Patenting Nanotechnology[1]

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ABSTRACT

Universities and companies are rushing to the patent office in record numbers to patent nanotechnology inventions. This rush to the patent office is so significant that many law firms have established nanotechnology practice groups, and the U.S. Patent and Trademark Office has now created a new technology class designed to track nanotechnology products. Three big differences between the emerging science of nanotechnology and other inventions make the role of patents more significant here than elsewhere. First, this is the first new field in a century in which people started patenting the basic ideas at the outset. In most other fields of invention over the past century – computer hardware, software, biotechnology, the Internet – the basic building blocks of the field were unpatented. In nanotech, by contrast, companies and universities alike are patenting early and often. A second factor driving the importance of patents in nanotechnology is its unique cross-industry structure. Unlike other new industries, in which the patentees are largely actual or at least potential participants in the market, a significant number of nanotechnology patentees will own rights not just in the industry in which they participate, but in other industries as well. This may significantly affect their incentives to

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license the patents. Finally, a large number of the basic patents have issued to universities, who have become far more active in patenting in the last 25 years. While universities have no direct incentive to restrict competition, their interests may or may not align with the optimal implementation of building-block nanotechnology inventions.

I. The Race to Patent Nanotechnology

Nanotechnology is the study and use of the unique characteristics of materials at the nanometer scale, between the classical large-molecule level to which traditional physics and chemistry apply and the atomic level in which the bizarre rules of quantum mechanics take effect. The unique behavior of materials at the nanoscale[3] offers intriguing possibilities for the cheap construction of rare molecules, for the production of light and incredibly strong microfibers, and the production of ultrasensitive detectors.[4] Nanotechnology is at a speculative early stage; only a few nanotech inventions have so far actually made it into commercial products. But the expectations surrounding it are immense, ranging from a utopia of free energy

[3] Steve Jurvetson offers one striking example of size-related changes in the behavior of materials:

> [C]onsider the simple aluminum Coke can. If you take the inert aluminum metal in that can and grind it down into a powder of 20-30nm particles, it will spontaneously explode in air. It becomes a rocket fuel catalyst.

Steve Jurvetson, *Transcending Moore's Law with Molecular Electronics and Nanotechnology,* 1 **Nanotechnology L. & Bus. J.** 70, 77 (2004). *See also* **Mark Ratner & Daniel Ratner, Nanotechnology: A Gentle Introduction to the Next Big Idea** 7 (2003) (nanoscale circuit components don't necessarily obey Ohm's law); *id.* at 56-57 (the physical structure of carbon nanotubes makes them stronger and lighter than any other configuration of material)

[4] For a general discussion of the science of nanotechnology accessible to the lay reader, see **Mark Ratner & Daniel Ratner, Nanotechnology: A Gentle Introduction to the Next Big Idea** (2003).

and abundant materials[5] that will be one of the "major drivers of economic growth" in the foreseeable future[6] to fears of environmental catastrophe.[7]

Whether nanotech is mostly hype or is the wave of the future remains to be seen. But universities and companies seem to think there is something quite significant going on here, because they are rushing to the patent office in record numbers to patent nanotechnology inventions. This rush to the patent office is so significant that more than a dozen law firms have established nanotechnology practice groups,[8] and the U.S. Patent and Trademark Office has now created a new technology cross-reference designed to track nanotechnology products.[9]

Some of those patents cover improvements in existing industries, notably semiconductors, where the continuous effort to shrink transistor size in order to increase the

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5 *See* **Neal Stephenson, The Diamond Age** (199_); **Eric Drexler, Engines of Creation** (1986).

6 **National Research Council, Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative** 2 (2002). Indeed, some predict that by 2015 nano-related goods and services will contribute $1 trillion to the global economy. *See* Raj Bawa, *Nanotechnology Patenting in the US*, 1 **Nanotechnology L. & Bus. J.** 31, 36 (2004).

7 *See* Glenn Harlan Reynolds, *Environmental Regulation of Nanotechnology*, 31 **Env. Rptr. __** (2001) (noting predictions that "rogue nanodevices will devour the planet.").

8 Intellectual property law firms with separate nanotechnology groups include Sterne Kessler, Brinks Hofer, Burns Doane, Fish & Richardson, Fenwick & West, Fitzpatrick Cella, Foley & Lardner, Greenberg Traurig, DLA Piper Rudnick, Howrey Simon, Needle & Rosenberg, Pillsbury Winthrop, Preston Gates, Sughrue Mion, and Townsend.

9 *See Nanotech Cross-Reference Digest is 1st Step In Improved Examination, PTO Official Says*, 69 **Pat., Trademark, & Copyright J. (BNA)** 25 (Nov. 12, 2004). This will hopefully help to deal with the difficulty of finding prior art in a technology that crosses many product disciplines. *See* Bawa, *supra* note __, at 38 ("searching for nanotechnology-related patents and publications is complicated relative to other technology areas"); Sampat, *supra* note __, [draft at 25] (noting that nanotechnology patents appear in hundreds of different PTO technology classes).

speed and memory of chips has led companies into sub-micron (i.e. nanoscale) components.[10] Others cover the commercial products so far enabled by the behavior of materials at the nanoscale, such as a transparent sunblock for windows, stain-resistant coatings for clothing or carpeting, improved drug delivery systems, and nano-level filtration systems that can separate pollutants or bacteria from air or water.[11] Still other patents – arguably the most important ones – cover the basic research and production tools or building blocks of nanotechnology, such as atomic force microscopes that can manipulate individual molecules or carbon nanotubes that can be used to build very light, extremely strong products.[12] This last category of technology may or may not have a commercial market itself, but will need to be used to produce downstream commercial products in the other two areas.

A recent study by Bhaven Sampat estimates that over 3,700 nanotechnology patents were issued in the United States between 2001 and 2003.[13] That's a significant number of patents for a technology that has so far produced few actual products. But in fact there are significant reasons to think that Sampat's numbers understate the pace of nanotechnology patenting. First, he is intentionally conservative in his definition, classifying as nanotech inventions only patents

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[10] *See, e.g.,* U.S. Patent Nos. 6,162,532 ("Magnetic storage medium formed of nanoparticles"); 6,720,617 ("Thin film field effect transistor"); 6,835,911 ("Method and system for optically sorting and/or manipulating carbon nanotubes").

[11] *See, e.g.,* U.S. Pat. Nos. 6,337,362 ("Ultraviolet resistant pre-mix compositions and articles using such compositions"); 6,607,994 ("Nanoparticle-based permanent treatment for textiles"); 5,718,919 (nanoparticle coating for drug delivery system); 6,662,956 ("Nano-crystal containing filtration media").

[12] *See infra* notes __-__ (giving examples).

[13] Bhaven N. Sampat, *Examining Patent Examination: An Analysis of Examiner and Applicant-Generated Prior Art* (working paper 2004). Running the same search for the same dates in Lexis produces 5,796 patents. It is unclear what explains the discrepancy.

whose claims include a restricted set of keywords, and properly excluding the use of terms like "nanosecond" that might pick up unrelated inventions.[14] This conservatism makes sense if the goal is to make sure that the patents you identify are truly inventions in nanotechnology. But if the development of other new fields is any indication, there may be many patents out there that Sampat's study does not pick up, because they use different terminology or employ it in the specification rather than the claims. Second, the pace of patenting seems to be accelerating. Replicating Sampat's methodology for 2004 shows that another 1,929 were issued in 2004.[15] Third, and most important, the nearly three-year average delay between the filing of a patent application and the ultimate issuance of a patent[16] means that the patents Sampat studied were almost all based on inventions from the last century.[17] If the pace of nanotechnology invention is in fact accelerating, the growth of nanotechnology patents can be expected to continue in years

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[14] He does include "nanometer," which could cover both clear nanotechnology inventions involving nano-scale gate size and nanofiltration and unrelated inventions dealing with optics (because the wavelength of visible light is measured in nanometers). Altering Sampat's search to exclude nanometer reduces the number of patents substantially: only 56% of Sampat's issued patents, and 67% of the published applications, did not include any reference to "nanometer" in the claims. Communication from Michael F. Martin to Mark A. Lemley, Feb. 4, 2005 (on file with author). But while some of those patents are likely to be unrelated to nanotechnology as I have defined it, many will be true nanotech patents, especially in the semiconductor field.

[15] Lexis search conducted January 14, 2005 using the same parameters as Sampat's.

[16] John R. Allison & Mark A. Lemley, *Who's Patenting What? An Empirical Exploration of Patent Prosecution*, 53 **Vand. L. Rev.** 2099, 2118 (2000) (patents spend 2.77 years in prosecution on average).

[17] Some time must elapse between invention and filing, though it is generally no more than a year. Further, there is some reason to believe that nanotechnology patent applicants will take advantage of the continuation practice to delay the issuance of their patents, as biotechnology and pharmaceutical patentees have done, since there is as yet only a small market on which to capitalize. If the rather larger time that biotechnology and pharmaceutical patents spend in prosecution is any indication, the average time nanotech applications spend in the PTO may be more like four or five years. *See id.* at 2155 Tbl. 10 (biotechnology inventions spend 4.72 years and pharmaceutical inventions 4.46 year in prosecution on average).

to come. And it is clear that that pace is accelerating. The number of published patent applications in the U.S. that include the relevant terms in their claims has increased dramatically, as the following table demonstrates.[18]

Table 1

Dates			Published U.S. applications
2001			403[19]
2002			1975
2003			2964
2004			1384 + 2458 = 3842[20]

II. What Makes Nanotech Patents Different?

The importance of nanotechnology patents is not simply a matter of numbers. Three differences between the emerging science of nanotechnology and other inventions make the role of patents more significant here than elsewhere.[21]

[18] It is worth emphasizing that these numbers understate the actual number of patent applications filed in the PTO covering nanotechnology, because U.S. law permits applicants who do not intend to file abroad not to publish their applications. Nor do they include European nanotechnology patents. For a discussion of the latter, see Matthew Dixon, *European Patent Review*, 1 **Nanotechnology L. & Bus. J.** 100 (2004).

[19] Because U.S. patent law changed at the end of 1999 to require most applications to be published 18 months after they were filed, applications were not published until the middle of 2001. As a result, this number likely understates by about 40% the true number of applications filed during 2001. Data from subsequent years suffer no such bias.

[20] The component numbers indicate the applications filed in the first six months and the last six months of 2004, respectively. The difference between the two periods provides further evidence of the acceleration.

A. Patents on Building Blocks

First, this is the first new field in nearly a century in which people started patenting the basic ideas at the outset.[22] In most other fields of invention over the past century in what we might think of as "enabling" technologies – computer hardware, software, the Internet, even biotechnology – the basic building blocks of the field were unpatented, either because they were created by government or university scientists with no interest in patents, or through mistake, or because the government compelled licensing of the patents, or because the patents were ultimately invalidated.

In each of these fields this was largely the result of inadvertence rather than an express result of patent policy.[23] Indeed, the history of emergent fields in the last eighty years is a

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[21] While Barry Newberger argues that there are "no real doctrinal issues, certainly no burning doctrinal issues, in intellectual property protection and nanotechnology," Barry Newberger, *Intellectual Property and Nanotechnology*, 11 **Tex. Intell. Prop. L.J.** 649 (2003), I think he means by that only that there haven't been cases litigated yet that present those issues. They are coming.

[22] Two emerging technologies in which patents did play a prominent role were the airplane industry between 1903 and 1917 and the radio industry between 1912 and 1929. In both cases, the early patenting led to debilitating patent battles and arguably delayed the deployment of products in both industries. On airplanes, see George Bittlingmeyer, *Property Rights, Progress, and the Aircraft Patent Agreement*, 31 **J. L. & Econ.** 227 (1988); Peter C. Grindley & David J. Teece, *Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics*, 39 **Cal. Mgmt. Rev.** 8, 12 (1997). On radio, see Grindley & Teece, *supra*, at 90 n.4; **William MacLaurin, Invention and Innovation in the Radio Industry** (1949) *But cf.* Sabety, *supra* note __, at 275-76 (noting the large number of patent suits in the radio industry but suggesting that they didn't necessarily slow product introduction).

[23] Patent law does prohibit the patenting of "abstract ideas," O'Reilly v. Morse, 56 U.S. (15 How.) 62, 112 (1853), and this may sometimes serve to prevent early-stage patenting of broad concepts. *See* Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 **Va. L. Rev.** 1575, 1642-44 (2003) (discussing the doctrine). But it would not have prevented the patenting of basic technologies in any of the industries I discuss in text.

remarkable story in which invention after invention is put into the public domain for one reason or another. The computer, for example, was largely the result of military research projects during World War II, and government-sponsored research was not generally patented at that time. Even if it were, the military applications of the early computers meant that secrecy, not public disclosure, was the order of the day. The inventor of the computer, John Atanasoff, and his employer, Iowa State, thought about seeking patent protection but never did so.[24] AT&T did obtain basic patents on the transistor, an important component of later computers,[25] but licensed them broadly at low royalty rates because it was compelled to do so by an antitrust consent decree that also precluded it from entering the market for transistors itself.[26] Similarly, antitrust

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[24] There is substantial dispute as to who is the true first inventor of the computer. For a strong argument that it was John Atanasoff, a professor at Iowa State during World War II, see **Alice R. Burks & Arthur W. Burks, The First Electronic Computer: The Atanasoff Story** (1988); *see also* **Clark R. Mollenhoff, Atanasoff, Forgotten Father of the Computer**. The Burks argue that he had completed the computer. *Id.* at 277-78. Atanasoff himself says that it was ready for patenting, and that he engaged a patent attorney to patent it, with the rights assigned to Iowa State. Nonetheless, it was never patented. He writes:

> During the spring and summer of 1942, I continued to work with [Iowa State] and Mr. Trexler to get the patent underway. There always seemed to be some reason why it should be put off, however, and put off it was. The patent was never applied [for] by Iowa State College, probably due to short-term financial considerations.

J.A.N. Lee, Computer Pioneers 36-37 (1995).

The Electronic Numerical Integrator Analyzor and Computer (ENIAC), was developed by the Ballistics Research Laboratory in Maryland to assist in the preparation of firing tables for artillery. It was completed at the University of Pennsylvania's Moore School of Electrical Engineering in November 1945. While it was long treated as the first computer, and was in fact patented, that patent was held unenforceable on the ground that it was in fact improperly derived from Atanasoff. Honeywell v. Sperry Rand, 180 U.S.P.Q. 673 (D. Minn. 1973).

Other significant advances in computing came from the development of radar analysis and display systems by the U.S. and British militaries during the war. Sperry did patent one early computer, the Univac, in 1952 but apparently never enforced the patent in court.

[25] U.S. Patent No. 2,569,347.

[26] United States v. AT&T, 552 F. Supp. 131, 136 (D.D.C. 1956). For this argument, see Sabety, *supra* note __, at 269; Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope,* 90 **Colum. L. Rev.** 839, 896 (1990).

consent decrees compelled IBM to grant nonexclusive licenses to all its computer equipment patents at reasonable royalties.[27]

Basic software inventions were not patented because during the 1960s, 1970s, and early 1980s the courts took the position that software wasn't patentable at all.[28] The basic protocols of the Internet are in the public domain because they were developed with federal funding and at universities in the late 1960s and early 1970s, and public inventions were not generally patented at that time.[29] Subsequent basic Internet inventions, such as the World Wide Web, generally were not patented either because they were created by individuals at public institutions that did not think patents were necessary or appropriate[30] or because the inventors believed software still

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[27] United States v. IBM Corp., 1956 U.S. Dist. Lexis 3992, at 25-26 (S.D.N.Y. 1956). *But cf.* David McGowan, who argues that the consent decrees against IBM did not cause the openness of basic *software* inventions).

[28] *See, e.g.*, Gottschalk v. Benson, 409 U.S. 63 (1972); Parker v. Flook, 437 U.S. 584 (1978). For a brief discussion of how that rule was eroded into nonexistence, see Julie E. Cohen & Mark A. Lemley, *Patent Scope and Innovation in the Software Industry*, 89 **Calif. L. Rev.** 1, 8-11 (2001).

[29] That is no longer true today, in large part because of the Bayh-Dole Act of 1980, 35 U.S.C. §§200-212.

[30] Thus, Tim Berners-Lee, the inventor of the World Wide Web, was employed by CERN, a government-sponsored high energy research physics laboratory in Europe. He developed it in order to facilitate communication between physicists, and both he and CERN treated it as a tool for use in their primary work rather than as an end product in itself. In any event, as Berners-Lee later put it, "had the technology been proprietary, and in my total control, it would probably not have taken off. The decision to make the Web an open system was necessary for it to be universal. You can't propose that something be a universal space and at the same time keep control of it." Tim Berners-Lee, "Frequently asked questions," *available at* http://www.w3.org/People/Berners-Lee/FAQ.html. For a discussion of the development of the Web, see Timothy Wu, *Application-Centered Internet Analysis*, 85 **Va. L. Rev.** 1163 (1999).

wasn't patentable.[31] The Internet story isn't perfectly clear – patentees pop up periodically claiming to own pieces of the Internet[32] -- but as a general matter people have been able to use the basic protocols of the Internet free of patent liability.[33]

Basic inventions in biotechnology also largely ended up in the public domain, a fact that is somewhat more surprising given the importance of patents today in that industry.[34] A variety

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[31] Mosaic is widely recognized as the first web browser with graphics capability. *See* **Katie Hafner and Matthew Lyon, Where Wizards Stay Up Late: the Origins of the Internet** 258 (1996). The first version of Mosaic was released in early 1993 by Marc Andreesen and Eric Bina, who were then employees of the National Center for Supercomputing Applications (NCSA), an affiliate of the University of Illinois, Urbana-Champaign. *See* Marc Andreessen and Eric Bina, *NCSA Mosaic: A Global Hypermedia System*, 4 **Internet Research: Electronic Networking Applications and Policy** 7 (1994). Although the University of Illinois never filed patent applications on Mosaic, this was not the result of any policy generally unfavorable toward intellectual property. On the contrary, they were vigorous in their enforcement of copyright in Mosaic. *See, e.g., Procedures for Licensing NCSA Mosaic* (July 19, 1995), *available at* http://archive.ncsa.uiuc.edu/SDG/Software/Mosaic/License/LicenseInfo.html

The best explanation for why the University of Illinois did not apply for patents on Mosaic is probably that prior to 1995 it was not clear to those unversed in the field that software inventions were subject matter eligible for patenting. This speculation finds some support in the chronology of events that unfolded in 1995, after Andreessen and Bina had left NCSA to found Mosaic Communications Corporation (later Netscape Communications Corporation). On June 2, 1995 the Patent and Trademark Office issued its first set of proposed guidelines for examining software patent applications. *See* 60 Fed. Reg. 28,778. On August 15, 1995, Netscape's first patent application on browser technology was filed. *See* United States Patent No. 5,978,817 (claiming the benefit of priority of abandoned patent application number 08/515,189, filed August 15, 1995). But the basic technology, which was developed at NCSA, was not patented.

[32] Among the many such claims are British Telecom's claim to own a patent covering hyperlinks, DE's claim to own a patent covering all international electronic commerce, Acacia's claim to own patents covering the provision of video on demand, and CL/Forgent's claim to own a patent covering data compression.

[33] In fact, the Internet Engineering Task Force, which sets Internet standards, until recently forbade patents on its standards. *See* Mark A. Lemley, *Intellectual Property Rights and Standard-Setting Organizations,* 90 **Calif. L. Rev.** 1889, 1893 (2002) (discussing the change). The new policy is available at http://www.ietf.org/ipr.html.

[34] On the importance of biotech patents, see Dan L. Burk & Mark A. Lemley, *Biotechnology's Uncertainty Principle*, 54 **Case W. Res. L. Rev.** 691 (2004).

of different facts combined to produce this arguably fortuitous result. As a product of nature, DNA is ineligible subject matter for patenting. Even non-naturally occurring biological materials were not considered patentable until the Supreme Court's decision in *Diamond v. Chakrabarty*.[35] Methods for isolating DNA, however, would presumably have been patentable even before that time. Yet the earliest patent including a claim that mentions DNA did not issue until 1976,[36] over twenty years after DNA's structure was first described.[37] A more plausible explanation is that the basic research on the structure of DNA occurred quite early, well before universities were involved in patenting. Watson and Crick did their work in the early 1950s. Holley, Khorana and Nirenberg won a Nobel prize in 1968 for their work on the genetic code.[38] At that time, universities had strong norms against patenting, particularly in medical inventions.[39]

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35 447 U.S. 303 (1980).

36 . *See* U.S. Patent No. 3,931,397 ("Biologically active material").

37 *See* Watson, J.D. and Crick, F.H.C., "Molecular structure of Nucleic Acids," 171 Nature 737 (1953).

38 http://www.nobel.se/medicine/laureates/1968/press.html

39 *See* Sally Smith Hughes, *Making Dollars Out of DNA: The First Major Patent in Biotechnology and the Commercialization of Molecular Biology, 1974-1980*, 92 **Isis** 541 (2001). In her study, she describes how academic doctors had observed private norms against patenting, at least as far back as the American Medical Association's Code of Ethics of 1847. *See id*. at 547. Harvard, for example, had put in writing a policy against patenting faculty research in public health and therapeutics in 1934. *See id*. at 547. Moreover, "[m]ost universities of the day lacked the capacity to evaluate, let alone exploit, the commercial potential of faculty research findings." *Id.* at 546. Indeed, even at Stanford, which had the capacity (having formally established its licensing program in 1970) and an institutional history of "close interactions with companies in the region," *id.* at 547, Neils Reimers, the Office of Technology Licensing's first administrator, had a difficult time gathering political support for the patent applications, even from Cohen and Boyer themselves. *See id.* at 549 (recounting Reimers's recollection "that he had to talk to Cohen 'like a Dutch uncle' in obtaining his permission to file a patent application"). For a general discussion of the norm of openness in academic research, see Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 **Nw. U. L. Rev.** 77 (1999).

That norm may have influenced the United Kingdom's Medical Research Council and National Research and Development Corporation's decision not to apply for patents on Kohler and Milstein's invention of monoclonal antibodies.[40] Shortsightedness also played a role in that decision, however. The Council concluded that "the general field of genetic engineering is a particularly difficult area from the patent point of view and it is not immediately obvious what patentable features are at present disclosed" and that "[i]t is certainly difficult for us to identify any immediate practical applications which could be pursued as a commercial venture."[41]

Even once that norm began to change, university patents on basic building blocks in biotechnology were generally licensed freely. For example, Cohen and Boyer did obtain a fundamental patent on a method of creating chimeric DNA sequences, and Axel on methods of inserting genes into a cell, and both licensed their patents for significant revenue,[42] but largely because they were funded by the federal government before the passage of the Bayh-Dole Act, they granted nonexclusive licenses to all comers,[43] meaning that their patent raised the cost of practicing biotechnology but did not prevent anyone from entering the downstream market.

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[40] *See* Gordon Kohler & C. Milstein, *Continuous cultures of fused cells secreting antibody of predefined specificity*, 256 **Nature** 495 (1975).

[41] *See* **Robert P. Merges and John F. Duffy, PATENT LAW AND POLICY: CASES AND MATERIALS** 747, 3rd ed. (2002).

[42] The Cohen-Boyer patents went on to earn Stanford over $250 million before they expired in 1997. *See* Hughes, *supra* note __ at 570, n. 77.

[43] *See* Bernard Wysocki Jr., *Columbia's Pursuit of Patent Riches Angers Companies*, **Wall St. J.**, Dec. 21, 2004, at A1, A12 (noting that NIH required Axel to license his patents nonexclusively and at a reasonable royalty).

Finally, polymerase chain reaction (PCR), one significant biotechnology building block that was patented by a private corporation,[44] did generate significant revenue for the patent owner for many years. Ultimately the core patent was held unenforceable for inequitable conduct, however.[45]

The sum of all these stories is rather remarkable – for one reason or another, the basic building blocks of what might be called the enabling technologies of the 20th century – the computer, software, the Internet, and biotechnology – all ended up in the public domain. Whether through a policy decision, a personal belief, shortsightedness, government regulation, or invalidation of the patent, no one ended up owning the core building blocks of these

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44 Kary Mullis first conceived polymerase chain reaction (or "PCR") while working at Cetus Corporation. See Kary B. Mullis, *The Polymerase Chain Reaction (Nobel Lecture),* 33 **Angew. Chem. Int. Ed. Eng.** 1209 (1994). Although a friend suggested that he "resign [his] job, wait a little while, make it work, write a patent, and get rich," *id.* at 1212, Mullis "responded weakly to [his friend's] suggestion," expressing concern that if PCR "turned out to be commercially successful [Cetus] would have lawyers after [him] forever." *Id.* at 1213.

Mullis and his employer Cetus Corporation began filing patent applications on PCR in early 1985. See U.S. Patent No. 4,683,202 ("Process for amplifying nucleic acid sequences") (claiming the benefit of priority from abandoned application number 716,975 filed March 28, 1985) ("the '202 patent"). Numerous continuation and continuation-in-part applications were filed claiming priority to the '202 patent, including U.S. Patent No. 4,889,818 ("Purified thermostable enzyme") ("the '818 patent").

45 The successors in title to the '202 patent and its progeny, F. Hoffman-La Roche, Roche Molecular Systems Inc., and Applied Biosystems, had achieved a remarkable measure of success in licensing PCR technology before the '818 patent was ruled unenforceable for inequitable conduct on the Patent and Trademark Office in 1999, *see Hoffmann-La Roche, Inc. v. Promega Corp.*, 1999 WL 1797330 (N.D. Cal. 1999). Although the Federal Circuit reversed in part, *see Hoffman-La Roche Inc. v. Promega Corp.*, 323 F.3d 1354 (Fed. Cir. 2003), on remand the district court again held the '818 patent unenforceable, but refused to hold its family patents unenforceable under the doctrine of infectious unenforceability. *See Hoffman-La Roche Inc. v. Promega*, 319 F. Supp.2d 1011 (N.D. Cal. 2004).

The effect of these decisions on the market for PCR related products is difficult to determine. For example, some suppliers apparently began selling Taq polymerase without a license after the initial district court judgment in 1999. *See* Aileen Constans, *Courts Cast Clouds Over PCR Pricing*, 15 **The Scientist** 1, 8 (2001).

technologies. This may be thought a happy accident for innovation, or at the very least for follow-on improvers who commercialized particular implementations of these technologies – and patented those implementations.

In nanotech, by contrast, companies and universities alike are patenting early and often. While some of these patents are on industry-specific improvements to existing work above the nano-scale, particularly in semiconductors, others cover basic building blocks in nanotechnology. Indeed, many of the most basic ideas in nanotechnology are either already patented or may well end up being patented.[46] For example, patents have issued on carbon nanotubes,[47] semiconducting nanocrystals,[48] light-emitting nanocrystals,[49] metal oxide nanorods,[50] atomic force microscopes,[51] a method of making a self-assembling nanolayer,[52] and a method of producing nanotubes through chemical vapor deposition.[53] Indeed, there are only a

[46] Because patents can spend an unlimited time in the patent office, *see* Mark A. Lemley & Kimberly A. Moore, *Ending Abuse of Patent Continuations*, 84 **B.U. L. Rev.** 63, 64 (2004), and because many such patent applications will not be published, either because they were filed before 1999 or because they are filed only in the United States, 35 U.S.C. § 122, it is impossible to tell for certain whether currently unpatented technologies like buckminsterfullerine will ultimately be patented.

[47] U.S. Patent No. 5,424,054.

[48] U.S. Patent No. 5,505,928; *see also* U.S. Patent No. 6,268,041 (covering silicon or germanium nanocrystals of consistent size).

[49] U.S. Patent No. 6,322,901.

[50] U.S. Patent No. 5,897,945.

[51] U.S. Patent No. 5,833,705; U.S. Patent No. 4,724,318.

[52] U.S. Patent No. 5,286,571 (Oct. 21, 2003 to Mirkin et al). [check].

[53] U.S. Patent No. 6,346,189.

few basic building blocks in nanotechnology that are *unpatented,* notably buckminsterfullerine.[54] It is too early to tell for sure how significant nanotech building block patents will turn out to be or how they will be enforced, but it is quite possible that more of the fundamental building blocks of nanotechnology will be patented than in any of the industries just discussed.

B. Cross-Industry Patents

A second factor driving the importance of patents in nanotechnology is its unique cross-industry structure. Nanotech is not confined to a single field of endeavor, but exploits the peculiar properties of matter at the nanoscale across many different fields of modern engineering. Thus, a basic nanotechnology patent may have implications for semiconductor design, biotechnology, materials science, telecommunications and textiles, even though it is held by a firm that only works in one of these industries. To be sure, many nanotechnology inventions exist comfortably within a single industry – this is notably true of semiconductors – and don't seem to have significant cross-industry applications. But many others take advantage of the unique physical properties of nanoscale materials to put things to radically different uses. Companies may use organic self-assembly to create electronic components that traditionally required mechanical deposition, for example.[55] Unlike other new industries, in which the patentees are largely actual or at least potential participants in the market, a significant number of corporate nanotechnology patentees will own rights not just in the industry in which they

[54] Buckminsterfullerine, or carbon-60, which was discovered in 1985 by Curl, Smalley and Kroto, see H.W. Kroto et al., *C60: Buckminsterfullerine*, 318 **Nature** 162 (1985), is itself unpatented, and might well be unpatentable as a naturally occurring product of nature. Hundreds of patents on *implementations* of the molecule have issued, however. See "Fullerine Patent Database," http://www.godunov.com/Bucky/Patents.html.

[55] Jurvetson, *supra* note __, at 83.

participate, but in other industries as well.[56] This may significantly affect their incentives to license the patents, as I discuss below. Certainly, the experience of the semiconductor and information technology industries has been that patentees who do not participate in the market are more likely to sue to enforce their patents than those who are in the market.[57] Whether it does or not, at a minimum it means that companies looking to clear patent rights in nanotechnology must look not only to inventors in their field but must search in widely disparate fields as well.

C. The Role of Universities

The uniqueness of nanotechnology is also a feature of the third significant fact about nanotechnology patents: they are held in surprisingly large proportions by universities. Universities and public interest foundations generally hold only about 1% of the patents issued in the United States each year.[58] But they hold a grossly disproportionate share of nanotech

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[56] The fact that Sampat's study identified patents in 253 different international patent classes is some indication of the breadth of the technology involved. *See* Sampat, *supra* note __, at 25.

[57] There are numerous examples of both small licensing shops and large companies who have essentially left the market filing patent lawsuits in these industries. For example, Jerome Lemelson is famous for having licensed his patents aggressively, and Texas Instruments is the most aggressive licensor of patent in the semiconductor industry. Lemelson did not make any products himself, and therefore didn't need cross-licenses from anyone. TI, while still a player in many markets, litigated primarily in the area of large scale integrated circuits, in which it did not have significant sales by the time of the lawsuits. Empirical evidence suggests that small companies are much more likely to enforce their patents than large ones, John R. Allison et al., *Valuable Patents*, 92 **Geo. L.J.** 435, 465-70 (2004), but does not provide a way to distinguish small market participants from small non-participants.

[58] John R. Allison & Mark A. Lemley, *Who's Patenting What? An Empirical Exploration of Patent Prosecution*, 53 **Vand. L. Rev.** 2099, __ (2000).

patents. Of the patents identified using Sampat's methodology, at least 12% are assigned to universities, a dozen times as many as in the general population.

Table 2

Nanotechnology Patents Assigned to Universities[59]

Issue Date	Number of Nanotech Patents	Number Assigned to Universities	Percentage Assigned to Universities	
2001	1077	148	13.7%	
2002	1217	138	11.3%	
2003	1534	175	11.4%	
2004	1708	203	11.9%	
Total	5536	664	12.0%	

Further, the university-owned patents are more likely to be the upstream patents on building blocks that are of critical importance to innovation than particular downstream implementations of a technology. This is harder to test empirically, but it seems to be borne out

[59] We searched those patents for those with the terms "university," "college," "trustee", or "foundation" in the assignee field. We found 664 of the 5536 issued nanotechnology patents that had this criteria. These criteria are possibly both over- and underinclusive – overinclusive because the term "foundation" or "trustee" in the name of a patent owner may sometimes signal a private rather than university non-profit, and underinclusive because there may be university-controlled patents that are held by entities with different names.

Interestingly, we found a much smaller percentage (381 of 9184, or only 4%) of published patent applications that met this criterion. But that appears to be a statistical artifact. A large number of published applications do not list *any* assignee, even though recent changes to PTO regulations require that information to be disclosed in the application, 37 C.F.R. § 1.215(b), and even though most of those patents will ultimately turn out to be assigned. *Id.* at __ (finding that __% of patents are assigned in the general population). We spot-checked applications from 2001 and found that many of the applications that list no assignee result in issued patents that do list an assignee. Further evidence that this is a data problem and not a trend is that it is true across all the years we studied, even 2001 and 2002. If there were a trend away from university patenting, we would expect to see it reflected in patents that issued in later years. But as Table 2 shows, there is no such trend.

when one looks at the specific patents being granted to universities. Indeed, of the eight foundational patents I identified above, six are owned by universities.[60] And 60% of the publicly announced nanotechnology patent licenses in 2003 were licenses granted by universities.[61]

There are several likely reasons for the comparative dominance of universities in nanotech patenting. First, the technology is still in its infancy, and many of the patents that have issued so far – certainly many of the basic building-block patents that are most relevant here – issue to research labs doing fundamental science, rather than to specific product implementations. It is not too surprising that most of those basic research labs are located in universities. Indeed, this may be a pattern with enabling technologies. Darby and Zucker argue that industries enter breakthrough technologies when university scientists publish significant enabling research – what Griliches calls the "invention of methods of inventing."[62] Thus, universities may be the drivers of early-stage nanotechnology just as they have been with many other enabling technologies.

Second, unlike the basic, government-sponsored university research of a past generation, universities in the modern era are extremely aggressive patenters. This shift was largely precipitated by the Bayh-Dole Act of 1980,[63] which was designed to encourage university technology transfer by permitting universities to patent their federally funded research projects.

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[60] U.S. Patent No. 6,268,041 is owned by Starfire Electronic Development and Marketing, and 5,424,054 is owned by IBM.

[61] Calculation from *Nanotechnology Updates*, 1 **Nanotechnology L. & Bus. J.** 130, 131-32 (2004). It is worth noting that these numbers may be skewed because private companies are less likely to announce their patent licenses.

[62] Michael R. Darby & Lynne G. Zucker, *Grilichesian Breakthroughs: Invention of Methods of Inventing and Firm Entry in Nanotechnology*, __ **Annales d'Economie et Statistique** __ (forthcoming 2005) (citing Zvi Griliches).

[63] 35 U.S.C. §§200-212.

The results were dramatic. Before 1980, universities worldwide obtained about 250 U.S. patents a year. In 2003, they obtained 3,933 patents, an almost sixteen-fold increase.[64] Given this across-the-board increase, it is all the more striking that universities hold twelve times as many patents in nanotechnology as they do in general. But it may reflect the disproportionate role of academic institutions in early-stage technologies more generally, something that we would have seen with prior enabling technologies had universities been involved in patenting when those technologies were in their infancy.

Third, nanotechnology may particularly lend itself to trade secret protection. It is relatively easy to keep many nanotech inventions secret, and even when nanotechnology products are released on the open market reverse engineering them may be significantly more difficult for competitors than it would be in other fields. As a result, companies may choose to forego patent protection in favor of trade secrecy, at least at this early stage. By contrast, universities have no such incentive; the benefit they get from IP protection for a nanotech invention comes entirely from licensing revenue. So they may be more likely than private companies to patent their inventions. This final explanation, if true, has an interesting side effect – it suggests that nanotechnology patents *understate* the innovation occurring in the field, since much of it is being kept secret.

III. Are Nanotech Patents Good for Innovation?

[64] Wysocki, *supra* note __, at A12 (reporting data from the Association of University Technology Managers). For a discussion of the growth of university patenting and its potential risks, see **David C. Mowery et al., Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act** (2004); Katherine J. Strandburg, *Curiosity-Driven Research and University Technology Transfer* (working paper 2005).

A. The Risks of Overpatenting

These facts in combination mean that patents will cast a larger shadow over nanotech than they have over any other modern science at a comparable stage of development. Indeed, not since the birth of the airplane a hundred years ago have we seen similar efforts to patent basic concepts in advance of a developed market for end products.[65] Some fear that ownership of nanotechnology patents is too fragmented, risking the development of a patent "thicket."[66] Miller offers several examples of nano-scale technologies that have overlapping patents covering the same basic invention, including the carbon nanotube and semiconducting nanocrystals.[67]

Some will worry that this larger role for patents will interfere with innovation in nanotechnology. While in theory patents spur innovation, they can also interfere with it.[68]

[65] One possible factor reducing the significance of nanotech patents is Doug Lichtman's finding that nanotechnology patents are amended more frequently than other types of inventions. Douglas Lichtman, *Rethinking Prosecution History Estoppel*, 71 **U. Chi. L. Rev.** 151 (2004). This may mean that the doctrine of equivalents will play a less significant role in ensuring that those inventions have effective patent scope, a particularly significant limitation in a new and rapidly changing field such as nanotech.

[66] *See, e.g.,* **John C. Miller et al., The Handbook of Nanotechnology: Business, Policy, and Intellectual Property Law** 224 (2005) ("In many different areas of nanotechnology, the intellectual property landscapes are fragmented. A large number of patents held by different entities cover similar inventions and improvements to the same invention."); *id.* at 68; Sabety, *supra* note __, at __. For a general discussion of the patent thicket, see Carl Shapiro, *Navigating the Patent Thicket: Cross Licensing, Patent Pools, and Standard Setting, in* 1 **Innovation Policy and the Economy** 119, 121 (Adam B. Jaffe et al. eds., 2001)

[67] **Miller et al.,** *supra* note __, at 69-71.

[68] A significant literature discusses the tradeoffs involved in setting the right level of intellectual property protection. This effort at balance is a constant theme in Supreme Court intellectual property cases and the discussions of commentators. *See, e.g.,* Graham v. John Deere Co. of Kansas City, 383 U.S. 1, 9 (1966) ("The patent monopoly was not designed to secure to the inventor his natural right in his discoveries. Rather, it was a reward, an inducement, to bring forth new knowledge."); Mazer v. Stein, 347 U.S. 201, 219 (1954) ("The economic philosophy behind the clause empowering Congress to grant patents and copyrights is the conviction that encouragement of individual effort by personal gain is the best way to advance public welfare

Broad patents granted to initial inventors can lock up or retard necessary improvements needed to take a new field from interesting lab results to commercial viability.[69] And the dispersion of

. . . ."); *see also* Fogerty v. Fantasy, Inc., 510 U.S. 517, 524 (1994) ("The primary objective of the Copyright Act is to encourage the production of original literary, artistic, and musical expression for the good of the public."); Feist Publ'ns, Inc. v. Rural Tel. Serv. Co., 499 U.S. 340, 349-50 (1991) (stating that the "primary objective of copyright" is to promote public welfare); Stewart v. Abend, 495 U.S. 207, 224-25 (1990) (noting the Copyright Act's "balance between the artist's right to control the work . . . and the public's need for access"); Bonito Boats, Inc. v. Thunder Craft Boats, Inc., 489 U.S. 141, 167 (1989) (noting the "careful balance between public right and private monopoly to promote certain creative activity"); Sony Corp. of Am. v. Universal City Studios, Inc., 464 U.S. 417, 429 (1984) (stating that the limited monopoly conferred by the Copyright Act "is intended to motivate creative activity of authors and inventors . . . and to allow the public access to the products of their genius after the limited period of exclusive control has expired"); Twentieth Century Music Corp. v. Aiken, 422 U.S. 151, 156 (1975) (noting that "private motivation must ultimately serve the cause of promoting broad public availability of literature, music, and other arts"); Goldstein v. California, 412 U.S. 546, 559 (1973) (discussing Congress's ability to provide for the "free and unrestricted distribution of a writing" if required by the national interest); Fox Film Corp. v. Doyal, 286 U.S. 123, 127 (1932) ("The sole interest of the United States and the primary object in conferring the monopoly lie in the general benefits derived by the public from the labors of the authors.") (quoted in United States v. Paramount Pictures, 334 U.S. 131, 158 (1948)). For commentators' discussions, see, e.g., 1 PAUL GOLDSTEIN, COPYRIGHT § 1.14, 1: 40 (2d ed. 1995); L. RAY PATTERSON & STANLEY W. LINDBERG, THE NATURE OF COPYRIGHT 120-22 (1991); Julie E. Cohen, *Reverse Engineering and the Rise of Electronic Vigilantism: Intellectual Property Implications of "Lock Out" Programs,* 68 **S. Cal. L. Rev.** 1091, 1198 (1995); Matthew J. Conigliaro et al., *Foreseeability in Patent Law,* 16 **Berkeley Tech. L.J.** 1045 (2001); Dennis S. Karjala, *Federal Preemption of Shrinkwrap and On-Line Licenses*, 22 U. DAYTON L. REV. 511 (1997); Mark A. Lemley, *Romantic Authorship and the Rhetoric of Property,* 75 TEX. L. REV. 873 (1997); Pierre N. Leval & Lewis Liman, *Are Copyrights for Authors or Their Children?*, 39 J. COPYRIGHT SOC'Y 1, 11 (1991); Jessica Litman, *The Public Domain,* 39 EMORY L.J. 965, 967- 68 (1990); Peter S. Menell, *An Analysis of the Scope of Copyright Protection for Application Programs*, 41 STAN. L. REV. 1045, 1082 (1989); Margaret Jane Radin, *Property Evolving in Cyberspace,* 15 J.L. & COM. 509, 515 (1996). These are only a few of the innumerable citations on this point.

Of course, the operative word here is "balance." Pioneering inventors will emerge only if there are sufficient incentives for them to invent. At the same time, too great a division of rights can impede effective use of technologies. *See* Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCI. 698 (1998). The fact that the law must also encourage competition to improve such pioneering inventions means that the law must take care to allocate rights between the parties. *See* Craig Allen Nard, *A Theory of Claim Interpretation,* 14 HARV. J.L. & TECH. 1, 36-40 (2000).

[69] There are at least three strands to this argument. First, for a variety of reasons, society cannot rely on pioneers to efficiently license to improvers the right to compete with them. *See* Rebecca

overlapping patents across too many firms can create an anticommons or thicket problem, making effective use of the technology difficult if not impossible.[70] Indeed, the executive director of the NanoBusiness Alliance expressed just such a worry in hearings before Congress,

S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, 56 U. CHI. L. REV. 1017, 1072-73 (1989) ("The risk that the parties will be unable to agree on terms for a license is greatest when subsequent researchers want to use prior inventions to make further progress in the same field in competition with the patent holder, especially if the research threatens to render the patented invention technologically obsolete."); Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989, 1048-72 (1997) (offering a variety of reasons why granting exclusive control to pioneers is inefficient); Robert P. Merges, *Intellectual Property Rights and Bargaining Breakdown: The Case of Blocking Patents*, 62 TENN. L. REV. 75 (1994) [hereinafter Merges, *Intellectual Property*]; Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 **Colum. L. Rev.** 893 (1990). Second, positive "spillovers" from innovation that cannot be appropriated by the innovator actually contribute to further innovation. *See, e.g.,* Wesley M. Cohen & David A. Levinthal, *Innovation and Learning: The Two Faces of R&D*, 99 ECON. J. 569 (1989); Zvi Griliches, *The Search for R&D Spillovers*, 94 SCAND. J. ECON. S29 (1992); Richard C. Levin, *Appropriability, R&D Spending, and Technological Performance*, 78 AM. ECON. REV. 424, 427 (1988); Richard Schmalensee, *R and D Cooperation and Competition: Comments and Discussion*, 1990 BROOKINGS PAPERS ON ECON. ACTIVITY 194, 195-96 (1990); *Cf.* Scotchmer, *supra* note **Error! Bookmark not defined.** (noting difficulties in the optimal allocation of rights between pioneers and improvers). Third, granting strong intellectual property rights encourages rent-seeking, which may dissipate the social value of the property rights themselves. *See* Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, 83 **Tex. L. Rev.** __ (forthcoming 2005); Jessica Litman, *Copyright Legislation and Technological Change*, 68 OR. L. REV. 275 (1989); Jessica D. Litman, *Copyright, Compromise, and Legislative History*, 72 CORNELL L. REV. 857 (1987); Mark S. Nadel, *Why Copyright Law May Have a Net Negative Effect on New Creations: The Overlooked Impact of Marketing* (working paper 2004).

[70] On the anticommons, see Heller & Eisenberg, supra note __; Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 **Harv. L. Rev.** 621 (1998); Arti K. Rai, *The Information Revolution Reaches Pharmaceuticals: Balancing Innovation Incentives, Cost, and Access in the Post-Genomics Era*, 2001 **U. Ill. L. Rev.** 173, 192–94. On the closely related concept of the patent thicket, see Carl Shapiro, *Navigating the Patent Thicket: Cross Licensing, Patent Pools, and Standard Setting*, in 1 **Innovation Pol'y and the Econ.** 119, 121 (Adam B. Jaffe et al., eds., 2001). See also James Bessen, *Patent Thickets: Strategic Patenting of Complex Technologies* (working paper 2003).

warning that "several early nanotech patents are given such broad coverage, the industry is potentially in real danger of experiencing unnecessary legal slowdowns."[71]

Risks of a patent thicket may be exacerbated by the application of pre-nanotechnology patents to nanotech inventions. For example, a last-generation patent on an invention in microprocessors might call for a "sub-micron gate." Such a claim would be literally infringed by a gate of 100 nm, even though the design and behavior of the materials in the nano-sized gate might be fundamentally different than that of a gate of 950 nm. If pre-nanotechnology patents are interpreted to cover their nanotech counterparts, it would multiply significantly the number of patents that nanotech companies had to deal with. Arguably those patents should not apply, for the very reason that there is something unique about the nanoscale that affects the behavior of materials in ways that pre-nanotech inventors did not contemplate. As a result, some have suggested that nanotechnologies should escape infringing those older patents under the reverse doctrine of equivalents,[72] though recent case law is not encouraging for application of the doctrine.[73] A similar issue arose in electronics during the transition from analog to digital technology; courts there had to consider whether technology from an older generation could apply to new inventions accomplishing similar goals but in different ways. The results from that

[71] Senate Commerce Committee Hearings, http://commerce/senate.gov/hearings/testimony.cfm?id=845&wit_id=2323 (testimony of Mark Modzelewski).

[72] Andrew Wasson, *Protecting the Next Small Thing: Nanotechnology and the Reverse Doctrine of Equivalents*, 2004 **Duke L. & Tech. Rev.** 10. For a general discussion of the doctrine, see Robert P. Merges, *Intellectual Property Rights and Bargaining Breakdown: The Case of Blocking Patents*, 62 **Tenn. L. Rev.** 75 (1994).

[73] Tate Access Floors v. Architectural Resources, 279 F.3d 1357 (Fed. Cir. 2002) purported to abolish the doctrine, or at least to say it was coextensive with the reach of 35 U.S.C. §112, ¶ 6. But the Federal Circuit reaffirmed the validity of the doctrine not long after in Amgen, Inc. v. Hoechst Marion Roussel, 314 F.3d 1313 (Fed. Cir. 2003).

experiment were mixed.[74] The specter of pre-nanotech patents piling on to the large number of nanotech patents may make the patent thicket loom large in the minds of innovators in this industry.

It is too early to tell whether these concerns will come to pass. The early airline industry was locked in debilitating patent disputes for a decade, until the government stepped in during World War I and required the parties to cross-license their patents.[75] By contrast, some recent developments in genomics suggest that it may be possible for patent owners to act collectively to open fundamental resources to individual exploitation, at least where their incentives are largely symmetric.[76] It is not clear whether a similar arrangement is possible in nanotech, given the somewhat different interests of firms applying nanoscale inventions in different engineering

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74 For a discussion, see Julie E. Cohen & Mark A. Lemley, *Patent Scope and Innovation in the Software Industry*, 89 **Calif. L. Rev.** 1, 45-47, 54-56 (2001).

75 *See, e.g.*, George Bittlingmeyer, *Property Rights, Progress, and the Aircraft Patent Agreement*, 31 **J. L. & Econ.** 227 (1988); Robert P. Merges, *Contracting Into Liability Rules: Intellectual Property Rights and Collective Rights Organizations*, 84 **Calif. L. Rev.** 1293, 1356-57 (1996). Ted Sabety suggests that radio is a better analogy. Hundreds of patents sprung up there, and produced substantial litigation and patent pooling, but Sabety concludes that they did not significantly impede downstream innovation. Ted Sabety, *Nanotech Innovation and the Patent Thicket: Which IP Policies Promote Growth?*, 1 **Nanotechnology L. & Bus. J.** 262 (2004).

76 *See, e.g.*, Dan L. Burk, *Open Source Patenting*, 1 **J. Int'l Biotech. L.** 221 (2004); Robert P. Merges, *A New Dynamism in the Public Domain*, 71 **U. Chi. L. Rev.** 183 (2004); Arti K. Rai, *Open and Collaborative Research: A New Model for Biomedicine*, in **Innovation in Frontier Industries: Biotech and Software** (Robert Hahn ed. forthcoming 2005) (all discussing open source genomics). The computer and telecommunications industries have somewhat similar rules mediated through the mechanism of standard-setting organizations. *See* Mark A. Lemley, *Intellectual Property Rights and Standard-Setting Organizations*, 90 **Cal. L. Rev.** 1889 (2002). And portions of the software industry achieve this result through the mechanism of open source licensing, at least where copyright rather than patent rights are concerned. *See* David McGowan, *Legal Implications of Open-Source Software*, 2001 **U. Ill. L. Rev.** 241; Yochai Benkler, *Coase's Penguin: Linux and the Nature of the Firm*, 112 **Yale L.J.** 369 (2002); Greg R. Vetter, *The Collaborative Integrity of Open Source Software*, 2004 **Utah L. Rev.** 563.

fields. If it is not possible, downstream innovation may be either rendered illegal or at best constrained within official channels pre-licensed by patentees. Scholars have worried in other contexts that such pioneer control over follow-on innovation may not be optimal.[77] And while universities at least could once rely with some confidence on their effective immunity from suit for engaging in basic experimentation, that is no longer true.[78]

Another consideration is practical – nanotechnology patents may be difficult to enforce because it is hard to detect infringement.[79] There are to date relatively few products that use nanotech inventions; much of whatever infringement of nanotechnology patents occurs today is confined to research laboratories. It is hard to tell from the outside whether a lab is using a particular invention, and therefore hard to establish the legal basis for an infringement action. As

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[77] *See* Arrow, *supra* note 36, at 620 (concluding that "preinvention monopoly power acts as a strong disincentive to further innovation"); *see also* KAMIEN & SCHWARTZ, *supra* note 36 (discussing various theories of the effects of economic structures on the rate and form of innovation); F.M. SCHERER AND DAVID ROSS, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE 660 (3d ed. Houghton Mifflin 1990) (criticizing Schumpeter's "less cautious" followers for advocating monopoly to promote innovation). In the specific context of intellectual property, the canonical argument from both theory and empirical evidence is Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839 (1990). *See also* Kenneth W. Dam, *The Economic Underpinnings of Patent Law*, 23 J. LEGAL STUD. 247, 252 (1994) (noting that in the computer industry, for example, companies coordinate improvements by broad cross-licensing because of "the pace of research and development and the market interdependencies between inventions"). For discussions of particular industries in which competition appears to spur innovation, see, for example, Mark A. Lemley & Lawrence Lessig, *The End of End-to-End: Preserving the Architecture of the Internet in the Broadband Era*, 48 UCLA L. REV. 925, 960–62 (2001) (the internet); Arti Kaur Rai, *Evolving Scientific Norms and Intellectual Property Rights: A Reply to Kieff*, 95 NW. U. L. REV. 707, 709–10 (2001) (biotechnology); Howard A. Shelanski, *Competition and Deployment of New Technology in US Telecommunications*, 2000 U. CHI. LEGAL F. 85, 85 (telecommunications).

[78] *See* Madey v. Duke University, 307 F.3d 1351 (Fed. Cir. 2002) (effectively eliminating the common law experimental use defense).

[79] *See* **Miller et al.,** *supra* note **__**, at 226 ("At this stage, it is difficult to detect infringement of nanotechnology patents.").

a result, it is possible that the nanotechnology industry will avoid a patent thicket at the research stage in much the way biotechnology seems to have done: not by limiting the scope or issuance of patents, but by simply ignoring them.[80] This would be harder to do so once nanotechnology products are actually sold on the market, of course.

B. Licensing As a Solution to Overpatenting

In thinking about the policy implications of nanotechnology patents, we should begin by asking whether and how companies and the law can harness the incentives provided by the patent system while minimizing the risks that strong patents pose for downstream innovation. One way businesses can respond to these challenges is by open licensing. Whether this will happen depends critically on the distribution of core patents among firms and on the markets in which those firms participate. If core patents are distributed roughly evenly among firms participating in a market driven by nanotechnology, those firms will have a strong incentive to enter into cross-licenses, since their interests are symmetrical: they need their competitors' patents just as much as the competitors need their patents.[81] Indeed, there are some early

[80] *See* John P. Walsh et al., The Patenting and Licensing of Research Tools and Biomedical Innovation (2000) (investigating the impact of research tool patents in biotechnology and finding that they did not interfere with product introduction, in significant part because researchers simply ignored them).

[81] This is what has happened in the semiconductor industry, *See* Bronwyn H. Hall & Rosemarie Ham Ziedonis, *The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1975,* 32 **RAND J. Econ.** 101 (2001). . It is no accident that semiconductor patents are far less likely to be litigated than patents in any other industry. Allison et al., *supra* note __, at 472-73 & Tbl. 3.

examples of nanotech patents being cross-licensed within an industry.[82] Still, Miller is skeptical that semiconductor-style cross-licenses will work in nanotechnology because of the disparity in size and business model between the stakeholders.[83] In short, he doubts whether the interests of nanotechnology patent owners are in fact symmetrical.

If patents are distributed asymmetrically, but are concentrated in established firms in different industries rather than nanotech-specific tool firms,[84] it is reasonable to expect that those firms holding core patents will use them to exclude competition in their particular industry.[85] But there is no reason to believe such a firm will have any incentive to exclude competition in other industries. For example, if a large biotech company holds a critical nanotech building block patent, it will likely seek to exclude competing nanotech firms from using the patented invention, but it will have no interest in precluding semiconductor firms from using the same invention. Rather, it is reasonable to expect the patent owner to be willing to license the invention outside its industry for a royalty.[86]

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82 *See* Drew Harris et al, *Strategies for Resolving Patent Disputes Over Nanoparticle Drug Delivery Systems*, 1:4 **Nanotechnology L. & Bus. J.** art. 1, at V (2004) (discussing BioCrystal-Crystalplex cross-license).

83 **Miller et al.,** *supra* note __, at 76.

84 The Ratners predict this outcome. **Ratner & Ratner**, *supra* note __, at 146.

85 Harris et al document three examples of nanotech patent litigation to date. *Id.* at VI & nn. 15-16 (discussing Caliper's suit against Molecular Devices, Ultratech's suit against Tamarack Scientific, and Veeco Instruments' suit against Asylum Research).

86 A more troubling possibility is that the biotech firm in this example will grant an exclusive license to one semiconductor firm rather than a series of nonexclusive licenses. Exclusive licenses tend to produce a higher royalty rate, and companies may therefore have an incentive to prefer them. But their effect may be to shut competitors out of a market in an extreme case, or at least out of the use of a particular technology.

Finally, if the market is vertically segmented, downstream firms will need to pay money to license patents from the upstream nanotech patent owners. Nanotechnology-specific firms that don't themselves make downstream products will likely be more interested in broad licensing in each industry, though they too may have an incentive to prefer exclusive rather than nonexclusive licensing in each field. But if they are not themselves making products, a situation that seems likely in the biotech and semiconductor markets at least, they will not be interested in trading patents. Instead, they will want money to license their patents.

A possible business response to strong nanotech patents owned by upstream firms is vertical integration. If patent owners are not inclined to open licensing, firms need to find ways to produce without infringing those patents. Designing around a patent may be possible, but it will likely prove harder in nanotechnology than in other fields if I am right that nanotech patents are broader and more basic than those in other fields. One way for companies making downstream products incorporating nanotechnology to avoid the risk of patent infringement is to purchase one or more upstream nanotechnology research firms that owns such patents. Doing so obviously avoids infringement of the purchased firm's patents. But it may also put the downstream firm in a better bargaining position vis-à-vis other patent owners, since it will now be in a position to have something to trade. Whether this trading will occur depends in large matter on how other firms behave. If other firms also vertically integrate, each of the vertically integrated firms will have created symmetry and will have similar incentives to cross-license. If only one firm integrates vertically, it will still have to deal with other upstream patent firms who seek license revenue. Vertical integration implicates the antitrust laws, though modern courts generally treat it leniently.[87] The ability of firms to ameliorate innovation risks by means of vertical merger provides an additional reason for antitrust courts to continue this deference.

The significant role played by university patents might at first blush be thought to ameliorate many of the risks identified above. Universities, after all, are not competing with private firms to make products, and so don't have incentives to prevent their competitors from using the invention. Further, precisely because universities do early-stage research, they patent inventions when they are further from commercialization, and may therefore actually speed the entry of some inventions into the public domain by obtaining patents that expire earlier.[88] In fact, however, there may be reason to worry that university patents could end up being more rather than less restrictive of nanotechnology than industry patents.

First, precisely because a university is not a market participant, it is not in a symmetrical relationship with other patentees.[89] Nor is a university likely to vertically integrate by merging with a downstream products firm. Some prior evidence has shown that patentees in such an asymmetrical position are more likely to enforce their rights, because they are interested only in maximizing their licensing revenue, rather than in any sort of cross-licensing arrangement.[90] In

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[87] *See* IVA **Philip Areeda, Herbert Hovenkamp, & Ken Solow, Antitrust Law** ¶1000a.

[88] I am indebted to David Jaffer for this point.

[89] To be sure, this is not entirely true. To the extent corporations own basic research tool patents, they could enforce those patents against universities engaged in nanotechnology research. The Federal Circuit has made it clear that universities enjoy no special exemption from patent liability stemming from their research, *see* Madey v. Duke University, 307 F.3d 1351 (Fed. Cir. 2002), though the Supreme Court may reconsider the issue when it considers the statutory exemption for FDA research later this year. *See* Merck v. Integra Lifesciences, __ U.S. __ (Jan. 7, 2005) But this is likely to be an exceptional case. By and large, universities will be more likely to hold building-block patents and businesses to hold implementation patents. Those implementation patents will not generally be enforceable against universities.

[90] *See* Allison et al., *supra* note __, at 468-70.

the semiconductor industry, for example, the established players rarely sue each other,[91] and most lawsuits are filed by outsiders who are not making products in the industry. And indeed universities have proven themselves adept at licensing patents for money. Collectively, they take in over $1 billion a year in patent licensing revenue.[92]

Second, universities have generally found that they could maximize their licensing revenue by granting exclusive rather than nonexclusive licenses. For most inventions this makes sense as an economic matter; to the extent any patent confers power over price, the private value of that power will be maximized by keeping control within a single firm. The royalty rates for exclusive licenses are accordingly significantly higher than the rates for nonexclusive licenses. But for certain basic inventions – specifically, those that enable broad or unpredictable new directions in research – exclusive licensing will have significant social and perhaps even private costs, because it limits competition in the exploitation of those building blocks and therefore limits the follow-on innovation that can occur.[93] This is particularly a risk in nanotechnology, where a basic invention may have applications in a number of different industries that a single private firm will be unable to efficiently exploit.

Ideally, universities will recognize that fundamental inventions that will open up new fields are most valuable not just to society but even to their owners when many different firms

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[91] *Id.* at 472-73 & Tbl. 3 (rate of semiconductor litigation is only 1/3 the rate in other industries).

[92] *The Big Ten: Universities That Made the Most Licensing Dollars Last Year*, **IP Law & Bus.**, Jan. 2005, at 14.

[93] This depends on whether improvement on a basic invention is best centrally coordinated or left to a competitive market. I have argued in detail elsewhere that it is best left to a competitive market, see Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 **Tex. L. Rev.** 989 (1997), and I won't repeat those arguments here.

compete to exploit and improve them, and therefore that for that class of inventions the university will likely maximize its revenue by licensing the patent on nonexclusive rather than exclusive terms. The Axel and Cohen-Boyer licenses from biotechnology are good examples of the wisdom of this approach. But nonexclusive licensing of nanotechnology patents requires a certain amount of swimming upstream on the part of licensing professionals,[94] as well as an ability to distinguish basic building-block inventions from other inventions for which an exclusive license is appropriate. The (admittedly meager) record so far is not promising. Of 15 publicly announced nanotechnology license agreements in 2003, all but two were exclusive, and all nine of the licenses granted by universities were exclusive, though one was exclusive only with respect to biological applications.[95]

C. Legal Solutions to Overpatenting

How might the law respond to strong and broad nanotechnology patents? One possibility would be to try to limit the strength of nanotechnology patents, for example by imposing a strict utility requirement that shifts patents away from upstream tools and raw materials towards downstream implementations. The law does something similar in the chemistry and biotechnology industries, imposing a utility requirement absent in the rest of patent law.[96] If we

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[94] A study of university technology transfer offices in 2000 found that 50% of their licenses were exclusive, but that 90% of their licenses to start-ups were exclusive. *See* **Ann Monotti & Sam Ricketson, Universities and Intellectual Property: Ownership and Exploitation** 447 (2003). Technology transfer officers claimed that exclusive licenses were essential in order to attract interest from licensees. *Id.* at 448.

[95] Calculations from *Nanotechnology Updates*, *supra* note __, at 131-32. Put another way, between 89% and 100% of the university licenses were exclusive, compared with only 67% of the corporate licenses. The small sample size prevents drawing any definitive conclusions from these differences, however.

[96] *See, e.g.,* In re Kirk, 376 F.2d 936, 961 (C.C.P.A. 1967) (Rich, J., dissenting) (*Brenner's* utility requirement would never be "indulged in with respect to other scientific 'tools' or a

think there is a significant risk that nanotechnology innovation will be retarded by broad upstream patents, we might want to replicate by law the result we got by accident in the biotech, software, hardware and Internet industries – freedom to use basic tools and processes, and patents only on downstream implementations.

A second possibility along the same lines would be to restrict the ability of universities and other owners of basic building-block patents to impose exclusive licenses that restricted downstream innovation. Most of this building-block technology is publicly funded, and the government has the power under the Bayh-Dole Act to compel licensing of that technology on reasonable terms.[97] It has never used this power,[98] but some scholars have suggested that it may be appropriate to do so in order to ensure that the basic tools of nanotechnology are not locked up in exclusive licenses.[99]

Nonetheless, it does not seem appropriate to me to seek at this early stage to restrict upstream nanotech patenting. Nanotech inventions will require substantial investment that will not be recouped for a long time, if ever. Development of basic nanotech building blocks such as carbon nanotubes is itself a complex and uncertain process. Turning those building blocks into

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mechanical or optical or electronic sort.”); Burk & Lemley, *supra* note __, at 1646. Forman endorses the use of utility as a technology-specific policy lever, though he believes the doctrine as applied to biotechnology is currently too powerful. Julian David Forman, *A Timing Perspective on the Utility Requirement in Biotechnology Patent Applications*, 12 **Alb. L.J. Sci. & Tech**. 647, 650 (2002).

[97] 35 U.S.C. § 203(a).

[98] For a discussion of one famous petition asking it to do so, see Barbara M. McGarey & Annette C. Levey, *Patents, Products, and Public Health: An Analysis of the CellPro March-In Petition*, 14 **Berkeley Tech. L.J.** 1095 (1999).

[99] *See* Ted Sabety, *Nanotech Innovation and the Patent Thicket: Which IP Policies Promote Growth?*, 1 **Nanotechnology L. & Bus. J.** 262 (2004). *Cf.* Rai & Eisenberg, *supra* note __, at 312-14 (discussing similar measures that might be taken in biomedicine).

useable products will take significant further research, and the commercial applications of those building blocks in many cases will not be apparent for some time. Both of these characteristics – the high investment in research and development required to produce *inventions* and the long and uncertain process of *innovating*[100] – suggest that nanotech patents, like pharmaceutical patents, should be relatively broad.[101] Patents provide a needed incentive for research and development into nanotech by established companies moving into the field, and for venture capital investment in start-up nanotech ventures, though their importance in funding university and government-backed projects is less clear.[102]

Restricting nanotech patents is also premature, because we haven't yet had an opportunity to see how significant the patents will turn out to be, how they will be licensed, and how industry participants will react. Biotechnology provides a somewhat encouraging example. While many of the basic building blocks entered the public domain, others were patented, but those patents were licensed by universities on nonexclusive terms. Perhaps the same thing will happen in nanotechnology. If not – if it turns out that broad nanotech patents are holding up innovation – courts and Congress will have to consider whether there are policy levers that can

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[100] I follow Schumpeter here in distinguishing between the act of inventing – coming up with a new idea – and innovating – turning that idea into a marketable product. See **Richard R. Nelson & Sidney G. Winter, An Evolutionary Theory of Economic Change** 263 (1982) (distinguishing the invention of a product from innovation, a broader process of research, development, testing and commercialization of that product, and attributing that distinction to Schumpeter); **William Kingston, Direct Protection of Innovation** (1987).

[101] *See, e.g.,* Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law,* 89 **Va. L. Rev.** 1575 (2003) (making the argument for strong patent protection of pharmaceuticals).

[102] Some scholars have suggested that patents issued to these latter groups under the Bayh-Dole Act might be limited in significant ways. *See* Rochelle Dreyfuss, *Protecting the Public Domain of Science: Has the Time for an Experimental Use Defense Arrived?,* 46 **Ariz. L. Rev.** 457 (2004); Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine,* 66 **L. & Contemp. Probs.** 289 (2003).

prevent this result without interfering with the incentives patents grant to pioneers. One possibility is a rule that limits injunctive relief in patent cases to patent owner who are also market participants.[103] Such a rule would permit patent owners to recoup a reasonable royalty, but not to hold up innovation by those actually participating in the market. And importantly, such an approach could be implemented after the fact, permitting us not to act precipitously in concluding that we need new rules for this emerging industry.

IV. Conclusion

Nanotechnology patents bear watching. They have characteristics that may well turn out to be fundamentally different than patents in any other industry in the last eighty years. How the market responds to these characteristics will determine whether and how the law must step in and tailor the rules of patent law to the needs of this nascent industry. It will also give us broader insight into the role of patents in enabling technologies. Nanotechnology is a natural experiment that can teach us whether we have learned anything since the days of the Wright Brothers about how to license and enforce patents without restricting innovation, or whether the absence of patent protection for the enabling technologies of the last century was a series of fortunate events.[104]

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[103] *See* Julie S. Turner, Comment, *The Nonmanufacturing Patent Owner: Toward a Theory of Efficient Infringement*, 86 **Cal. L. Rev.** 179 (1998); *see also* Michelle Armond, Comment, *Introducing the Defense of Independent Invention to Motions for Preliminary Injunctions in Patent Infringement Lawsuits*, 91 **Cal. L. Rev.** 117 (2003) (proposing a different solution directed at the same problem of enforcement by non-manufacturing patent owners). There are issues with implementation of such a rule that would have to be addressed, such as the extent to which licensing a patent qualifies as participating in a market and whether to except those who patent research tools that generate primarily data rather than products.

[104] With apologies to Lemony Snicket.