Influence of Ti Adhesion Layer and ALD Al_2O_3 Thickness on Metal/Insulator/Metal (MIM) Interfacial Energy Barriers

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Understanding and control of interfacial energy barriers ($\varphi_{Bn's}$) at metal/insulator contacts is essential for designing MIM and MOS based devices. Interfacial energy barriers are difficult to predict as they depend not only on the metals and dielectrics used, but also on deposition method, deposition order, interfacial interactions such as diffusion and oxygen scavenging, intrinsic and extrinsic defects, and possibly even film thickness. Ultrathin dielectrics are needed for MOS gates and MIM capacitors. It has been reported that the dielectric constant, density, and optical refractive index of ALD Al_2O_3 are a function of film thickness. Thin interfacial metals have been investigated to tailor barrier heights and are required for good adhesion of noble metal electrodes to oxides. In this work, we investigate the impact of Ti adhesion layer (d_{Ti}) and Al_2O_3 film (d_{Al2O3}) thickness on $\varphi_{Bn's}$ in bimetal electrode Pt/Ti/Al_2O_3/TiN MIM devices using internal photoemission (IPE) spectroscopy.

100 nm TiN bottom electrodes were reactive ion sputtered. Al_2O_3 was then deposited via ALD at 250 ˚C using TMA / H_2O in either a Picosun R150 or R200 chamber. Following ALD a thin Ti IL (0.5, 1, 2, 5, 10 nm) and a 10 nm Pt top electrode were deposited via electron beam evaporation using a shadow mask. CV and IV measurements were taken on the MIM structures. Energy barriers were measured using a lab-built IPE spectrometer system.[1] Top gate voltage was swept from 0 to +/- 2 V using +/- 0.1 V steps. At each bias, incident photon energy was swept from 1.7 to 5.5 eV. IPE thresholds (φ_{thresh}) were determined at each voltage using yield plots and zero field barriers (φ_{Bn}) were determined using Schottky plots.

d_{Al2O3}: Impact Both the top Pt/Al_2O_3 and bottom TiN/Al_2O_3 electron barriers were found to be a function of d_{Al2O3}. While both barriers were roughly constant at ~3.6 eV for Al_2O_3 films ≥ 12 nm thick, both decreased by roughly 0.5 eV as d_{Al2O3} decreased down to 5 nm.

d_{Ti}: For bimetal Pt/Ti electrodes, a 0.5 to 1.0 nm thick interfacial Ti layer was found sufficient to completely dominate the barrier with Al_2O_3. Insertion of the Ti layer resulted in band tailing at the top interface, likely due to oxygen scavenging, but had no impact on the bottom Al_2O_3/TiN barrier.

The degradation of interfacial energy barriers with Al_2O_3 thickness and the dominant influence of even a very thin Ti interfacial layer on φ_{Bn} are important considerations for the prediction and optimization of leakage currents and performance for these devices.

[1] J Haglund, T Mimura, JF Ihlefeld, JF Conley Jr., ACS Applied Electronic Materials 6(5), 3249 (202

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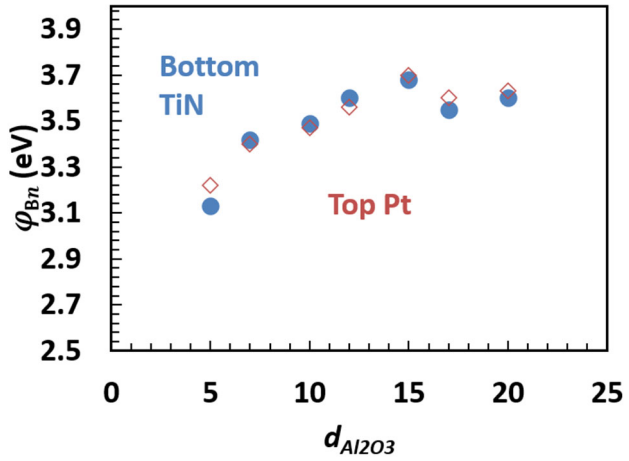

Fig. 1: φ_{Bn} vs. d_{Al2O3} for the top Pt (◊) and bottom TiN (●) interfaces of Pt/Al_2O_3/TiN MIM devices.

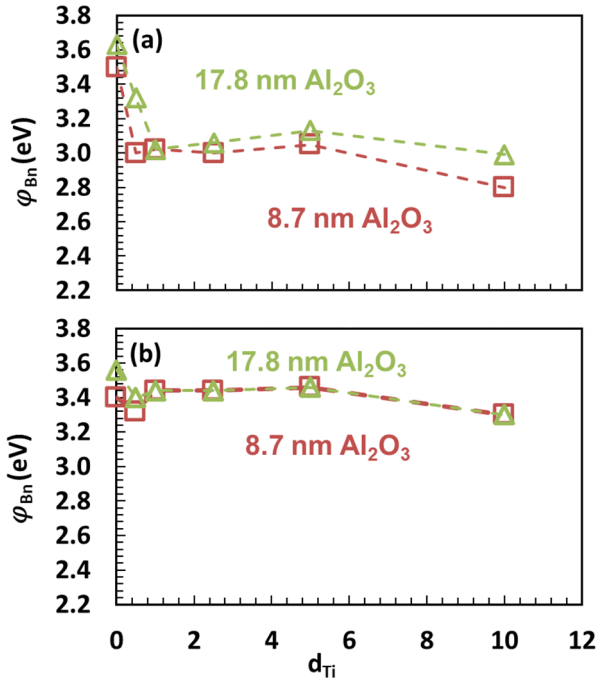

Fig. 2: Plots of φ_{Bn} vs. d_{Ti} plots for Pt/Ti/Al_2O_3/TiN MIM devices for the (a) Pt/Ti/Al_2O_3 top and (b) Al_2O_3/TiN bottom electron barriers.