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Offered for a chapter in a strategic latency book entitled ***Latency Unleashed: The Role of Technology in a Revisionist Global Order. Publisher: Lawrence Livermore National Laboratory***

Working Title: Will Nanoscience and Nanomaterials ever Change the World?

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Abstract: Nearly four decades have passed since the advent of scanning, tunneling microscopy that enabled scientists to peer into the nanoworld (around a millionth of an inch!) and see matter at a scale slightly above molecular. Many prominent researchers have also speculated on the societal implications of fabrication and manipulation of matter at this scale (the "nanoscale") since the mid-50s, and despite many successes in nanotechnology (e.g. photonics and microelectronics), barriers still exist that prevent full-scale nanomaterials, the product of nanoscience, from impacting wide-ranging technologies.

So-called nanomaterials (either nanoparticles or nano-structured bulk or surface materials) are defined as those which have feature size control at the 10-100 nm scale. Nanoparticles are now routinely produced from a wide range of materials across the periodic chart (including metals, semiconductors, dielectrics, polymers and magnetic materials) and with unprecedented control in size (from 10-100 nm), shape, and morphology (two-dimensional, core-shell, etc.). Nanoparticles are made up of smaller, molecular or atomic components and can possess unique characteristics. More importantly, because they are significantly larger than their atomic constituents, they can be manipulated with hydrodynamic and other macroscale external forces more effectively, leading to the potential for larger-scale more rapid processing into composites. Nanoparticles themselves can be organized on surfaces (bottom-up) or integrated into bulk materials to form nanocomposites with extraordinary properties (light management, etc.). Nano-structuring of materials can also be achieved with precision mechanical forces or photonic energy (top-down) through printing/sculpting or engraving. Whatever the means, remarkable properties with far-reaching implications on technology can be achieved. Examples are already legion, including numerous in electronics, healthcare, and energy. But the full-scale potential of nanomaterials is far from being realized.

In this chapter we will discuss technologies far beyond those that have realized the benefits of nanoscience and focus on that have only been "touched" by the possibility of nanoscale materials control. To the synthetic chemist making nanomaterials, the periodic chart now presents a "playground" of possibilities to far-reaching impacts on materials performance, functionality, security and more. The primary barriers to realizing these impacts are manufacturing (at the particle scale and device scale), metrology, and fundamental understanding of ways to manipulate nanofeatures over wide areas/volumes with forces. We further discuss these barriers and speculate the means to overcome them, and the potential technological implications of doing so.

*Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

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