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Davisson-Germer Prize Talk: Atomically Uniform Thin Films as Quantum Wells and Device Components

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Atomically uniform films can be made for various overlayer-substrate combinations (such as Ag, Pb, Sb, . . . on Si, Ge, Fe, . . .), many of which are not even lattice matched. These films show remarkable property variations as the film thickness is built up in atomic-layer increments. The thermal stability of the film, its work function, electron-phonon coupling, superconducting transition temperature, etc. exhibit damped and modulated oscillations as the film thickness increases toward the bulk limit. The underlying physics can be understood generally in terms of the energetics of a coarsened electronic structure of thin films and more specifically in terms of a "one-dimensional shell effect" – the quantized electronic levels in the film are progressively filled at increasing film thicknesses just like the elemental atomic shells in going through the periodic table. The phase and the amplitude of the oscillations can be tailored by surface/interface engineering that leads to changes in the surface potential and the interface Schottky barrier or band mismatch. These quantum size and confinement effects are important and observable at film thicknesses well in the realm of practical device dimensions and at room temperature, suggesting opportunities for applications. When the films are made of topologically nontrivial materials, the electron spin and its transport become relevant parameters. This talk will discuss issues related to uniform film growth, general trends in connection with reduced dimensions, surprising findings including phonon-mediated pseudogaps, and technology potential.