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BUILDING THE NEW WORLD OF NANOTECHNOLOGY

Michael A. Van Lente†

I. INTRODUCTION

Would we appreciate a golf ball that dramatically reduces hooks and slices? A new company known as NanoDynamics plans to use nanomaterials to bring about less weight shift inside the golf ball as it spins.¹ Advanced materials made possible through the use of nanoscale additives or additives having nanoscale structure are yielding performance improvements in everything from military aircraft to cars, bicycles, and tennis rackets.² How about downloading a book that actually looks, feels, and sits on a shelf like a real book? 3Netics Corporation is working to develop "electronic paper" containing tiny pixels made using self-assembled monolayers of nanoscale materials.³ Doctors are working to use nanotechnology to diagnose and treat diseases like cystic fibrosis and cancer.⁴ For those with no time for laundry, including nanoparticles of titanium dioxide in fabrics could produce clothing that cleans itself when the wearer exposes it to sunlight.⁵ After studying the nanofibers on the toes of geckos, researchers are working to make “nanofur” that might allow soldiers to use sticky

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¹ Kevin Maney, Nanotech Could Put a New Spin on Sports: One Example Golf Balls That Make Hacks Look Good, USA TODAY, Nov. 17, 2004, at 1B.

† B.S., Chemistry, Hope College (1980); Ph.D., Chemistry, University of Minnesota/Minneapolis (1987); J.D. expected, Case Western Reserve University School of Law (2006). I would like to especially thank Professor Hiram Chodosh, Kevin Kunzendorf, and the rest of the staff of the Case Western Reserve Journal of International Law for their helpful comments and encouragement during the writing of this note. Any remaining errors are entirely my own.
gloves and boots to climb up walls.\textsuperscript{6} The ability to work on a nanoscale promises to make life in the 21st century continuously exciting and new.

Nanotechnology, a collection of technologies for building materials and devices "from the bottom up," atom by atom, has been getting a great deal of attention lately.\textsuperscript{7} New advances in materials, energy, medicine, and electronics promise to bring technological changes in the near future that will be even more breathtaking than those of the past thirty years. As modern conquistadors including governments, companies, and academic communities scramble to organize themselves and claim appealing pieces of this New World, no one in the industrialized world wants to be left out. But, as in the day when Juan Ponce de Leon claimed Florida and all adjacent lands for Spain in the 16th century, modern conquerors may find that holding on to vast areas of crudely understood territory is just as difficult today as it was 400 years ago. Early explorers in nanotechnology have been awarded thousands of patents, and knowledgeable commentators have begun to wonder whether the resulting "patent thicket" will unnecessarily choke future innovation.\textsuperscript{8} Is the advent of nanotechnology similar enough to the introduction of earlier technologies as to require no modification to the incentive structures built in earlier times? Has the pace of change become so overwhelming that changes in intellectual property structures will be needed? What is the best and fairest way to encourage the rapid development in nanotechnologies that will inevitably come? Part I of this note builds appreciation for the promise, scope, and direction of present-day nanotechnology, the massive and competitive efforts that are underway for its development over the coming decade, and the stunning pace with which researchers are likely to bring these changes about. Part II discusses the present state of the nanotechnology intellectual property landscape. Part III summarizes current thinking about the need for modification in current intellectual property structures in order to promote development of this new field in the optimum way.

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II. THE PROMISE, SCOPE, AND DIRECTION OF NANOTECHNOLOGY

The unifying idea behind the variety of nanotechnologies under investigation is that of working on a scale measured in nanometers and constructing new substances by positioning the atoms and molecules that make them up. This way of putting materials together is revolutionary because it allows scientists to achieve greater uniformity of structure and greater control over properties than has ever before been possible. Experts widely acknowledge that this revolution has its origins in a very insightful talk given by Richard Feynman in 1959 at the annual meeting of the American Physical Society at the California Institute of Technology. Feynman later won the Nobel Prize in Physics in 1965 and had a very distinguished scientific career. The invention of tools for manipulating atoms, notably the invention at IBM in the 1980's of the scanning probe microscope and the atomic force microscope, moved the fledgling field along. The arrangement of 35 xenon atoms into the shape of the IBM logo in 1989 is often cited as a major milestone.

To appreciate the challenge of working on this scale, one must visualize how small it is. A nanometer is a billionth of a meter. A chemist might relate this to bond lengths; the distance between the nucleus of an oxygen atom in a water molecule and the nucleus of either hydrogen atom has been measured as 0.0958 nanometers. Therefore, a nanometer is about ten O-H bond lengths. To consider a dimension that may be more generally familiar, a human hair has a diameter on the order of 100 microns, which is

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11 ULDRIC & NEWBERRY, supra note 9, at 35-38.


100,000 nanometers. Worlds having dimensions from one to 100 nanometers are generally considered the realm of nanotechnology, and this is incorporated into the definition of nanotechnology used by the U.S. government's National Nanotechnology Initiative (NNI). In characterizing a new technology, the NNI "calls it 'nanotechnology' only if it involves all of the following: 1) research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range, 2) creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size, and 3) ability to control or manipulate on the atomic scale."14

This definition includes many techniques, and the boundaries of what may be called nanotechnology are still a bit fuzzy. After all, molecules have always had nanoscale dimensions. What is new about this? Modern nanotechnology involves orienting molecular features or aligning molecules in relation to each other on a nanoscale or exploring and utilizing the distinctive properties observed for previously familiar materials such as semiconductors or metal powders when their dimensions are reduced to the nanoscale. Many materials exhibit new and exciting properties when made on a nanoscale. As nanoscience pioneer Professor Chad Mirkin said, "Nanoscience is about redoing everything. Everything when miniaturized will be new."15 Thus, nanotechnology is not limited to using an atomic force microscope to move individual atoms around. There are many other ways to work on a nanoscale, and an appreciation for what nanotechnology is may perhaps best be developed by getting a sense of the many new applications and accomplishments that constantly appear.16 The entire industrialized world will see the fruits of these efforts in such diverse areas as electronics, computers, pharmaceuticals, defense, structural materials, manufacturing, energy production, communications, environmental science, and consumer

products. Associating nanotechnology projects with one of these or another application area is one means of classifying them.

The electronics industry is a good example of an industry experiencing a complete transformation as a result of its newfound ability to work on the nanoscale. Nanotechnology in the electronics industry divides itself into two broad categories—advances in optical lithography and those in molecular electronics. For decades, electronic integrated circuits have been made using photoresist technology (optical lithography), in which formation of the features of the circuits depends on photopolymerization reactions (interaction of light with free-flowing or soluble chemicals to form insoluble hard solids) that block portions of conductor surfaces in a subsequent etching (dissolution of exposed conductor) step. Improvements in miniaturization have been measured by the minimum distance attainable between adjacent “wires.” Experts speak of Moore’s Law, the name given to the fact that this minimum distance (feature size) has decreased, showing a striking (log-linear) trend at the rate of 11% per year since the first integrated circuit appeared in 1960. This technology, which made possible feature sizes in the micron (1000 nanometer) range prior to the mid-1980’s, has been steadily improved. By the mid-1990’s, feature size had reached the 300 nanometer range. More recently, Fujitsu achieved a feature size of 90 nanometers using nanolithography. IBM has “[m]anufacturing capability now coming online for the production of semiconductors with 180 nanometer dimensions.” using photoresist technology. Without disclosing its method, Intel has announced the construction of a test chip using “65 nanometer technology” capable of “packing ten million transistors into a space the size of the tip of a ballpoint pen.” Sony and Toshiba have said that they also have 65 nanometer technologies and expect to “[d]evelop 45-nanometer processing and design technologies for next-generation system chips by the end of 2005.”

17 ULRICH & NEWBERRY, supra note 9, at 22; ATKINSON, supra note 9.
19 Will Conley, Photoreist Technology for 0.25 Micron Lithography, SEMICONDUCTOR FABTECH, Oct., 1996.
The new field of molecular electronics takes a different approach to constructing circuits: chemists prepare molecules for particular circuit functions, and the molecules then "self-assemble" into circuits. More than a dozen research groups, mainly in academic institutions, are working with various molecules in this exciting area.

An alternative to the classification of nanotechnologies by application is their classification according to the laboratory environments and the collections of instrumentation needed to explore the science. The Center for Nanoscale Science and Technology at Rice University classifies nanotechnologies into three main types—wet, dry, and computational. The Center defines "wet" nanotechnology as "the study of biological systems that exist primarily in a water environment," such as "genetic material, membranes, enzymes, and other cellular components." "Dry" nanotechnology "focuses on fabrication of structures in carbon . . . silicon, and other inorganic materials" and is studied without a water environment. Finally, "computational" nanotechnology complements the other two by making predictions that researchers can check out in the lab.

A. Worldwide Government Initiatives to Stimulate Research and Development in Nanotechnology

The need to support the development of these technologies as they become the new industries of the twenty-first century has been recognized by governments around the world for at least several years. According to the 2003 report of Mihail Roco, a U.S. National Science Foundation official, "[T]he worldwide nanotechnology research and development (R&D) investment reported by government organizations has increased approximately seven-fold in the last six years . . . from $432 million in 1997 [1] to


27 Smalley Institute, supra note 26.

28 Smalley Institute, supra note 26.

29 Smalley Institute, supra note 26.
about $3,000 million in 2003." A year later, Mr. Roco updated his estimate of worldwide government investment in nanotechnology to $3.5 billion. According to Mr. Roco's 2001 report, "More than 30 countries have activities and plans at the national level in [the] nanotechnology area in 2001." The report defines nanotechnology as "[r]esearch and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range . . ." Government investment is one measure of the scale of nanotechnology investigation worldwide. In attempting to track this investment, however, the pace at which the interest of governments in nanotechnology is growing worldwide and the partnering of governments with industry make pinpointing total government investment a nontrivial exercise. Even so, several useful summaries have appeared. The countries of the industrialized world are taking concrete steps to place themselves at the forefront of this new frontier. The Japanese government devoted $800 million in funding to nanotechnology in 2003, and this was scheduled to rise by 20% by 2004. The British government is making $163.8 million in grants available under its "micro and nanotechnology manufacturing initiative." In Taiwan,
an industry group known as the Taiwan Nanotechnology Industrialization Promotion Association (TNIPA) has raised $87 million for nanotechnology research and expects support from government funds.\textsuperscript{37} The Taiwan government budget plans for nano research amount to $625 million over the six-year period from 2003 to 2008.\textsuperscript{38} The Korean government announced last summer that its investment in nanotechnology development would total 273.4 billion won ($265 million) for 2004 alone\textsuperscript{39} and plans are in place to spend about $2 billion in public funds over ten years.\textsuperscript{40} The New Zealand government is spending about $1.57 million annually to support the McDiarmid Institute for Advanced Materials and Nanotechnology.\textsuperscript{41} Even Singapore is heavily involved in the nanotechnology race.\textsuperscript{42}

In the United States, Congress passed and President Bush signed the 21st Century Nanotechnology Research and Development Act in 2003.\textsuperscript{43} The Act provided approximately $3.7 billion in funding in support of nanotechnology research.\textsuperscript{44} Most recently, 2005 spending for the NNI exceeded $1 billion, and President Bush has included more than $1 billion in his proposed 2006 budget for NNI.\textsuperscript{45} Strong government support for NNI, which began in 2001 and grew out of discussions within the government dating back to 1996,\textsuperscript{46} serves as recognition of the importance of nanotechnology to the economy of the future. Illustrating the broad applicability of

\textsuperscript{37} News Detail, National Science and Technology Program for Nanoscience and Nanotechnology, Taiwan Gives its Nanotech Industry a Push (July 20, 2004), http://nano-taiwan.sinica.edu.tw/HeadLineNewsDetailEn.asp?NewsNo=2&DetailNo=499.


\textsuperscript{40} TOWARDS A EUROPEAN STRATEGY FOR NANOTECHNOLOGY, supra note 34, at 7.

\textsuperscript{41} Richard Terra, New Zealand Funds Nanotech Research Center, http://nanodot.org/article.pl?sid=02/04/10/0048225.


nanotechnology research, the NNI includes 22 agencies representing a cross section of the executive branch of the federal government. The result of disbursement of funding from these agencies has been the establishment of multidisciplinary centers on more than 34 U.S. university campuses.

States and numerous companies are also investing in nanotechnologies. The fifty state governments combined invested more than $400 million in nanotechnology research and development in 2004. Statistics rate Massachusetts as the number one nanotechnology state "in terms of the per capita number of nanotech companies, patents, research activity, commercial applications and other factors." In California, a major nanotech research facility known as the California Nanosystems Institute is being built on the UCLA campus. The State of New York will contribute $150 million to support a new semiconductor plant that IBM is building along the Hudson River and related nanotechnology research. Other examples are numerous.

B. Private Sector Initiatives to Grow Nanotechnology

The private sector has invested a great deal of energy in the nanotechnology area. According to a recent Wall Street Journal story, "About 1,500 companies world-wide have announced nanotechnology research plans, including 19 of the corporations in the Dow Jones Industrial

50 Jay Fitzgerald, Mass. Tops in Nano, But Execs Worry, BOSTON HERALD, Jan. 19, 2005, at 33; see also Choi, supra note 49.
52 IBM to Pour $2.5B into Upstate N.Y., CNNMONEY, Jan. 5, 2005.
Lux Research, Inc., of New York has reported that corporations were expected to collectively spend $3.8 billion on nanotechnology research and development in 2004. The Nanobusiness Alliance, a nanotech industry support association with over 250 member companies, publishes "The Nanobusiness Directory," which lists over 800 businesses that are involved in nanoscale research. The online nanovip.com nanotechnology business directory organizes companies into categories—capital and funding, computers (which would include software for modeling and simulation), consulting, electronics, governmental, life sciences, materials (including nanotubes and thin films), physics (including optics), research, and tools and instruments. Examples of corporate investment in nanotechnology are many. Nanosys, Inc. caused a serious stir on Wall Street in the summer of 2004 by withdrawing its initial public stock offering, in which it had been seeking to raise $100 million. Hon Hai Precision Industry Company, a maker of computer parts and the largest private manufacturer in Taiwan, began building a $355 million nanotechnology R&D facility in 2004. In Germany, Advanced Micro Devices and Infineon Technologies plan to invest $204 million over the next five years in a nanotechnology research center to be built in Dresden.

Nanotechnology profits are not just a dream for business interests, however. Manufacturing of nanotechnology products is underway for some, and others are actively organizing their production schemes. Consulting Resources Corp., a market research firm based in Lexington, Mass., estimated in 2003 that nanotechnology companies were doing $385 million dollars in annual business in the United States, and the firm projected that this figure would reach $3.5 billion by 2008 and $20 billion by 2013. For example, QuantumSphere "[i]s opening a facility in Costa Mesa, Calif., where it will manufacture a projected 2,500 lb. of nanoaluminum and

55 Id.
60 Technology Briefing Nanotechnology: 2 Companies to Invest in Research Center, N.Y. TIMES, Aug. 31, 2004, at C14.
nanonickel powders per month for aerospace, defense, and energy applications such as propellants and munitions.\textsuperscript{62} The recent merger of Carbon Nanotechnologies and C Sixty in Texas formed a company that planned to make 100 pounds of carbon nanotubes per day in 2005.\textsuperscript{63} Carbon nanotubes represent a remarkable new (allotropic) form of carbon, and experts expect them to have application in electronic displays, shielding for electronic devices, bulletproof clothing for soldiers, batteries, sensors, and a host of products yet to be conceived.\textsuperscript{64} Carbon nanotubes are also used as capacitors in electronic circuits.\textsuperscript{65} The research firm Frost & Sullivan has estimated that the nanotube market could grow to $540 million by 2007.\textsuperscript{66}

With the magnitude of research activity, business investment, and manufacturing in nanotechnology increasing, collaboration between business and industry and internationally between universities clouds efforts to categorize and track this activity.\textsuperscript{67} Overall, however, there is ample evidence for the premise that research activity in nanotechnology fields is ramping up at a very rapid rate worldwide. The planners of Nano Tech 2005, which was held in Japan in February, 2005, were expecting 40,000 attendees.\textsuperscript{68}

\textit{C. The Need to Go Forward While Staying Safe}

The high rate of change being brought about by new activity in nanotechnology fields has brought with it uncertainty, and the uncertainty


\textsuperscript{68} International Nanotechnology Exhibition & Conference, http://www.ics-inc.co.jp/nanotech/top_e.html.
with respect to risks has led some to suggest that a deliberate slowing of nanotechnology activity is in order.\textsuperscript{69} In 2003, “[G]reenpeace International called for a moratorium on the release of nanoparticles in commercial products until any risks can be assessed.”\textsuperscript{70} The idea of uncontrolled, self-replicating machines built on a nanoscale and capable of turning the whole world into “grey goo” was conceptualized by early nanotechnology researcher Eric Drexler in the mid-1980’s.\textsuperscript{71} More recently, science fiction novelist Michael Crichton popularized the “grey goo” idea in his fictional work entitled “Prey.”\textsuperscript{72} In the wake of the resulting public stir, Drexler acknowledged:

\begin{quote}
[N]anotechnology-based fabrication can be thoroughly non-biological and inherently safe: such systems need have no ability to move about, use natural resources, or undergo incremental mutation. Moreover, self-replication is unnecessary: the development and use of highly productive systems of nanomachinery (nanofactories) need not involve the construction of autonomous self-replicating nanomachines.\textsuperscript{73}
\end{quote}

Drexler does see potential risks in “exponential manufacturing,” i.e., manufacturing involving self-assembly of molecules into useful devices on the nanoscale.\textsuperscript{74} He particularly suggests that nanoscale weapons could be a threat in this age of terrorism and that “[t]here are no simple technical solutions to this problem, which involves questions of military power and political control.”\textsuperscript{75} He also expresses the general idea that this venture into the unknown could have adverse effects on the environment and that some vigilance will be required to reduce this risk.\textsuperscript{76} This is, of course, true for any new chemical technology. Some thoroughness is necessary for the protection of our environment, but no identified risk is high enough at this point to justify bringing the entire motion of progress in nanotechnology to a halt.

\begin{footnotes}
\item[71] K. Eric Drexler, Engines of Creation: The Coming Era of Nanotechnology (1986).
\item[74] Phoenix & Drexler, supra note 73, at 871.
\item[75] Id.
\item[76] Id.
\end{footnotes}
Fortunately, some concerned scientists are taking action to protect the environment from harm caused by nanotechnology. The International Council on Nanotechnology, “a collaboration of academic, industry, regulatory, and nongovernmental interest groups” funded by industry, has been set up at Rice University “to assess, communicate, and reduce potential environmental and health risks associated with [nanotechnology].” There is also a report of an Institute of Medicine workshop discussion of nanotechnology threats, including the expected toxicity of nanoparticles. Finally, the Environmental Protection Agency recently awarded $4 million in grants for study of risks to human health and the environment resulting from the manufacture of nanomaterials.

In summary, though some critics have expressed concern about particular potential risks involved in the pursuit of nanotechnology, no overarching threat or smoking gun requiring the cessation of nanotechnology development is evident. Furthermore, nanotechnology research and development has clearly become a key part of the global race for technological dominance in the 21st century, and none of the key players will want to incur disadvantage through an overabundance of caution.

III. THE NANOTECHNOLOGY INTELLECTUAL PROPERTY LANDSCAPE

Every player in the global race for technological dominance in nanotechnology sees the collection and exploitation of intellectual property as a critical part of the competition. In nanotechnology, patents are particularly important, because they protect the turf of a new venture, they eliminate the risk of inadvertent disclosure carried by a trade secret strategy, they are an offensive strategy for avoiding expensive litigation or the need to purchase an excessive number of patent licenses, and, in most cases, they are considered essential for attracting the funding that is needed for getting a new venture off the ground. Accordingly, nanotechnology patenting has

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81 Ainsworth, supra note 80, at 18; MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 211-12.
skyrocketed in the past few years. "[I]n 1985, approximately 250 new nanotechnology patents were filed, but by 2003, that number had increased to more than 5,500, according to figures from Thomson Derwent, a scientific information consulting firm." Figures from Thomas Heinze of the Fraunhofer Institute for Systems and Innovation Research show that less than 100 EPO/PCT nanopatent applications (applications referred to the European Patent Office through the provisions of the Patent Cooperation Treaty) were filed in 1985, whereas that number first exceeded 400 in 1996 and was projected to exceed 1,800 in 2002. Clearly, there has been extensive participation among new players in nanotechnology in the patent systems of the world. In the following pages, the intellectual property landscape of the United States will serve as a model for those of the industrialized countries of the world with the realization that the same tensions are playing out in other countries. This is particularly true in light of all of the progress that has been made in recent years in the global harmonization of intellectual property laws.

A. The Thirst for Patents

According to Dr. Raj Bawa, a patent agent and consultant specializing in nanotechnology, the growth in nanotechnology patenting is driven by the widespread perception that patents show their greatest value when viewed in combination:

For a startup, patents are a means of validating the company's foundational technology in order to attract investment. Most experts agree that a start-up should focus on obtaining a broad intellectual property portfolio that includes both patents and trade secrets that cover clusters of an emerging sector in nanotechnology. Alternatively, the start-up may seek dominant (or pioneering) patent protection as a means of gaining an advantage. The start-up (or any skilled inventor) should consider filing patents on their concepts to protect them from predatory inventors, and later file on the details of these early concepts when those are worked out. A nanotechnology start-up should also consider patenting peripheral technology and non-related technology in addition to the base technology. This strategy may sustain it during times of economic down or provide it with additional revenue, through licensing or sale to other companies that are better positioned to take advantage of the technology.

84 Bawa, supra note 80, at 44-45.
John C. Miller, coauthor of the recent “Handbook of Nanotechnology,” corroborates the idea that nanotechnology entrepreneurs view the task of obtaining patents as an important precaution when setting up a business. “In the quest to build strong IP portfolios, many nanotech companies are filing as many provisional patent applications as possible.” Provisional patent applications establish a priority date with a specification describing the invention but do not require claims. Companies can then do some cost/benefit analysis later before deciding whether to follow up provisional applications with more expensive nonprovisional applications that do contain claims and could garner twenty-year patent monopolies for the holders. The central role for patents that nanotechnology start-up companies see is summed up in the mission statement crafted by California Molecular Electronics Corporation, which was established in 1997:

California Molecular Electronics Corporation is committed to profitably invent, acquire, assimilate, and utilize intellectual property in the field of molecular electronics to develop and sell quality products based on molecular electronics technology, sell and collect license fees on the rights to use its molecular electronics intellectual property, and build royalty streams on products developed and sold by others because of the application of its molecular electronics intellectual property.

Rather than viewing patents as a way to protect business activity, young companies may view their research and business activities as mere facets of their primary identities as intellectual property dealers and rulers of particular pieces of the intellectual property landscape.

But going beyond anecdotal indications to portray an accurate picture of the patenting habits of fledgling nanotechnology companies presents a challenge. Efforts to count patents can be problematic because they could involve difficulties in classifying technologies and counting or not counting multiple international patents describing the same invention. For many relevant patents, the company name is not the same as the assignee name listed on the patent; the research could have been done someplace else by someone unaffiliated with the company. Finally, licensing agreements have greatly increased the patent portfolios available to some companies, and this information is not public unless the companies choose to disclose it.

Some companies have disclosed information about their patent portfolios. For example, Carbon Nanotechnologies, Inc., which was founded in 2000 in Houston and grew out of Professor Richard Smalley’s work in the carbon nanotube area, claims to have “over 100 patents and patent appli-

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85 Miller, Handbook of Nanotechnology, supra note 9, at 212.
86 Id. Provisional patent applications are authorized under 35 U.S.C. § 111(b) (2000).
Nanosys, a California company founded in 2001, fabricates nanostructures from inorganic materials usually associated with semiconductors and claims to have over 400 issued and pending patents. This compares with the more than 130 patents and pending patents claimed by Nanosys in September of 2003. On its website, nGimat™, a manufacturer of nanopowders, claims to have over 30 U.S. patents and "numerous" patent applications pending. The websites of Iljin Nanotech of Korea, Materials and Electrochemical Research of Tucson, Arizona, and Xintek of Research Triangle Park, North Carolina, claim holdings of 37 issued patents, 24 issued patents, and more than 20 patents issued and pending, respectively. A search using the United States Patent and Trademark Office ("PTO") website search engine showed 66 patents assigned to Hyperion Catalysis of Cambridge, Mass., and 47 of those appeared related to carbon nanotechnology products. The numerous other carbon nanotube companies appear to be keeping their patent portfolios closer to the vest, but these examples and the writings of professionals involved with nanotechnology companies strongly suggest that collections of patents are valued by these new companies.

Notably, investors are not always impressed with all of this patenting and like to point out that allowing obsession with patenting to overshadow product development is not healthy. On the cancellation of plans by Nanosys for an initial public stock offering, one commentator recently opined that nanotechnology "is still more about hype than real world business applications." "There is demand for nanotech but other companies whose primary assets are intellectual property will not receive a warm reception."
All of this nanotechnology patenting has led to a condition that some have described as a "patent thicket." The general premise of the "patent thicket" idea is that a new entrant into a nanotechnology business might find his progress impeded or stopped because the unreasonable breadth of patent claims in relevant patents and the large number of relevant patents that have already issued will make progress difficult or impossible. The newcomer might find that he needs to license so many patents in order to carry out his intended work that he cannot proceed. As the argument goes, the overall progress of nanotechnology innovation will proceed in a suboptimal way if too many aspiring innovator/competitors are repelled at the gates. Of course, patents exist partly to encourage innovation by offering a limited monopoly as a reward, and limiting that reward could diminish the extent to which it encourages innovation.

Mr. Miller and coauthors illustrate the concept of the patent thicket using the example of carbon nanotubes. Early pioneers in the science of carbon nanotubes include Professor Smalley and Sumio Iijima of NEC Corporation, who brought nanotubes onto the world stage in the early 1990's. Developed from the "fullerene" technology that won Smalley and two others the Nobel Prize in Chemistry in 1996, nanotubes were prepared by laser vaporization of graphite (a form of elemental carbon) in an oven at 1200 degrees Celsius. The many applications envisioned for carbon nanotubes include display technology; nanoscale batteries, electrodes in fuel cells (electrochemical cells that consume hydrogen to produce electrical energy cleanly), electromagnetic radiation shields, polymeric materials showing better mechanical properties with nanotubes blended into them (e.g., improved materials for sports equipment), components such as capacitors or transistors in nanoscale electronic circuits, sensors, catalysts, absor-
bents, pharmaceutical capsules, and optoelectronics for use in communications. Not just one industry, but numerous industries could be heavily dependent on carbon nanotubes in the not-too-distant future.

NEC and IBM, which were in some collaboration in the 1990's, now claim dominion over the entire realm of nanotubes through their seminal patents. NEC has publicly invited anyone who wants to develop a carbon nanotube application to come forward and negotiate a license. To some, the claims of the seminal patents seem broad in light of current expectations for the future usefulness of carbon nanotubes. Claim 3 of an early IBM patent reads simply, "A hollow carbon fiber having a wall consisting essentially of a single layer of carbon atoms." This claim encompasses the products of at least 19 smaller, younger nanotechnology companies. Hyperion Catalysis has a comparable claim in a now expired patent relating to multi-walled carbon nanotubes:

An essentially cylindrical discrete carbon fibril characterized by a substantially constant diameter between about 3.5 and about 70 nanometers, length greater than about $10^2$ times the diameter, an outer region of multiple essentially continuous layers of ordered carbon atoms and a distinct inner core region, each of the layers and core disposed substantially concentrically about the cylindrical axis of the fibril.

A subsequent Hyperion patent reduced the minimum length to five times the diameter of the fiber and added a limitation requiring some level of purity and another requiring preparation by catalyzed chemical vapor deposition. Chemical vapor deposition of one form or another is a popular way to grow nanotubes. Another patent recently issued to Professor Smalley shows a first claim that reads, "A composition of matter comprising at least

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101 MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 224; Press Release, Sumitomo Corp. & NEC Corp., supra note 100.


103 See infra tbl.1.


about 99% by weight of single-wall carbon molecules." The time lag between the early IBM patent and this one perhaps reflects the nontrivial task of purifying nanotubes, but this claim could also underlie numerous industries that entrepreneurs would like to develop well before this patent’s expected expiration in 2018.

Even patents that read one step downstream from those featuring simple, general claims to nanotubes may be considered seminal because they could underlie great commercial activity just over the horizon. A recent patent assigned to Hyperion Catalysis claims, "A capacitor having an electrode comprising nanofibers having a surface area greater than about 100 m²/gm." This encompasses nanotubes because the Federal Circuit has said that patentees can be their own lexicographers, and the specification says, "The term ‘nanofiber,’ ‘nanotube,’ and fibril are used in interchangeably.” Capacitors are fundamental parts of electronic circuits, and this claim is undoubtedly fundamental to fledgling efforts in molecular electronics. For example, Nano-Proprietary of Austin, Texas, has claimed in a recently issued patent, "A field emission cathode comprising: a) a substrate; and b) a field emission cathode material comprising a mixture of carbon nanotubes and particles." The electronics industry has high interest in using carbon nanotubes to develop display technology, and this patent may encompass much of that effort. Professor Smalley’s patent on a method for preparing derivatized single walled carbon nanotubes has a first claim that reads, "A method for derivatizing a single wall carbon nanotube comprising the step of covalently bonding substituents to carbon atoms on a sidewall of the single wall carbon nanotube." Chemists will recognize that this is an extremely nonspecific description—an almost unlimited multitude of chemical methods can achieve covalent bonding, and this claim does not specify the substituents involved. Others who might wish to be at the forefront of these and other industries that will be built with nanotubes could well be deterred from getting started by broadly claimed inventions staked out at the outset.

On the other hand, the fact that dissenting voices dispute the premise that nanotechnology patent claims are in general overly broad is impor-

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109 '711 Patent, col.8 l.25.
tant to note. Attorneys Donald Featherstone and Michael Specht recently published their analysis of the "top 10 patents" in nanotechnology. Based on the prosecution histories of the patents, the authors conclude that PTO examiners are doing a good job of narrowing the scope of patent claims. They present no analysis, however, of whether the resulting claims are still too broad, and there seems to be some room for argument on both sides in that regard.

Miller and coauthors say that several hundred patents related to carbon nanotubes have been issued, and they show a chart indicating the potentially significant number of patents, including numerous patents other than the seminal ones held by NEC and IBM, that would need to be licensed in order for a newcomer to develop a new technology in one of the many application areas.

Matthew Nordan, Vice President of Research at Lux Research, agrees: "If you pick up one of these [carbon nanotube] patents, you're going to have to license a whole bunch of others in order to use the one that you've got." In the eyes of some observers, strict enforcement of the seminal patents in the carbon nanotube area will lead either to a stifling of development in these exciting and important areas or to untold wealth for NEC and IBM. Similar analysis has led Miller and coauthors to conclude that similar patent thicket difficulties exist in other seminal nanotechnologies including quantum dots (semiconductor nanocrystals with applications in medical diagnostics) and dendrimers (breakthrough materials with medical applications).

A recent analysis of nanotechnology patents by Lux Research and the Washington office of Foley & Lardner, L.L.P., reaches the same conclusion, noting the issuance of large numbers of patents in seminal areas of nanotechnology. The report also points out that, in contrast to the carbon nanotube industry, the fledgling nanotechnology industries known as quantum dots, nanowires, and dendrimers either already have seen or likely will soon see relevant patents come under the control of a single business entity.

Mindful of the fact that their audiences include investors and customers, companies sometimes boast in public statements of having dominant intellectual property positions. In his recent announcement of a newly

113 Id. at 5.
114 MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 73.
116 MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 72-74.
117 Moore, supra note 115.
118 See id.
issued patent for composites containing single-wall carbon nanotubes, Bob Gower, President and CEO of Carbon Nanotechnologies (CNI) of Houston, characterized the company’s patent position:

Single-wall and other small diameter carbon nanotubes offer great potential in applications ranging from electrically-conductive plastics to fuel cells and flat panel displays. CNI’s industry-leading intellectual property portfolio, including this latest patent, broadly covers nanotube production, enabling technology and end-use applications, and will likely underpin almost all commercial products benefiting from these remarkable new materials.\(^{119}\)

If true, this statement gives CNI an astonishing level of monopoly over developing industries. The patent that Mr. Gower was announcing broadly covers any “[m]acroscopic assembly of single-wall carbon nanotubes . . . .” in which the nanotubes are aligned,\(^{120}\) and it will expire in 2021. On a similar occasion and in a similar vein, Professor Smalley said:

This is a critical piece of technology and could be one of the most important patents related to carbon nanotubes. This opens a wide range of new possibilities in this rapidly developing field. It is difficult to imagine carbon nanotechnology applications which will not be enhanced by this enabling patented technology.\(^{121}\)

(CNI utilizes Professor Smalley’s patented technologies). When Nano-Proprietary learned of the issue of its new U.S. Patent on two-dimensional carbon nanostructures that it calls “carbon flakes,” the CEO of its Applied Nanotech subsidiary said, “These new patent developments, when combined with our existing portfolio, further our dominance of any applications where carbon is used as an electron emission source.”\(^{122}\) Those applications include flat panel displays and X-ray machines, either of which could turn into huge industries in a relatively short time.

Such sentiments are not limited to the carbon nanomaterial industry. Altair Nanotechnologies of Reno, Nevada, has been experimenting with a

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method for production of titanium dioxide catalyst structures that could allow for electrochemical production of titanium metal, dramatically reducing its price.\textsuperscript{123} Similar catalyst structures could have application in the building of fuel cells or sensors.\textsuperscript{124} The properties of titanium metal make it useful in the construction of military vehicles and in other applications requiring a metal with a high strength to weight ratio.\textsuperscript{125} The company president said, "If testing confirms the suitability of our micro-structured electrode materials for titanium metal production—this could be the first 'killer app' for nanotechnology."\textsuperscript{126} Indeed, the only reason that titanium is not used much more extensively as a structural material is that the current method of refining it is troublesome and expensive.\textsuperscript{127} Titanium could replace currently used steel products in many applications.

Recently, Dendritic Nanotechnologies of Mount Pleasant, Michigan, completed a deal giving the company access to the entire dendrimer intellectual property portfolio of the Dow Chemical Company (196 patents comprising 41 patent families).\textsuperscript{128} On the occasion, a Dow official said, "This move consolidates a great amount of the important intellectual property in the dendrimer field into one company. It will be very positive for developing the applications and further demonstrating the value of this technology."\textsuperscript{129} Dendrimers are "treelike macromolecules with branching tendrils that reach out from a central core" and have been used by researchers in a wide variety of applications.\textsuperscript{130} By custom-designing these molecules, researchers can preposition substituent groups in relation to each other on a nanoscale. By virtue of their relative positions, the substituent

\begin{itemize}
\item \textsuperscript{124} Id.
\item \textsuperscript{125} Id.
\item \textsuperscript{126} Id. (quoting Dr. Rudi E. Moerck, President of Altair Nanotechnologies).
\item \textsuperscript{127} Id.
\item \textsuperscript{129} Press Release, Dendritic Nanotechnologies, supra note 128 (quoting Mike Pirc, Manager of Intellectual Property, The Dow Chemical Company).
\item \textsuperscript{130} Bethany Halford, Dendrimers Branch Out, CHEMICAL & ENGINEERING NEWS, June 13, 2005, at 30.
\end{itemize}
groups can cooperate to achieve some useful purpose, such as to "prevent HIV infection by binding to receptors on the virus's surface." Wider use of dendrimers could bring about major advances in the treatment of HIV. They are also studied for possible roles in combating other viruses and cancer. Dendrimers are useful in drug delivery and the pharmaceutical industry generally.

For another example, Quantum Dot Corporation explains the exclusive position it derives from patents licensed from the University of California and the Massachusetts Institute of Technology. Quantum Dot has an exclusive license for biological applications of this technology, which involves tying semiconductor nanocrystals to biological molecules without affecting their biological activities. The crystals emit particular colors of light upon illumination, allowing for many new studies that involve tracking the movements of biological molecules in their natural environments or in other environments. (The wavelengths of light emitted by the crystals, perceived as their colors, are determined by their nanoscale dimensions).

Thus, examples of ownership by individual organizations of seminal technologies that could create completely new industries within a period of a few years are quite common in nanotechnology.

In all of these materials industries, the question at hand is whether the patent system is properly configured to allow these vitally useful technologies to develop at the maximum rate possible. In all cases, benefits paid as rewards to pioneers in an industry—commercial gain through monopoly—must be balanced with the cost to those who pay them—downstream customers who could benefit from their products.

C. Battles Waiting to Happen

Apart from patents with claims that may be too broad from the standpoint of optimally encouraging the development of nanotechnology and may lock up large application areas, observers and participants also see a problem with patents that may not have met the required non-obviousness standard and may therefore be in conflict. The patent statute provides:

131 Id.
135 Id.
A patent may not be obtained . . . if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. 137

Commentators have opined that the maze of dominant and overlapping patents in nanotechnology will be likely to lead to litigation as new companies attempt to stake out their beachheads on previously claimed continents. 138 Matthew Nordan calls the problem of overlapping issued patents with their potential for extensive litigation "[t]he biggest threat to commercialization" of nanotechnology. 139

With respect to the carbon nanotube business, one way to understand the problem is in the context of the business environment in which nanotube companies operate. Table 1 lists start-up companies involved in making carbon nanotubes and shows how recently this industry has formed. With all of these companies making nanotubes with some sort of carbon vapor deposition method, the aforementioned predictions of conflict seem reasonable. Many of these companies do not advertise their patents on their websites, and, as mentioned above, searches using the company name as assignee often fail to identify any patents. This lack of readily available information may lead to unease and may contribute to the filing of conflicting patents.

As shown in Table 2, the nanopowder industry is another industry that has grown up rapidly. Nanopowders are used widely in sunscreens, electronic components, food additives, catalysts, and other applications.

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138 Koppikar et al., supra note 82, at 27; MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 225; see generally Bawa, supra note 80, at 49; Ainsworth, supra note 80, at 20.
Table 1: Companies that Produce Carbon Nanotubes, Their Products, and Their Founding Dates

<table>
<thead>
<tr>
<th>Company</th>
<th>Products*</th>
<th>Founding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucky USA (Houston, TX)</td>
<td>S, M</td>
<td>1998</td>
</tr>
<tr>
<td>CarboLex (Lexington, KY)</td>
<td>S</td>
<td>1998</td>
</tr>
<tr>
<td>Carbon Nanotechnologies (Houston, TX)</td>
<td>S, D</td>
<td>2000</td>
</tr>
<tr>
<td>Carbon Solutions (Riverside, CA)</td>
<td>S</td>
<td>1998</td>
</tr>
<tr>
<td>Frontier Carbon (Japan)</td>
<td>fullerene</td>
<td>2001</td>
</tr>
<tr>
<td>Helix Material Solutions (Richardson, TX)</td>
<td>S, M</td>
<td>2003</td>
</tr>
<tr>
<td>Hyperion Catalysis (Cambridge, MA)</td>
<td>M</td>
<td>1982</td>
</tr>
<tr>
<td>Iljin Nanotech (Korea)</td>
<td>S</td>
<td>1998</td>
</tr>
<tr>
<td>Materials and Electrochemical Research (Tucson, AZ)</td>
<td>S, M</td>
<td>1985</td>
</tr>
<tr>
<td>Materials Technologies Research (Cleveland, OH)</td>
<td>S, M</td>
<td>1992</td>
</tr>
<tr>
<td>Microtechnano (Indianapolis, IN)</td>
<td>S, M</td>
<td></td>
</tr>
<tr>
<td>Molecular Nanosystems (Palo Alto, CA)</td>
<td>S, M</td>
<td>2001</td>
</tr>
<tr>
<td>Nanocarlab (Russia)</td>
<td>S</td>
<td>2001</td>
</tr>
<tr>
<td>Nanocraft, Inc. (Renton, WA)</td>
<td>S, M</td>
<td>2003</td>
</tr>
<tr>
<td>Nanocs, Inc. (sales office New York, NY)</td>
<td>S, M</td>
<td></td>
</tr>
<tr>
<td>Nanocyl (Belgium)</td>
<td>S, M</td>
<td></td>
</tr>
<tr>
<td>Nano Lab (Newton, MA)</td>
<td>M</td>
<td>2000</td>
</tr>
<tr>
<td>Nanoledge (France)</td>
<td>S, M</td>
<td>1999</td>
</tr>
<tr>
<td>Nanostructured &amp; Amorphous Materials, Inc. (Houston, TX)</td>
<td>S, M</td>
<td>2001</td>
</tr>
<tr>
<td>Rosseter Holdings (Cyprus)</td>
<td>M</td>
<td>1998</td>
</tr>
<tr>
<td>SES Research (Houston, TX)</td>
<td>S, M</td>
<td>1991</td>
</tr>
<tr>
<td>Southwest Nanotechnologies (Norman, OK)</td>
<td>S</td>
<td>2001</td>
</tr>
<tr>
<td>Sun Nanotech (China)</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>Thomas Swan &amp; Co., Ltd. (UK)</td>
<td>S, M</td>
<td></td>
</tr>
<tr>
<td>Xintek (Research Triangle Park, NC)</td>
<td>M</td>
<td>2000</td>
</tr>
</tbody>
</table>

*Products: S = single-walled carbon nanotubes, D = double-walled carbon nanotubes, M = multi-walled carbon nanotubes. The term “fullerene” often refers to geometric shapes other than tubes (e.g., buckyballs) but can include nanotubes.
Table 2: Companies that Produce Nanopowders, Their Products, and Their Founding Dates

<table>
<thead>
<tr>
<th>Company</th>
<th>Products</th>
<th>Founding</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP Materials, Inc. (St. Louis, MO)</td>
<td>tantalum</td>
<td>developing 1st product</td>
</tr>
<tr>
<td>Fuel Cell Materials (Lewis Center, OH)</td>
<td>gadolinium-doped ceria</td>
<td>2000</td>
</tr>
<tr>
<td>Inframat Advanced Materials (Farmington, CT)</td>
<td>tungsten carbide</td>
<td>1996</td>
</tr>
<tr>
<td>Meliorum Technologies (Rochester, NY)</td>
<td>silicon, zinc oxide, ceria</td>
<td>2003</td>
</tr>
<tr>
<td>NanoDynamics, Inc. (Buffalo, NY)</td>
<td>copper</td>
<td>2002</td>
</tr>
<tr>
<td>Nanomaterials (Malvern, PA)</td>
<td>complex oxides</td>
<td>1995</td>
</tr>
<tr>
<td>NanoPowders Industries (Israel)</td>
<td>silver, copper, nickel</td>
<td>1997</td>
</tr>
<tr>
<td>NanoSonic (VA)</td>
<td>metal rubber nanocomposite</td>
<td>1997</td>
</tr>
<tr>
<td>NanoSource (Oklahoma City, OK)</td>
<td>titanium dioxide</td>
<td>1999</td>
</tr>
<tr>
<td>Nanotechnologies, Inc. (Austin, TX)</td>
<td>aluminum, zinc, tin, gold, silver, aluminum</td>
<td>1999</td>
</tr>
<tr>
<td>nGimat™ (Atlanta, GA)</td>
<td>numerous</td>
<td>1994</td>
</tr>
<tr>
<td>QinetiQ (Britain)</td>
<td>silver, oxides</td>
<td>2001 (split from gov agency)</td>
</tr>
<tr>
<td>Samsung Corning (Corning, NY)</td>
<td>indium tin oxide</td>
<td>began nano in 2000</td>
</tr>
<tr>
<td>Tetronics (Britain)</td>
<td>numerous</td>
<td>1964</td>
</tr>
</tbody>
</table>

There is more insight to be gained from looking at comparable patents. Consider the following first claims from patents for carbon vapor deposition methods for preparing carbon nanotubes:

A method of making single wall carbon nanotubes comprising: a. providing metal particles on a support in a reaction zone; b. supplying a first carbon-containing gas to the reaction zone, under first conditions such that the metal particles which are large enough to primarily produce multiwall carbon nanotubes are deactivated; and c. supplying a second carbon-containing gas, which can be the same or different than the first carbon containing gas, to the reaction zone, under second conditions that are dif-
ferent from the first conditions and wherein single wall carbon nanotubes primarily are formed. 140

A method of synthesizing carbon nanotubes, comprising the steps of: introducing a catalyst in a reactor on a support structure that is not tolerant of a reaction temperature of the catalyst; supplying a reactant gas containing a carbon source gas over the catalyst; selectively and locally heating the catalyst in the reactor, without necessarily heating anything else, to the reaction catalyst temperature; and growing carbon nanotubes from the heated catalyst. 141

These patents were filed on March 16, 2001, and April 27, 2001, respectively. Comparing these two claims (CNI and Iljin, respectively), the methods appear to be quite similar; the CNI method emphasizes selective deactivation of the catalyst to prepare single wall carbon nanotubes exclusively.

Another example comes from the quantum dot field. Consider the following first claims from patents for quantum dots:

A water-dispersible nanoparticle comprising: an inner core comprised of a semiconductive or metallic material; a water-insoluble organic coating surrounding the inner core; and, surrounding the water-insoluble organic coating, an outer layer comprised of a multiply amphipathic dispersant molecule, wherein the dispersant molecule comprises at least two hydrophobic regions and at least two hydrophilic regions. 142

A semiconductor nanocrystal complex comprising: a surface-coated semiconductor nanocrystal comprising a semiconductor nanocrystal having a surface comprising molecules having a moiety with an affinity for the semiconductor nanocrystal and a moiety with an affinity for a hydrophobic solvent coating the semiconductor nanocrystal; and a diblock polymer coating surrounding the surface-coated semiconductor nanocrystal, the diblock polymer coating comprising a plurality of diblock polymers, each of the plurality of diblock polymers having a hydrophobic end for noncovalently interacting with the surface-coated semiconductor nanocrystal and a hydrophilic end, wherein adjacent ones of the plurality of diblock polymers are linked together by a bridging molecule. 143

143 Water-Stable Photoluminescent Semiconductor Nanocrystal Complexes and Method of Making Same, U.S. Patent No. 6,872,450 col.8 1.64 (filed Jul. 11, 2003) (issued Mar. 29, 2005).
These patents were filed by Quantum Dot, Inc., on April 23, 2001, and by Evident Technologies, Inc., on July 11, 2003, respectively. Both patents describe the structure of a quantum dot—a nanoscale semiconductor crystal with an inner hydrophobic coating and an outer coating with both hydrophilic and hydrophobic groups. The “plurality of diblock polymers” would have to have “at least two hydrophobic regions and at least two hydrophilic regions.” In this and the previous example, there seems to be room for argument, and all participants know that arguing in court is time-consuming and expensive.

Avoiding court battles seems to have become a priority for nanotechnology companies. Observers have made the general observation that there is not much, if any, patent infringement litigation ongoing in the nanotechnology area.\textsuperscript{144} A Lexis party search using the names of sixty nanotechnology companies revealed no patent infringement litigation, past or present, involving nanotechnology.\textsuperscript{145} This is striking, considering that twenty-one of these companies are attempting to develop carbon nanotube technology.\textsuperscript{146} Investor advisors have opined that players are holding back on legal action in the interest of allowing the total market for nanotechnology (and carbon nanotube-based) products to grow but that patent litigation will ensue when commercial activity becomes significant.\textsuperscript{147} Nanocor, a

\textsuperscript{144} Ainsworth, supra note 80, at 20 (quoting Edward K. Moran, director of product innovation for Deloitte & Touche’s technology consulting practice and leader of its nanotechnology practice) (“There’s not a lot of litigation going on yet in nanotechnology, which is curious, because it’s not difficult to find examples of one company’s IP bleeding into another’s.”); Bawa, supra note 80, at 49 n.49; MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 226.


\textsuperscript{146} MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 253.

\textsuperscript{147} Ainsworth, supra note 80, at 21 (quoting Q. Todd Dickinson, former PTO head, at this writing Vice President and Chief Intellectual Property Counsel at General Electric, and Douglas W. Jamison, Vice President of the investment house Harris & Harris Group, which has invested in nanotechnology).
commercial supplier of nanoclays since 1998, backs up the first part of that
counteue by saying on its website, "Nanocor purposely avoids any down
stream patents, in order to not impede customers from entering the market
place."148 Companies that have not avoided downstream patents may feel
reluctant to enforce them against those who are expanding markets in their
product areas. Companies might be deterred from initiating litigation by its
cost or by the risk of exposing themselves as infringers of intellectual prop-
erty that is still secret. Alternatively, the patent holder might be attracted by
the prospect of collecting greater damages after the target organization
achieves more success.149

D. Reforms at the United States Patent and Trademark Office Ease
Tensions

Mr. Miller and coauthors present a clear picture of what they per-
ceive are the problems with the present system, some of which are discussed
above. The perception of a patent thicket has been incorporated into the list
of problems that they see at the PTO. The problems include rejection of
valid claims, issuance of broad and overlapping claims, a fragmented and
chaotic IP landscape, insufficient expertise at the PTO, lack of centralized
review of nanotechnology applications, non-comprehensive searching of the
prior art, a high backlog of applications, issuance of patents that are too
broad, and issuance of too many patents in a given technology area.150 Other
difficulties that they perceive are caused by patent holders acting with im-
proper motivations. These include the use of patents to strangle competitors,
the use of patents by start-ups to block other start-ups, and the use of patents
by established corporations having market dominance to keep out new tech-
nology with potential for displacing their own.151

Dr. Bawa acknowledges the patent thicket problem, referring to the
"patent land grab" taking place as companies attempt to acquire patents with
broad claims.152 Problems he sees at the PTO include the lack of a Technol-
gy Center devoted to nanotechnology, lack of a classification system that
takes nanotechnology into account, high attrition among PTO staff, funding
problems, high patent pendency, limited industry-PTO interaction, and no
examiner training or guidelines relating to nanotechnology.153

The PTO has addressed some of the problems expressed by
nanotechnology patent practitioners since the Miller and Bawa comments

149 MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 226.
150 Id. at 65-71.
151 Id. at 74.
152 Bawa, supra note 80, at 46.
153 Id. at 18-20.
were published in 2004. The PTO has established a Class—Class 977—that is devoted to nanotechnology. The PTO has established a new cross-reference digest for nanotechnology to facilitate prior art searching across technology centers. President Bush submitted a budget request to Congress for fiscal year 2006 that includes $1.7 billion for the PTO, an amount equal to the fees the PTO anticipates will be collected. Congress has been in the habit of using some of the PTO fees for other purposes, but the President has opposed this. The PTO plans to hire 900 additional examiners in fiscal year 2006, bringing the total to over 4,500. This might be dependent on Congressional approval of the President’s budget request, but, if it passes, pendency should be reduced somewhat. Average patent pendency now exceeds two years for all but one of the PTO’s seven centers and exceeds three years for two of them. Also, the PTO reportedly “[b]egan training its examiners in nanotechnology concepts and terminology in November [2003], and has set up a working group of outside lawyers and researchers to give advice.”

IV. PROTECTING NANOTECHNOLOGY WHILE PROMOTING ITS GROWTH

Nanotechnology catches the imagination, government-supported research and development in nanotechnology is growing, and nanotechnology businesses are burgeoning. Taking advantage of the propensity of the PTO to grant patent applications, practitioners have collected numerous patents and find themselves in a patent thicket. Absent new legislation to rescue them, they must invent or license in order to free themselves. What action


157 Bawa, supra note 80, at 48 n.43.


160 Feder, supra note 139.
should be taken now to best protect the interests of all parties and promote the development of nanotechnology in the public interest?

A. Can’t We All Just Get Along?

Maybe we can. Indeed, as noted in the last section, heading off potential disputes through licensing has become the predominant means of continuing progress in nanotechnology, if only because the cost of litigation is so frightening. Innovators can and often do take matters into their own hands by making arrangements to share patented technology with each other and cut through the patent thicket. Individual licensing deals are quite common. For example, Sumitomo Corporation of Japan has licensed carbon nanotube technology from NEC and seems to have arranged an investment for technology deal with CNI. Nano-C, a Westwood, Massachusetts, nanotechnology company, recently licensed patents from the Massachusetts Institute of Technology for the synthesis and refining of fullerenes. Nanomix has licensed its technology for field-emitting thick film materials containing carbon nanotubes to DuPont. Evident Technologies of Troy, New York, has licensed lead selenide quantum dots from IBM. As noted above, there does seem to be some trend, exemplified for the dendrimer industry by Dendritic Technologies, to collect rights to large numbers of patents in a single organization. The collection by Nanosys, Inc., of patents relating to nanowires, nanoscale wire

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or rod structures made of semiconductors, is another example of this trend.167

But should all of this fraternization be left to chance and a multitude of bilateral agreements? One alternative that has been widely discussed in patent reform circles is patent pooling. Patent pools are cooperative arrangements that allow access by members of the pool to the patents of the entire group in exchange for what is deemed by the group to be a fair price. Patent pools have proliferated throughout U.S. history despite tension with and sometimes collision with the antitrust provisions of the Sherman Act.168 In 1856, the holders of sewing machine patents formed a patent pool that helped to get the new industry off the ground and lasted until the expiration of the patents.169 In the early days of the motion picture industry, ten manufacturers of motion picture films formed a patent pool covering manufacture, distribution, and exhibition of the films.170 The U.S. government sued under the Sherman Act and won in federal district court because the Court decided that the patents were incidental to the monopoly scheme.171 Four early manufacturers of gasoline formed a patent pool in the 1920's because patent disputes were inhibiting the growth of their businesses.172 This eventually led the Supreme Court to articulate in the Standard Oil case of 1931 that the formation of patent pools is permissible as long as this does not constitute domination of an industry with attendant price fixing.173 Patent pools in the twentieth century aided development of some of the most important new industries of the era including automobiles, aircraft, and television.174

Patent pools are still very much evident in modern practice. Economist Carl Shapiro has written a thoughtful discussion of patent pooling and antitrust law as they relate to the type of patent thicket problem that afflicts nanotechnology.175 Mr. Shapiro explains the tenuous way in which patent pools coexist with antitrust laws:

169 Id. at 40-41.
170 Id. at 46.
171 Id. (citing United States v. Motion Picture Patents Co., 225 Fed. 800, 811 (E.D. Pa. 1915)).
172 Id. at 47-49.
173 Id. at 48-49 (citing Standard Oil Co. v. United States, 283 U.S. 163, 167-75 (1931)).
174 Id. at 62-68.
175 See generally Shapiro, supra note 95 (suggesting that prosecutors avoid using antitrust law to discourage the pooling of complimentary patents in developing industries).
NEW WORLD OF NANOTECHNOLOGY

The Department of Justice has clearly articulated its policy towards patent pools/package licensing in a trio of business review letters regarding an MPEG [video compression technology] patent pool and two DVD [digital versatile disc] patent pools. The essence of this approach...is that inclusion of truly complementary patents in a patent pool is desirable and procompetitive, but assembly of substitute or rival patents in a pool can eliminate competition and lead to elevated license fees. Put differently, the key distinction in forming a patent pool is that between "blocking" or "essential" patents, which properly belong in the pool, and "substitute" or "rival" patents, which may need to remain separate.176

What about the patent thicket—a network of patents that are both essential and overlapping? Would patent pools in emerging areas of nanotechnology be lawful? If so, would they be desirable? Some commentators are answering "yes" to both questions. Mr. Miller and coauthors suggest that government encouragement of patent pooling would be beneficial, but they are skeptical about its feasibility.177

The lawfulness of patent pools in emerging areas of nanotechnology has not specifically been litigated, but related questions were at issue in a 1996 antitrust suit in Federal District Court in Delaware.178 Plaintiff Procter & Gamble (P&G) alleged that defendant Paragon infringed P&G’s “patent rights to the barrier leg cuff feature on disposable diapers.”179 Paragon counterclaimed for infringement of one of its patents and for violation of the antitrust laws.180 The Court noted that “At the close of 1994, P&G accounted for 38% of the disposable diaper sales in the United States” and that “Kimberly-Clark Corporation ("K-C") is the second largest producer of disposable diapers, with a 32% share of the market.”181 According to the Court, “P&G has been granted more than 250 U.S. patents on technology relating to disposable diapers. K-C holds even more.”182 After opposing each other numerous times in patent litigation at enormous cost, P&G and K-C came to an agreement to stop suing each other.183 One Paragon claim read, “P&G has entered into agreements and arrangements concerning competing patent rights creating a patent pool and discriminatory licensing venture,” and another claimed that P&G had “a wrongful policy of soliciting and obtaining United States letters patents which are excessive in number

176 Id. at 17.
177 See MILLER, HANDBOOK OF NANOTECHNOLOGY, supra note 9, at 80-82.
179 Id. at 103.
180 Id. at 103-104.
181 Id. at 104.
182 Id.
183 Id.
and virtually inextricable from each other and from the prior art."\textsuperscript{184} The Court considered the first of these under Section 1 of the Sherman Act and the second under Section 2.\textsuperscript{185}

The resulting summary judgment for P&G turned on P&G's intent in establishing the agreement with K-C and the Court's determination that P&G did not alone have a monopoly—Paragon had alleged only that P&G and K-C combined wielded monopoly power.\textsuperscript{186} Under Section 1 of the Sherman Act, Paragon had the burden of proving: "(1) that there was concerted action involving P&G; (2) that the concerted action caused anticompetitive effects within the relevant product and geographic markets; (3) that the objects of the conduct pursuant to the concerted action were illegal; and (4) that plaintiff was injured as a proximate result of the concerted action."\textsuperscript{187} The Court found that Paragon had failed under the first and third prongs, saying that "[t]he settlement of patent litigation, in itself, is not an antitrust violation."\textsuperscript{188} According to the Court, "[t]o be illegal under the antitrust laws, settlement agreements must 'be entered into in bad faith and utilized as part of a scheme to restrain or monopolize trade.'"\textsuperscript{189} Under Section 2 of the Sherman Act, Paragon had the burden of proving: "(1) that the defendant has engaged in predatory or anticompetitive conduct with (2) a specific intent to monopolize and (3) a dangerous probability of achieving monopoly power."\textsuperscript{189} Paragon's argument failed under the third prong because P&G was a party to the suit while K-C was not. In this instance, wherein a significant portion of the market was left outside of the patent pool, the pool was permitted.

Thus, in areas of nanotechnology where a single business entity has not become dominant, such as carbon nanotubes, participants might find patent pooling to be a legal and viable alternative. In fields where market areas are well defined and those market areas would be dominated by entities that pool resources, patent pooling may be more hazardous. But

\textsuperscript{185} \textit{Id.} at 106.
\textsuperscript{186} \textit{Id.} at 107-109.
\textsuperscript{187} \textit{Id.} at 107 (citing Petruzzi's IGA Supermarkets, Inc. v. Darling-Delaware Co., 998 F.2d 1224, 1229 (3d Cir. 1993)).
\textsuperscript{188} \textit{Id.} at 107 (citing Duplan Corp. v. Deering Milliken, Inc., 540 F.2d 1215, 1220 (4th Cir. 1976)).
\textsuperscript{189} \textit{Id.}; For a discussion of the intersection of antitrust and intellectual property law in the pharmaceutical and medical device industries, see also M. Howard Morse, \textit{Settlement of Intellectual Property Disputes in the Pharmaceutical and Medical Device Industries: Antitrust Rules}, 10 GEO. MASON L. REV. 359 (2002).
courts may indeed find that drawing the boundaries of market areas would not be easy. For example, nanotubes made of carbon have dominated the nanotube area up to the present time, participants have clearly thought of the nanotube market in that context, and that concept was becoming settled. Recently, however, scientists have found that nanotubes made from inorganic materials like tungsten sulfide or titanium dioxide have interesting properties and potential applications. Envisioned applications for these nanotubes include "bulletproof materials, high-performance sporting goods, [and] specialized chemical sensors . . . ." Carbon nanotubes will probably be competing in each of these markets. Nanotubes made from inorganic materials would be quite likely to fall outside of the claims of most of the patents said to form the "patent thicket" in the nanotube area, suggesting that the patent thicket concept could be thought of as a kind of researchers' mental block. In addition, from a public policy standpoint, patent pools carry the risk that existing patentees in patent pools might overvalue their contributions to future inventions and set prices too high to make participation by newcomers practical.

B. Practitioners Suggest Reform

Of course, some would argue that voluntary licensing of patents or voluntary patent pooling will not work fast enough and will not afford the many desirable rewards of nanotechnology research to the public in a way that is efficient and optimal. This line of thinking posits that if voluntary action will not achieve the goal, then government must act in the interest of the public to get research moving at a faster clip. The least irritating way to do this from the point of view of the participants would be to spend some money to widen the bottleneck at the USPTO. As noted above, Dr. Bawa suggests that what is needed is simply a repair of the current system, mainly in the form of more support for the USPTO to allow for some reform there and allow better compliance with current law. Perhaps the USPTO leadership read his paper—many of the reforms that he suggested were implemented in one form or another in 2004-05 as noted in the last section.

In his recent paper, attorney Ted Sabety champions somewhat stronger medicine involving some change in patentees' rights and better law enforcement in the public interest. Mr. Sabety argues first that government could be doing more within its existing authority to encourage pro-

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192 Id. at 31.
193 See Jacoby, supra note 2; See also Nikkei On Line, supra note 65.
194 See Bawa, supra note 80, at 47-49.
195 Sabety, supra note 8.
gress. He says, "Public funding agencies should more liberally apply their authority under the Bayh-Dole Act to encourage non-exclusive licensing of foundational nanotechnology patents."\textsuperscript{196} The portion of the patent statute enacted as part of the Bayh-Dole Act allows a federal agency providing funding for nanotechnology to require a resulting patentee to license her technology to applicant(s) of the agency's choosing under "reasonable" terms if the agency determines, presumably through administrative adjudication, that the patentee has not worked hard enough to achieve practical application of the invention within a reasonable time.\textsuperscript{197} Government agencies have been understandably reluctant to do this.

Secondly, Mr. Sabety argues that government imposition of compulsory licensing of "foundational patents" developed with public funding might be necessary in order to break up monopolies held by dominant patent holders.\textsuperscript{198} He further suggests that patentees be allowed to retain exclusivity for patents covering "follow-on innovations."\textsuperscript{199} In his consideration of the nanotechnology patent thicket, Mr. Sabety compares the development of nanotechnology with both the early development of the information technology industry in the 1950's and the early development of the radio industry in the 1920's.\textsuperscript{200} He bases his argument on inferences that the former developed in a nearly optimal way while the development of radio was hindered by early intellectual property (patent) monopolies.\textsuperscript{201} Explaining, he cites consent decree lawsuit settlements involving giants of the information industry—Western Electric, AT&T, and IBM—that involved compulsory licensing.\textsuperscript{202} The early development of radio, on the other hand, was subject to rampant patent litigation.\textsuperscript{203} The deadlock in radio development was broken only with the formation of Radio Corporation of America, which acquired much of the technology and entered into crosslicensing arrangements with other players in the industry.\textsuperscript{204} He goes on to say that the current legal status of nanotechnology innovations compels the conclusion that nanotechnology is more like radio of the 1920's than it is like the early information industry of the 1950's.\textsuperscript{205} This conclusion devolves from the fact

\textsuperscript{198} Sabety, supra note 8, at 279.
\textsuperscript{199} Id.
\textsuperscript{200} Id. at 8-15.
\textsuperscript{201} Id. at 11.
\textsuperscript{203} Id. at 11.
\textsuperscript{204} Id. at 12-13.
\textsuperscript{205} Id. at 15.
that "there was extensive patenting among a diverse group of unaffiliated private entities" in the radio industry,\textsuperscript{206} whereas, in the information industry, AT&T and the Bell System had already achieved a patent monopoly before court action mandated compulsory licensing.\textsuperscript{207} As he acknowledges, the analogy is not perfect. Early radio patents resulted from privately funded research,\textsuperscript{208} while early nanotechnology patents came largely out of government-funded university programs with some participation by industry. He suggests that "imitating the IP policy context under which the information technology industry was launched may be appropriate" and that moving toward a two tier patent system that mandates wide licensing of foundational technology would be best.\textsuperscript{209} He clearly believes that government must step in to establish a licensing scheme in order to avoid widespread and wasteful litigation in the future.

\textit{C. Just Ask the Professors}

Mr. Sabety is not alone in suggesting a two tier patent system. The problem is that proposing such a system presents the question of how to decide which patents are going to be foundational and should be selected for special treatment. As noted above, government agencies have been reluctant to get involved in this at all. One idea is to allow patent applicants to make the decision at the time of application. Professors Mark Lemley and Carl Shapiro have considered the idea of allowing applicants to apply for either a "Standard Patent" or a "Super Patent."\textsuperscript{210} The professors point out that this type of system, which would allow for two levels of scrutiny of applications at the PTO and two levels of property rights for patentees, would have some features in common with Australia's system of "petty patents."\textsuperscript{211} Conceptually, one could imagine cafeteria-style offerings by the PTO of numerous plans.\textsuperscript{212} The obvious drawback here is the fact that while inventors may have the best technical information about their inventions, they may not always be the best predictors of the commercial success of the invention and its future importance in generating the follow-on inventions that will redefine the boundaries of the endeavor involved.

Professors Lemley and Shapiro consider the potential of a two-tiered patent system in the context of a larger discussion of patenting as a

\begin{itemize}
\item \textsuperscript{206} Id. at 11.
\item \textsuperscript{207} Id. at 8.
\item \textsuperscript{208} Id. at 11.
\item \textsuperscript{209} Id. at 17-18.
\item \textsuperscript{210} Mark A. Lemley & Carl Shapiro, \textit{Probabilistic Patents}, 19 J. ECON. PERSP. 75, 85 (2005).
\item \textsuperscript{211} Id. at 85 n.9.
\item \textsuperscript{212} Id. at 85.
\end{itemize}
They point out that "only 1.5 percent of patents are ever litigated, and only 0.1 percent of patents are ever litigated to trial," and that "[r]oughly half of all litigated patents are found to be invalid ..." Of course, patents may be said to serve their purpose as a deterrent to infringers. With respect to the initial generation of patents, "the overwhelming majority of patent applications in the United States, perhaps 85 percent, ultimately result in an issued patent—far more than in Europe and Japan." Adding to this picture is the fact that, since the creation of the Court of Appeals for the Federal Circuit in 1982, the percentage of patents to be held on appeal to be valid and infringed has dramatically increased. The result is a system in which some patents are more valuable than ever, and others turn out to have much less value and may even be discarded before the end of the patent term through nonpayment of maintenance fees. Applicants have rushed to place their bets at the PTO, creating a backlog that is particularly burdensome for those involved in rapidly changing fields like those in nanotechnology. Some have suggested that a positive step would be to raise the non-obviousness standard by which patents are granted through more rigorous examination of applications and by getting applicants and their competitors more fully involved in the prosecution of patents. This might be done by instituting some form of post-grant opposition (right of competitors to challenge and invalidate a newly issued patent) as is now done in Europe or by eliminating the provision allowing treble damages for willful infringement of a patent. The European Patent

213 Id. at 80-83.
214 Id. at 75.
215 Id. at 76.
219 See Gallini, supra note 217, at 147.
220 See id. at 148.
Office currently allows post-grant opposition for a period of nine months after the grant; European patent attorney Matthew Dixon recommends that nanotechnology companies watch for new European patents and oppose them when necessary. This would offer challengers (potential infringers) a way of weeding out weak patents that would be cheaper than the current system of litigation. The treble damages provision has been blamed for the present maze of overlapping patents because it discourages patent filers from finding and reading too much prior art. (If an inventor does not know about prior art, he cannot be said to be willfully infringing it.)

Professor Shapiro makes other suggestions for reform as well. He makes his comments in the context of a discussion of two government reports that have appeared on the subject of patent system reform. He agrees with Dr. Bawa about the need to improve the PTO, especially with respect to speed and accuracy. He asserts that PTO procedures heavily favor applicants, and reforms could place more emphasis on patent quality. He suggests publishing all patent applications after eighteen months. Presently, applicants are allowed to suppress publication of their ideas until the patent issues if they do not intend to file in other countries. Professor Shapiro favors expanding prior user rights that give some relief to the applicant who files before an interfering patent issues. Under the current system, a patent filer can be surprised and preempted by another still-secret filing.

In their recent book about the "broken" U.S. patent system, Adam Jaffe and Josh Lerner argue the complaints expressed in the above studies—too many patents too easily approved and enforced—more forcefully than did Mr. Shapiro. Their prescription includes both pre-grant opposition

224 Gallini, supra note 217, at 139-40.
225 Shapiro, supra note 221.
227 Shapiro, supra note 221, at 1037-38.
228 Id.
229 Id. at 1038-39.
231 Shapiro, supra note 221, at 1044-45.
and post-grant opposition to allow for much more effective challenges to patent validity.  

Thinking outside of the box may lead one to consider leaving the patent system behind and finding a more suitable way to protect nanotechnology IP. In his discussion of hybrid patent/copyright regimes a decade ago, Professor Reichman pointed out that recent innovations such as software are characterized by ever shorter development times and decreased non-obviousness thresholds separating the innovations from improvements by second-comers.  

For example, software can often be copied with ease and improved incrementally in short time segments. He argued that this feature of inventions causes breakdown in the usual dual system of intellectual property because neither copyright nor patent can provide appropriate protection. His proposed remedy was to replace the natural time imposed by trade secret law between innovations, i.e., the time normally required for reverse engineering of a new product, by requiring payments from borrowers to originators. This seems essentially similar to the licensing system proposed by Mr. Sabety. Also, from a scientist's perspective, the fit to nanotechnology does not seem perfect because there is undoubtedly great toil and trouble separating inventions from the prior art in nanotechnology. Perhaps there has been some temptation at the PTO to reward the toil and trouble while paying too little attention to the actual progress made.

Finally, the "Law and Economics Approach" to understanding intellectual property regimes that is championed by Judge and Professor Richard Posner may be illuminating. Using this approach, patents are understood in terms of fixed costs, marginal costs, transaction costs, and a consideration of whether rewards to patentees are appropriate. Judge Posner discusses the tension between the monopolies that patents provide to the patentee and the ability of others to undermine those monopolies by inventing around the invention or finding flaws in the patent that invalidate it. He says that a policy of narrowly interpreting patents leads to prices (license fees) closer to marginal cost (lower and more efficient in an overall sense relative to prices that would attach to more broadly interpreted patents) but also to greater

233 *Id.* at 206.
235 Samuelson et. al., *supra* note 234, at 2337-38.
236 *Id.* at 2332-33.
239 *Id.* at 68.
aggregate costs because a new inventor may need many licenses in order to get started.\textsuperscript{240} More broadly interpreted patents may have lower aggregate costs and may have a healthy, incentive-increasing effect on the thinking of researchers because their work will have to show larger leaps relative to the prior art in order to get patented.\textsuperscript{241} The resulting patents would then have greater value to the patentee. On the other hand, a network of narrowly interpreted and overlapping patents might be stronger in the sense that each patent might be less readily invalidated. According to Judge Posner, a collection of more narrowly interpreted patents would cost more than fewer broadly interpreted ones and would thus counter monopoly by reducing the "incentive to expand and combine in order to diversify the risks of invention and internalize the benefits of inventions."\textsuperscript{242} But is this good or bad? This analysis has produced no generally applicable answer. The result is a situation that is intractable in the abstract and suggests that any single collection of patent statutes will produce among the aggregate of inventors very significant scatter relative to the target of optimum overall efficiency and fairness to all. As Judge Posner says, "[n]o one knows whether the current scope of patent protection is optimal."\textsuperscript{243}

\textit{D. Let Congress Fix It}

At this writing, Congress is considering a bill to be called on enactment the "Patent Reform Act of 2005."\textsuperscript{244} The bill proposes sweeping change, most notably a change to a "first to file" system that would scrap the current "first to invent" system that distinguishes the U.S. from all other countries internationally.\textsuperscript{245} The bill also provides for post-grant opposition to patents by allowing a competitor to file documents in an attempt to invalidate a patent within nine months of patent issue or within six months of a notice of infringement from the patentee.\textsuperscript{246} With respect to the treble damages for willful infringement now provided under section 284 of the patent statute, the bill would limit these increased damages to situations in which infringement continues for longer than a reasonable time following notice from the patentee, the infringer is found to intentionally have produced a copy of the invention with knowledge that it was patented, or he is a repeat infringer.\textsuperscript{247} By making the "willful" part of "willful infringement"
more clear-cut, this change is clearly designed to encourage applicants to become more aware of the prior art. Applicants might then be less prone to write applications that overlap with issued patents or published applications. Together with the existing requirement that an application for which a filing is to be made in another country be published 18 months after its U.S. filing date, the first-to-file provision would reduce the risk to applicants of later encountering prior art that was still secret at the time of filing. The first-to-file provision also, of course, continues the long term trend of harmonization with international intellectual property laws. (The disadvantage of a first-to-file system is that an inventor who has been holding and practicing an invention as a trade secret would have no recourse against another inventor who later independently develops and files a patent application for the invention.) Finally, the post grant opposition provision allows any flawed patents to be weeded out by the inventors' competitors in procedures that would be less costly than full blown litigation.

V. CONCLUSION

Nanotechnology is here to stay and will directly or indirectly improve the life of each person in the industrialized economies of the world. Governments and businesses are energizing to organize this great endeavor all around the globe. There is a great buzz to expand the boundaries of nascent fields such as carbon nanotubes, quantum dots, dendrimers, and nanowires and also to establish entirely new ones. Early fears of nanobots and "gray goo" have given way to realistic discussions of ways to protect the public and manage the uncertainty that comes with the emergence of a multitude of materials never before seen.

As with previous revolutionary advances in science, intellectual property laws must function to promote progress in the public interest. Many participants in the nanotechnology revolution agree that intellectual property is crucial to its development, and any business-related discussion about nanotechnology will invariably be about patents. They feel a great thirst for patents. Inventors file for as many patents as they think that they can get, viewing them as bricks that will cooperate to form the wall that will protect them from those who would deny them their reward. Newcomers who could enrich these fields with their talents can find this defense to be too formidable and unfair and may argue that it is not in the public interest. Those who do not turn away in discouragement generally find licensing to be preferable to the costly option of litigation, and there have been many license agreements among nanotechnology companies.

Some have said that licensing among nanotechnology companies should be more systematic and point to the historical success of patent pools, both those that were voluntary and those that were mandated by courts. This method might be chosen on a case by case basis as the optimum
way of breaking down the defensive walls around foundational advances and encouraging the growth of new industries.

Many voices have suggested that changes to the patent statutes will be needed in order to achieve this goal. Arguments center around the popular criticism that many of today’s patents should be more easily invalidated, or, in the alternative, that would-be patentees should have to clear a few more hurdles in order to obtain their patents. Among the proposed changes to current U.S. law, limiting the treble damages provision that causes inventors and patent attorneys to hesitate to explore the patent literature and getting would-be competitors involved in limiting patent scope prior to the expensive litigation stage seem to be the most helpful and practical. Congress is considering these two changes but has bundled them with a switch to a “first to file” patent system, a sweeping change that is certain to be controversial and unpopular among some inventors. Current law limits the involvement in the creation of property rights of those with the best information, leaving the courts to later sort out the injuries that occur as a result. In the end, we may have to defer to the complexity of the patent reform quandary, recognizing that some sacrifice of convenience may be required of many participants in the patent system for the greater good of having a single system within which we can all work as a unified nation. May the pioneer spirit that made our land what it is continue to improve it.