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This is an occasion to recognize the development of a new fundamental building block for chemistry and materials science, nanocrystals. These are tiniest possible periodic or regular arrangements of atoms into a simple pattern and consist of anywhere from a hundred to so to hundreds of thousands of atoms/. They are about the size of familiar macromolecules like natural proteins and artificial polymers, and as with those, they are the smallest collections of atoms that display collective phenomena. As with proteins and polymers, nanocrystals are both objects of great beauty and are the subject of our fascination and study, yet they also offer us a massive variety of physical and chemical properties that can be used in technologies that benefit humanity, enabling new kinds of biological imaging and diagnostics, as well as new materials that for renewable energy. In this lecture, I will offer a brief introduction to nanocrystals, how they are made, the reason their properties are so interesting, and why they will be the subject of study and use in the future.

A qualitative picture for many properties of nanocrystals can be seen by looking at "scaling laws" for their basic properties, such as melting. A crystal is held together by the bonds between all of the atoms; yet, when it is very small, a large fraction of its atoms are located on the surface, and hence there are fewer bonds holding it together. For this reason, nanocrystals melt at lower temperatures than ordinary macroscopic ones. The reduction in melting temperature is approximately proportional to the surface to volume ratio, or the inverse of the radius of the nanocrystal, and that relationship is an example of a scaling law. A few decades ago, we documented that for a 5 nanometer diameter nanocrystal of a typical semiconductor thar solar cells or light emitting diodes are made out of, the melting temperature is about half of the normal melting temperature for big crystals, so the effect is large and consequential.

A second important example of how nanocrystals are different form their larger counterparts arises when we consider defects in solids. You are likely familiar with the fact that larger diamonds are more costly than smaller ones. Indeed, the price of a diamond of the same quality but twice the volume is four times greater. This is because large high-quality diamonds are rarer than small ones; more time at high temperature is requited for a defect to anneal out of a crystal the larger it gets. Here is where something very special happens on the nanoscale. When crystals are very tiny, the chances of making one that is perfect improve enormously. This is something we could document through a series of a studies in the 1990s.

In fact, with the combination of lower melting temperature and the propensity to exclude defects, our community demonstrated that it is possible to make extremely high quality, electronic grade nanocrystals with very simple methods that resemble the ways in which bulk commodity chemicals are made. This is very important because we need vast quantities of high-performance materials for renewable energy systems in the future.

There is one more scaling law for me to share with you, and that is called the quantum size effect. I was able to study this one alongside my postdoctoral mentor Louis Brus, in the late 1980s. Perhaps you can conjure up a mental image of a common science museum exhibit, a large funnel into which a marble is spun along the rim. As the marble descends lower into the funnel, its speed increases. A tiny semiconductor crystal displays a similar phenomenon. When an electron that helps bond the atoms in the crystal together gets some extra energy from some external source, it will start to move around within the nanocrystal. The smaller the nanocrystal, the faster its' motion. Eventually, the excited electron will lose the excess energy by emitting light. The smaller the crystal the higher the energy this light, or the bluer the color. That is a si ole picture pf the qua rum size effect. On practice, it means that by making extremely uniform and very high-quality nanocrystals of semiconductors, we can create tiny light emitters of any color we choose, and those light emitting particles have innumerable uses.

The first practical use of semiconductor nanocrystals; quantum dots emerged in the late 1990s when we and others first used them for as biological probes to visualize cells ne tissues. Today they are used widely in biomedical research, for instance biopsy tissues are frequently stained with quantum dots by pathologists to classify tumors as benign or malignant and to gain addition; insights. A second common application is in Quantum Dot televisions that display a much fuller range of colors than others and use much less energy than others.

The principles for understanding and controlling nanocrystals that I have described are quite general and open the door to many future opportunities, some even that seem exotic today, but that may come into use one day. I am particularly excited about two. One is to create engines that use light, similar to engines that work on expanding and contraction gases, but where light that is moving in all directions is funneled into single direction. To achieve this requires the development of nanocrystals quantum dots that are extraordinarily efficient converting sunlight into a single color of lower energy, as well as separate development of highly efficient mirrors that work at just that one wavelength. This will require atomic level precision in the design and construction of nanocrystals, demanding that we learn to make nanoscale objects with the kind of precision that nature employs in making proteins.

An equally grand challenge relates closely to the beautiful work of Michael Graetzel, namely conversion of sunlight into fuels. Nature accomplishes this with an exquisite array of membranes, proteins and molecules. Nanoscientists are emulating nature with human made nanocrystals and molecules, and one key step is to transfer a charge from an excited nanocrystal to an attached molecule, initiating a cascade of subsequent events. The prospect of doing this with greater efficiency than nature is very real and one path to addressing the challenges of climate change. In this common journey, it is interesting to contemplate that our efforts to overcome the greatest challenges on global scale may well depend upon on our ability to imagine and control such tiny objects as nanocrystals.