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Challenges in bridging theory and applications with examples from Materials Design

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Over the past 3 decades the semiconductor industry has doubled the number of transistors on integrated circuits every 2 years, following an empirical law widely known as Moore's law. The ability of the semiconductor industry to stay on Moore's law has enabled the digital revolution and now the convergence of communications and computing. However, as the size of the smallest structures decrease, this has required the introduction of many new materials and the interactions of these heterogeneous materials and processing is increasing in complexity. The increasing use of the nano materials and the ever-shrinking dimensions requires development of an improved understanding of material properties (electronic, thermal, mechanical, and optical) at differences scales. Due to the presence of multiple thin films and metal alloys in the nano technology, grains, and interfaces assume more significance than before. This paper reviews some of the challenges in materials and the opportunities for using fundamental modeling and characterization techniques to enable successful management of these heterogeneous interactions. As the industry evaluates new materials for future technologies, research is needed to develop new modeling and characterization techniques to evaluate nano-materials and materials with nano-scale dimensions and structure.