

46) and U.S. Food and Drug Administration (21 CFR 50 and 56) regulations for the protection of humans.

The NIEHS IRB is part of the Human Subject Protection Program of the NIH. The NIEHS began to consider possible uses for nanotechnology in environmental health science when the 1997 House Appropriations report included the term *nanofabrication*. In 2001, U.S. Congress asked the NIEHS to explore how nanotechnology might be used to address environmental health problems. The NIEHS is particularly interested in the possibilities of using nanotechnology to improve the detection, prevention, and remediation of environmentally related illnesses. NIEHS has funded research in bioengineering toward this goal.

The NIEHS is also interested in the development of detection technologies at the nanoscale level, including creating minute light sources and the smallest and fastest fiber-optic chemical sensors that could enable optical, spectral, and chemical imaging on a nanometer scale. Another area of interest for the NIEHS is the design and production of sensors with intracellular targeting capabilities. Such sensors will be able to monitor environments immediately proximal to the cellular targets of environmental toxicants. For example, nanotechnology could be used to monitor physiological processes inside a cell in response to toxicants. From such a finding, it may be possible to find a correlation between physiological effects and a disease caused by an environmental factor.

Nanotechnology has the potential to mitigate some of the worst aspects of industrialization such as pollution. In 1992, Mobil Oil announced the creation of a family of aluminosilicates that could be made with atoms packed in an orderly manner to create consistent, tiny pores. Research has shown that ordered nonporous ceramic substrates with controlled shapes and sizes can serve as efficient traps for specific environmental and chemical pollutants. Thus, materials with nanosize pores could be used as filters to remove contaminants.

See Also: Cancer Treatment, Nanoenabled; Nanobiotechnology; Nanomedicine, Toxicity Issues of; National Cancer Institute (U.S.).

Further Readings

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National Institute of Standards and Technology (U.S.)

The U.S. National Institute of Standards and Technology (NIST) has been an important player in nanotechnology since before there was nanotechnology or even a NIST (it was known as the National Bureau of Standards until 1988). As the Department of Commerce's primary representative in the National Nanotechnology Initiative (NNI), NIST gives precompetitive aid to American nanotechnology firms through metrological standards and instruments, fundamental research, and user facilities.

Too Little, Too Soon

Congress established a Bureau of Standards in 1901 to house and maintain the United States' standard weights and measures. In addition, the Bureau frequently took on technology development projects (such as the proximity fuze during World War II) for government agencies, contract measurement jobs for industry, and pioneering basic research in areas such as spectroscopy and biological electron microscopy. In the early 1960s, the NBS recruited a very strong interdisciplinary group in surface science, a new field situated at the intersection of basic research and technology development in electronics, catalysis, aerospace engineering, and so on. One of the leaders of this group, Russell Young, sought ways to make his expertise in the interaction of electrons and surfaces relevant to the Bureau's core areas of calibration and metrology.

In 1966, Young developed an "ultramicrometer" that used field-emitted electrons to measure very small length changes. He followed up with the Topografiner, which scanned a field emitter over a sample to create microscopic images of diffraction gratings, gage blocks, surface finishes, and so on. The Topografiner's advo-

cates today see it as a precursor to the scanning tunneling microscope (STM).

At the time, though, NIST was undergoing budget cuts and Young's managers dropped the Topografiner, believing that if it was a useful tool, industry could develop (as, indeed, happened when IBM invented the STM). Young was promoted, so he entrusted gradual improvement to the Topografiner (largely hidden from upper management) during the 1970s to a young protégé, Clayton Teague.

Molecular Scales and Yardsticks

In the 1980s, as STM, atomic force microscopy (AFM), and other probe microscopy techniques took off, Teague and NIST were well positioned. NIST built one of the earliest copies of IBM's first STM, and heavily recruited former IBM STMers such as Joe Stroscio. NIST's work in this area closely tied to its core mission: for instance, NIST researchers developed ways to calibrate the sharpness of STM and AFM tips, and elaborated AFM techniques to measure very small forces and even "weigh" tiny handfuls of atoms.

NIST especially led in development of nanoscale measurement techniques to aid the U.S. microelectronics industry. For instance, NIST strongly supported work on scanning capacitance microscopy, which can detect the concentration of crucial "dopants" in microelectronic components. Teague spearheaded the Molecular Measuring Machine project, which provided closed-loop, quantitative nanoscale metrology (with uncertainty less than 0.1 nanometer) over the long distances (more than a millimeter) needed in semiconductor manufacturing. Ideas from the M³ have become standard in commercial AFMs used by the microelectronics industry.

Building and Coordinating

With this long history in nanoscale research, it was perhaps natural that NIST, and in particular Teague, would push for the institutionalization of nanotechnology. In 1991, for instance, Teague became chief editor of *Nanotechnology*, a journal founded the previous year to bring together researchers in probe microscopy and other nanoscale fields, bureaucratic proponents of a national nanotechnology initiative, and futurist advocates for "molecular nanotechnology." As the National Science and Technology Council planned the NNI in the late 1990s, Teague was NIST's representative; and once the NNI was formed, he became director of the National Nanotech-

nology Coordination Office (the clearinghouse for all federal nanotechnology activities) and the chair of the American National Standards Institute's advisory group to the International Standards Organization's Technical Committee on Nanotechnologies in its attempt to set standards and definitions for engineered nanomaterials.

Most recently, NIST has built a NanoFab user facility as part of a \$235 million Advanced Measurement Laboratory. The NanoFab makes available more than \$19 million in tools to users inside and outside the federal government. It is operated by NIST's Center for Nanoscale Science and Technology, a \$22 million annual budget research group working closely with the University of Maryland and the University at Albany to develop new metrological tools.

See Also: Government Laboratories (U.S.); International Standards Organization; Microscopy, Scanning Tunneling; National Nanotechnology Coordination Office (U.S.).

Further Readings

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National Institutes of Health (U.S.)

The National Institutes of Health (NIH) has been a major sponsor of nanotechnology research and development since the late 1990s. NIH supports a wide range of projects, both on its Bethesda, Maryland, campus and around the world, including basic research on properties of nanomaterials; applications of existing nanotechnology to biomedical problems; and studies of health and safety issues that could arise as nanotechnology products interact with the human body and the environment. The primary aims of NIH's involvement in nanotechnology