Internal Photoemission Spectroscopy Measurement of Energy Barrier Heights at Interfaces of ALD Materials in Metal/Insulator/Metal (MIM) Device Structures

ABSTRACT

Metal-insulator-metal devices find application as high-speed tunnel diodes, hot-electron transistors, single electron transistors, resistive random access memory, and capacitors. Precise knowledge of metal/insulator energy barrier heights, ϕ_{Bn}, is critical for predicting and understanding charge transport and optimizing MIM device operation. The simplest theoretical model predicts that ϕ_{Bn}'s should vary linearly with both the vacuum work function of the metal, $\Phi_{M,vac}$, and the insulator electron affinity. In the more sophisticated induced gap state theory, charge transfer at intrinsic interface states is considered to create an interfacial dipole that drives the metal Fermi level, E_F, towards the charge neutral level of the insulator, $E_{CNL,i}$ so that the metal behaves as if it has an effective work function, $\Phi_{M,eff}$, different from $\Phi_{M,vac}$. ϕ_{Bn} varies $\Phi_{M,vac}$ depending on how effectively the insulator "pins" E_F at the $E_{CNL,i}$. In devices, ϕ_{Bn}'s depend strongly on processing and can deviate substantially from predictions due to extrinsic effects such as interfacial and near-interfacial trapped charge arising from point defects, charge dipoles due to interfacial chemical reactions, and remote scavenging of oxygen. It is therefore necessary to directly measure ϕ_{Bn} for the specific metal-insulator combination. The only technique capable of measuring ϕ_{Bn} in-situ (in operating devices) is internal photoemission spectroscopy.

After a brief overview of the Conley research group, IPE measurements of ϕ_{Bn}'s in MIM structures between various insulators (Al_2O_3, HfO_2, SiO_2, NiO, CoO_x, and ferroelectric $HfZrO_x$,) deposited via atomic layer deposition and various metals will be described. Comparisons with electrical measurements are qualitatively consistent with IPE determined ϕ_{Bn}, even when inconsistent with the theoretical model predictions, demonstrating the utility of IPE in understanding MIM devices.

SPEAKER BIO

John F. Conley, Jr. received the B.S. in Electrical Engineering and a Ph.D. in Engineering Science and Mechanics from The Pennsylvania State University where he received a Xerox award for his dissertation. He has worked in industrial research labs, government research labs, has served as a patent litigation consultant/expert witness, and has been a Full Professor at Oregon State University in EECS and Materials Science since 2007 where he also serves as Director of the Materials Synthesis and Characterization facility. He is currently an associate editor of IEEE Transactions on Electron Devices.

Conley's research interests include atomic layer deposition development of novel materials, metal/insulator/metal devices, amorphous oxide semiconductor thin film transistors, and internal photoemission. His research has involved numerous collaborations with industry. He has authored or co-authored over 150 journal and/or conference papers; over 160 additional conference presentations; more than 40 invited talks at universities, government labs, and companies; and 20 U.S. patents.

Conley is a Fellow of the IEEE, the American Vacuum Society, and the Oregon Nanoscience and Microtechnologies Institute.

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TUESDAY
Nov 10, 2020

Talk: 11:00-11:30 AM PDT
Q/A: 11:30-11:45

Zoom: https://beav.es/tech-talk

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