsten Electrode on HfO_2-based Resistance Random Access Memory (RRAM)**, ***Hao-Xuan Zheng***, *T Chang, T Chu, M Wang, C Lin, C Yang,* National Sun Yat-Sen University, Taiwan

In this study, using tungsten as the role of the electrode in Resistive Random Access Memory (RRAM) has good characteristics. In addition, on/off ratio achieves two orders, and the 85°C Retention test also has a very good stability. However, after a number of the pulse cycle, there has a significant degradation in this kind of device, which is an uncommon phenomenon from the RRAM which electrode is made by inert elements such as platinum. RRAM can cause significant effects on endurance and retention due to the difference in the electrode material. By clarifying the switching mechanism and conduction current fitting, we can find that the on state conduction mechanism is transformed from Poole-Frenkel emission to Schottky emission. In addition, we use the Energy Dispersive X-Ray Spectroscopy (EDS) analysis and proposed a physical model to explain the main cause of degradation, due to oxygen ions diffusing to the electrode.

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