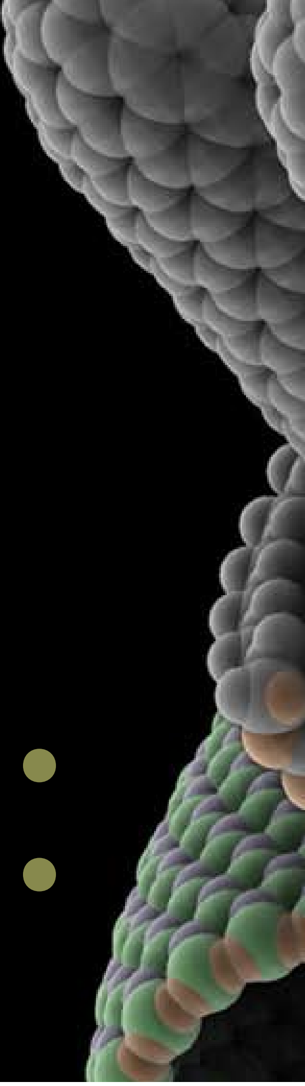

Forget smart phones and smart cars — smart particles are at the cutting edge of really smart technology.

smarticles:

Nanotechnology Materializes

During the late 19th century, George Parsons Lathrop was in the enviable position of engaging Thomas Edison in a number of conversations, which he described in a delightful account in the February 1890 issue of *Harper's New Monthly Magazine*. His "Talks with Edison" article was written with the intention of preserving their exchanges; however, Lathrop also proved a graceful listener, "learning from [Edison's] own lips some of those things which tend to give one at least a more vivid perception of how an inventor invents."

Edison considered atoms to be intelligent particles, as corroborated by their ability to form, disassociate, and reform with other elements. One day at dinner, Lathrop recounts, Edison marveled at the possibilities, and personal gratification, that would emerge if humans could gain complete control of all of their constituent atoms. Edison explained, "then I could say to one particular atom in me — call it atom No. 4320 — 'Go and be part of a rose for a while.' All the atoms could be sent off to become parts of different minerals, plants, and other substances. Then, if by just pressing a little push button they could be called together again, they would bring back their experiences while they were parts of those different substances, and I should have the benefit of the knowledge."

Had a nutritionist joined the two friends for dinner, Edison of course would have been reminded that he was already benefiting, at least in part, from experiences offered by the minerals, plants, and other substances that nourished him. Edison's ruminations on anthropomorphically charged atoms and his dominion over them often come to mind in the course of my research into the architectural implications of nanotechnology. Consider, for example, this excerpt from "Molecular Manufacturing: Societal Implications of Advanced Nanotechnology," a presentation by Christie Peterson before the US House of Representatives Committee on Science in 2003: "Humanity's drive to improve our control of the physical world is intrinsic to our species and has been in progress for millennia. A vast international economic and military momentum pushes us toward the ultimate goal of nanotechnology: complete control of the physical structure of matter, all the way down to the atomic level."

Nanotechnology is the study and fabrication of small molecular structures that measure between one nanometer and 100 nanometers in at least one dimension. Due to this dimensional definition, the field of nanotechnology has a very broad scope and can be thought of as a territory within which a range of disciplines converge, including chemistry, physics, materials science and engineering, medicine,

by Peter Yeadon AIA, RIBA

biology, and systems architecture for computing. Imagine defining architecture as a structure wherein at least one of its dimensions is between one and 100 meters! Imagine the number of disciplines that could lay claim to such creations! The dimensions matter, however, as nanotechnology would otherwise be difficult to identify. Like biotechnology, nanotechnology is not a single technology; rather, it is multiple technologies. Generally speaking, nanotech is concerned with single molecules. But this, too, can be cause for some confusion, as some single-molecule structures are much larger than the 100-nm ceiling that helps define nanoscale science and engineering.

Often the last to arrive at the party and occasionally the last to leave, architecture has been slow to embrace and participate in the development of nanotech innovations. The paucity of architectural publications that have been devoted to the subject over the past two decades suggests that most of us can likely be counted among the 70 percent of Americans who know little, or nothing at all, about nanotechnology. This is beginning to change and, as it was with the last industrial revolution, architecture is awakening to a new industrial revolution that is already substantial. Nanotechnology fundamentally alters our relationship to matter; it has already produced a variety of

Image: nBots by Peter Yeadon. A detail of three carbon nanotube "fingers" and a molecular bearing "wrist" for the nBots. The project is being developed with HyperChem and NanoENGINEER advanced molecular modeling suites, which can simulate atomic reactions. (See cover and caption, page 1.)

Architecture has been slow to embrace nanotech innovations, but this is beginning to change, and architecture is awakening to a new industrial revolution.

materials with novel properties, and it offers new approaches to making that will undoubtedly affect the fabrication of architecture in the future.

Two recent books, one by John M. Johansen and the other by Sylvia Leydecker, begin to address the vast implications of nanotechnology in terms of materials and making. Johansen's *Nanoarchitecture: A New Species of Architecture* (Princeton Architectural Press, 2002) was likely one of the first books to introduce many of us to the topic of nanotechnology in architecture. Although it contains an assortment of uninspiring projects by Johansen with dubious connections to nanotech (and he doesn't actually get around to mentioning molecular nanotechnology until page 151), he was one of the earliest architects to identify the emergence of nanotechnology as the dawn of a new epoch. Johansen borrowed heavily from K. Eric Drexler's *Engines of Creation* (Anchor, 1987) to proffer a vision of post-fabrication architecture, in which architecture is self-assembled and can grow like a seed in a vat of nutrients.

Leydecker's *Nano Materials in Architecture, Interior Architecture and Design* (Birkhäuser, 2008) surveys a number of projects that incorporate nano-engineered materials. Most of these are coatings that are self-cleaning, anti-fogging, anti-graffiti, or antibacterial, but Leydecker also includes nanomaterials that provide enhanced thermal insulation or fire-resistance. These technologies demonstrate how nanotech is discreetly infiltrating architectural systems, lying dormant but ready to perform.

To expand upon Leydecker's list, the products of nanotechnology are generally of two types: existing products that have been optimized and enhanced by nanotechnology, and an entirely new class of materials and products that have heretofore never existed. Composite materials are a ready example of the first type, whether they are stronger industrial plastics that can biodegrade, or have been reinforced by the unsurpassed strength of carbon nanotubes. Many sensors and smart materials, too, have had their properties improved by nanotechnology, including thermoelectric and piezoelectric materials, and second- and third-generation thin film photovoltaics.

Of the entirely new products, many are focused on energy abundance, efficiency, storage, and conservation. Products like nanoantenna photovoltaics that continue to work at night, and quantum dots that efficiently luminesce in a bright, visible spectrum of light, might eventually play a significant role in architecture. They are also good examples of recent advancements in optics/photonics research, which has also produced metamaterials that guide light around cloaked objects. But the most striking new products are the biomimetic nanomaterials wherein our knowledge is finally able to benefit from plants and other organisms that have developed a number of remarkable mechanisms for sustaining their existence over millennia. These include super-adhesives that mimic the byssal threads of mussels and can stick to nearly anything, tapes that emulate the van der Waals forces found in the setae of a gecko's foot, anti-reflective materials that mimic the structure of a moth's eye, synthetic membranes that efficiently filter water in the same way as kidneys, self-healing synthetic systems that sense damage and then mend the defect, "nastic materials" that respond to external stimuli, and strong, stretchy nanocomposites that have the desirable properties of spider silk.

It is interesting to reflect on the six short years that have passed between these two publications, one visionary (even if lacking substance) and the other a review of commercially available material technologies. The evolution of nanotechnology has followed a similar trajectory. Nanotech funding is increasingly shifting toward achievable near-term applications and is wicking away from the kind of scientific research that has remained unsullied by industry and commerce during the past 10 years, as the field itself migrates away from the visionary roots set down 20 years ago in Drexler's *Engines of Creation*.

One of Drexler's central tenets was that nanotechnology would eventually enable us to create molecular machines that could replicate themselves, and might then be reprogrammed to carry out useful tasks by assembling products from the bottom-up, atom-by-atom, molecule-by-molecule, from a reservoir stock of elements. Twenty years ago, Drexler's critics were undermined by his adroit analogies to living organisms that self-replicate — for example, a potato, and you and me. Even today, Drexler's nanofactories might seem fanciful, but a variety of molecular machines have already been developed. Single-molecule couriers have been created at the University of California that can transport other molecules on a surface, a nanocar was built at Rice University that has its own molecular motor, and an array of programmable DNA robots were self-assembled at NYU that can grab molecules from a solution and fuse them into finished materials.

Thomas Edison would have been delighted. ■

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