

Novel Plasma and Vacuum Electronic Devices

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PROBLEM

There has been ever-increasing demand for the development of electronic devices for applications in extreme environments, ranging from space communications to nuclear sensing. Transformative technologies for future device/system designs are crucial to fulfill the stringent requirements on both device performance and robustness.



OVERVIEW

Plasma and vacuum electronic devices remain the workhorse for satellite communications, radar systems, high-energy particle accelerators, plasma heating for controlled thermonuclear fusion, and high power microwave sources, as they have profound advantages in terms of radiation resistance, robustness, and high frequency and high power handling capabilities. Vacuum electronics offer the highest available speeds, because electrons travel with minimal scattering.

One of the great challenges in these areas is the miniaturization of plasma and vacuum electronic devices. With the combination of recent advances in electronics, photonics and nanotechnology, these miniature plasma and vacuum devices may integrate with solid-state platforms, thus forming highly compact systems, with high-speed operation and resistance to radiation and high temperatures.



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MORE INFORMATION

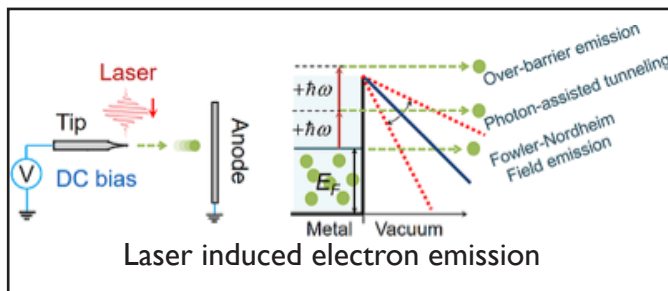
To learn more about Dr. Zhang's research, visit his website at www.egr.msu.edu/~pz/

APPROACH

My team develops theoretical and computational models to understand the basic physics of charge and energy transport, especially at ultrashort spatiotemporal scales, which is of fundamental importance in the development of next generation vacuum and plasma electronics.

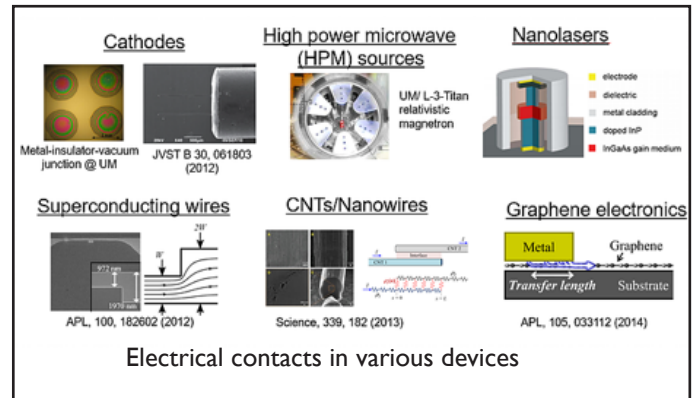
Quantum Modeling of Ultrafast and Nanoscale Charge Transport

Quantum mechanisms would become increasingly important and perhaps even dominant in future ultrafast, nanoscale plasma and vacuum devices. We propose to develop general scaling laws on ultrafast and nanoscale charge transport. The issues include ultrafast laser-induced electron emission, quantum tunneling, space charge, exchange-correlation, effects of surface morphology and material properties, scattering events, and frequency response.



RF Electrical Contacts for High Current Carrying Systems

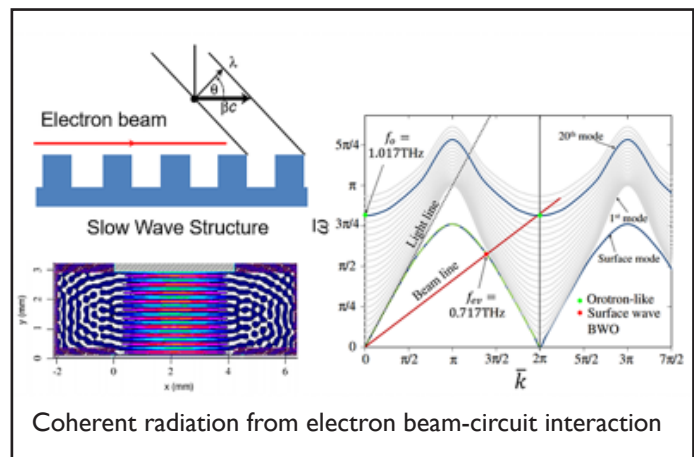
Electrical contacts are important to fusion science and other plasma enabling technologies, including ion cyclotron resonance heating system in International Thermonuclear Experimental Reactor, superconducting accelerators, high power microwave and millimeter wave sources, vacuum switches, and pulsed power systems. Contact problems have been estimated to account for approximately 40 percent of all electrical/electronic failures, ranging from small scale consumer electronics to large scale aerospace and military systems. Making good electrical contacts remains the major challenge for using electronic materials with exceptional mechanical, electrical, and thermal properties, such as carbon nanotubes and graphene. We propose to study RF (or AC) electrical contacts under high current conditions. Proposed topics include capacitive and inductive effects, skin



depth, excessive joule heating, nonuniform material properties, breakdown phenomena in microgaps.

Beam-Circuit Interaction

We explore electron beam interaction with novel structures, such as plasmonics, metamaterials, and photonic crystals, to realize chip-scale accelerators and tunable light sources. We will focus on the basic physics of electron beam-circuit interaction. A better understanding of the instabilities (convective or absolute) in beam-wave interaction is essential to determine the maximum power conversion of these devices. We investigate various processes, such as mode competition, harmonics, frequency multiplication, intermodulation and parametric excitation.



IMPACT

Our research is interdisciplinary, and is important to plasma science, nanoelectronics, ultrafast physics, material science, and accelerator technology. It has applications in communication, energy, security, and medicine.