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Nanotechnology in the Environment: Lessons From and For Solid State Physics

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Nanotechnology-enabled systems offer great promise for solving difficult environmental and biological problems. Their small size, high surface areas, and unique properties all provide opportunity for use-driven science and engineering research. At Rice University, in a NSF research center termed CBEN, we have since 2001 been studying applications in biological and environmental engineering and the science of the "wet/dry" interface between living systems and inorganic materials. Ultimately with the appropriate tools we aim to predict the behavior – the transport, biokinetics and effects – of engineered nanoparticles in natural systems. I will give two examples of applications driven research which have exploited fundamental understanding of solid state physics in both magnetic and optical systems. Quantum dot/metal complexes, for example, can be generated to act as probes in biological systems. When linked with specific peptide sequences, these systems can detect the presence of metalloproteases or MMPs. These elusive biomolecules are thought to be excellent indicators for the biological state of solid tumors, and their application could yield a combination of both structural and functional imaging. In a second example the nanoscale behavior of magnets are the basis for developing point-of-use water purification for arsenic-rich sources. High surface area and monodisperse Fe_3O_4 nanocrystals will move in very low magnetic field gradients (< 100 T/m) in a size-dependent fashion. The striking size dependence of the magnetic separation process permits the first multiplexed separation of nanocrystals by magnetic field strength. This phenomena makes it possible to demonstrate in one proof-of-principle systems that high specific surface area Fe_3O_4 nanocrystals can be used in a magnetic separation process to remove arsenic. From these examples which are clearly cases where solid state physics taught users of nanotechnology how best to apply novel materials, I will move to lessons for solid state physics from this area of nanotechnology. Much of this discussion will center on the need for a proactive dialog about measuring the risk of technology's that are on the frontier; such debates are now a visible hallmark of nanotechnology programs worldwide. While it may seem that concerns about the health of environmental impactsof nanomaterials are far from the expertise or interest of physicists, the critical role of the interface in these studies elevates the importance of surface science in particular in this emerging area. The need for more quantitative and basic studies of these interfaces in water is acute, and defines a topic well suited for the physics community.