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**Research focus:**

My research interest lies in designing and engineering devices at the meso-scale, where quantum and classical phenomena are said to co-exist. These devices exhibit characteristics that could be leveraged for novel applications as well as for pushing the limits of performance in traditional architectures with existing applications. One such example is discussed below.

A DARPA funded effort, which I am participating in and which is led by Prof. Roger Howe in collaboration with Profs. Boris Murmann and Ron Davis, is attempting to engineer a platform that mimics the function of the olfactory receptor that is responsible for the sense of smell. Though our understanding of how the sense of smell works is still controversial, recent theoretical and experimental evidence has indicated that the olfactory receptor protein function is far more advanced than the traditional lock-and-key mechanism that is associated with most enzyme proteins. The receptor molecule architecture mimics a nanoscale metal-insulator-metal (MIM) junction, though at the molecular level. An electron at a specific energy in the left arm of the receptor protein tunnels across the pocket volume and is accommodated in the acceptor arm of the receptor molecule, at a different energy. Since the tunneling electron loses energy ~  as it tunnels across, that quantum of energy is picked up by a vibration mode of the odorant molecule, of frequency , that sits within the receptor pocket in the tunnel junction. Tunneling is allowed only when , by conservation of energy, and therefore the tunneling of the electron is gated by chemistry of the odorant molecule in the pocket. This particular mechanism of detection is all-electronic and, yet, highly specific to the chemistry of the target analyte.

Long before the tunneling process was identified as the primary transduction process in the sense of smell, scientists at the Ford Motor Research Labs had fabricated a nanoscale MIM tunneling junction that utilized tunneling currents to spectroscopically identify chemical compounds present within the nanoscale gap of the junction. The new spectroscopy technique was christened as Inelastic Electron Tunneling Spectroscopy (IETS), and is the most recent form of spectroscopy to be invented. IETS had some significant drawbacks as an analytical tool in that the measurements had to be conducted at ultrahigh vacuum and liquid helium temperatures to get measurable signals. Damping interactions between the tunneling electron and a thermally-active environment tend to dissipate out resonance signals in the measured tunneling current. However, the fact that our sense of smell operates as a resonant tunneling sensor at room temperature and in a liquid environment indicates that with appropriate design of the physical front-end as well as the signal acquisition back-end, a resonant tunneling sensor could be developed that could mimic the function of an olfactory receptor protein. An all-electron, chemistry-specific sensor could be deployed for point-of-use healthcare/defense applications. New paradigms for characterizing biological molecules and their interactions could also be enabled from this technology platform that could be utilized in pharmaceutical research and drug development.

A multi-pronged approach is employed in this specific research thrust that relies on a) understanding the physics of the “damping” phenomena operating within charge transfer events occurring at a metal-electrolyte interface, b) developing design rules to mitigate these dissipative phenomena, c) fabricating and characterizing the physical nanoscale sensing front ends, d) designing the analog back-end responsible for signal conditioning and data acquisition, e) designing and fabricating a sample preparation module to interface with the physical sensor, to strip the sample of extraneous biological matter, f) interpretation of signal using pattern recognition and clustering algorithms and g) integrating these components on-chip for a low power, multi-array architecture capable of mobile deployment in-field.



