Material and Device Challenges for GHz-THz Electronics

Prof. James C.M. Hwang / AFOSR Program Manager
(E-mail: james.hwang@afosr.af.mil)

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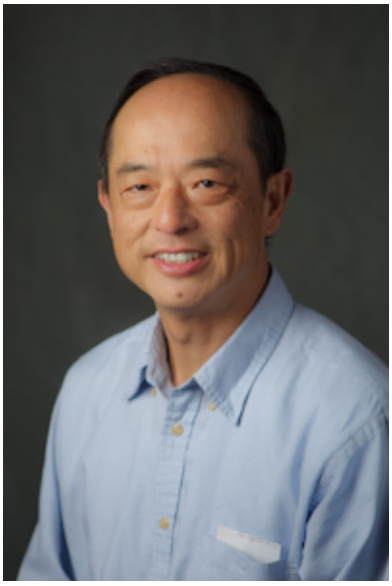

Abstract – The Air Force Office of Scientific Research seeks scientific breakthroughs in solid-state materials and devices that are vital for game-changing capabilities in sub-millimeter-wave radar, ultra-wideband communications, chemical/biological/nuclear remote sensing, and ultra-high-speed on-board and front-end data processing. Such capabilities are crucial for long-term USAF C4ISR capability breakthroughs. Research proposals are sought that address high-risk, high-payoff topics having fundamental challenges that are scientifically interesting as well as technologically relevant. Currently, the research portfolio is organized in three thrusts: I) THz Electronics: These include materials and devices of covalent-bond semiconductors such as C, Si, Ge, GaAs, InP, GaN, and related compounds. The main challenges are in perfecting crystals, interfaces, transports and hetero-structures, as well as scaling to nanometer dimensions for THz operations, while maintaining adequate device characteristics such as on/off current ratio, sub-threshold turn-on slope, and breakdown voltage. Particular emphasis will be placed on approaches that can lead to high-power THz sources, such as MOSFETs or MISFETs with high-*K* gate stack on wide-bandgap semiconductors capable of high channel trans-conductance and low electron tunneling. II) Novel GHz Electronics: These include materials and devices of ionic-bond semiconductors such as complex oxides of transition metals, with less overlapped electron orbitals and much higher bandgaps that may relax the requirement on crystalline perfectness while delivering much higher power than covalent-bond semiconductors can. The main challenges are in understanding different mechanisms for higher-quality, larger-area, and lower-cost growth on flexible or conforming substrates, as well as in understanding doping mechanism, correlated transport, and metal-insulator transitions, especially in terms of high-concentration *p*-type doping and transport in oxide hetero-structures. Scaling to advance operation speed from the GHz range toward the THz range will also be explored. III) Reconfigurable Electronics: These include materials and devices of non-semiconductors that can perform multiple electronic, magnetic and optical functions. Devices based on meta-materials, artificial dielectrics, ferrites, multi-ferroics, nano-magnetics, and micro/nano electromechanical systems for reconfigurable radio-frequency front-ends will be of interest. The main challenges are in understanding the interaction between electromagnetic waves and electrons, plasmons and phonons on the nanometer scale. Additional challenges involve understanding of reproducible material preparation and approaches for devices that are compact, light, low-power-consumption, and low-cost.

Biography – James C. M. Hwang is a Professor of Electrical Engineering and Director of the Compound-Semiconductor Technology Laboratory at Lehigh University. He graduated with a B.S. degree in Physics from National Taiwan University in 1970, and completed M.S. (1973) and Ph.D. (1976) studies in Materials Science at Cornell University. After twelve years of industrial experience at IBM, AT&T, GE, and GAIN, he joined Lehigh University in 1988. His current research interests include micro-electromechanical systems, radio-frequency transistors and integrated circuits, optoelectronics and bio-electromagnetics. He has been a Nanyang Professor at Nanyang Technological University in Singapore and an Advisory Professor at Shanghai Jiao Tong University, East China Normal University and University of Science and Technology of China. He co-founded GAIN and QED; the latter became a public company (IQE). He has published approximately 300 refereed technical papers and has been granted five U. S. patents. He became an IEEE Fellow in 1994. He received the CIE Outstanding Achievement Award and the IBM Faculty Award in 2007, as well as the WOCC Outstanding Contribution Award in 2011. Currently, he is on leave from Lehigh University to serve as a program manager of GHz-THz electronics at the US Air Force Office of Scientific Research.