Utilizing Ultra-High Vacuum Technology for Engineering Materials & Surfaces

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Ultra-high vacuum (UHV) technology creates a unique environment where we can build materials from atoms up, and can control surface, interface, and thin film properties for a wide variety of nano-scale technology applications. One such application under UHV is thermoelectric devices, which have attracted attention in recent years due to their ability to directly convert heat into electricity. With a predicted 60 % increase of global energy consumption by 2030 and a large portion of that energy being dissipated as waste heat annually, exploring devices that have the potential to harvest energy is important in terms of saving energy and renewable energy sources.[1] Up to now, however, low conversion efficiency (~10%) due to materials associated with thermocouple modules of the thermoelectric devices has restricted the usage of thermoelectric devices.[2] Breakthroughs in the study of thermoelectric materials and device design require a thorough understanding of surface physics and multilayer interfaces as properties of the surface and interfaces are the most influential in meeting the overall efficiency goals. UHV technology is ideal for exploring the atomic-level mechanisms that need to be first understood and then controlled in order to create efficient energy harvesting devices with thermoelectric materials.

UHV operates in the range of 10^{-9} Torr or less, meaning that the number of atom or molecules hitting a surface area is much less than that hitting a surface at ambient pressure. In the UHV environment the mean free path between collisions of molecules is in the kilometer range and the gasses present flow and behave differently than gasses at ambient pressure. The theory behind the equipment necessary to create and monitor processing conditions inside a UHV system, is different from that of what is normally used when dealing with atmospheric pressures. Understanding the uniqueness of the UHV environment enables understanding of the unique experiments that can be performed in this environment. In the UHV environment, the rate of impingement upon the surface being studied of molecules from the ambient residual atmosphere in the vacuum chamber is negligible in the time required for observations.[3] Ultra-high vacuum environment allows the trajectories of particles such as ions and electrons use in surface analysis to remain undisturbed when in a surface analysis system.[4] Since vacuum technology deals primarily with gas and vapor, it is imperative to understand gaseous behavior. In this presentation, I will discuss the UHV technology and its advantages for research involving next-generation energy harvesting devices.

References:

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