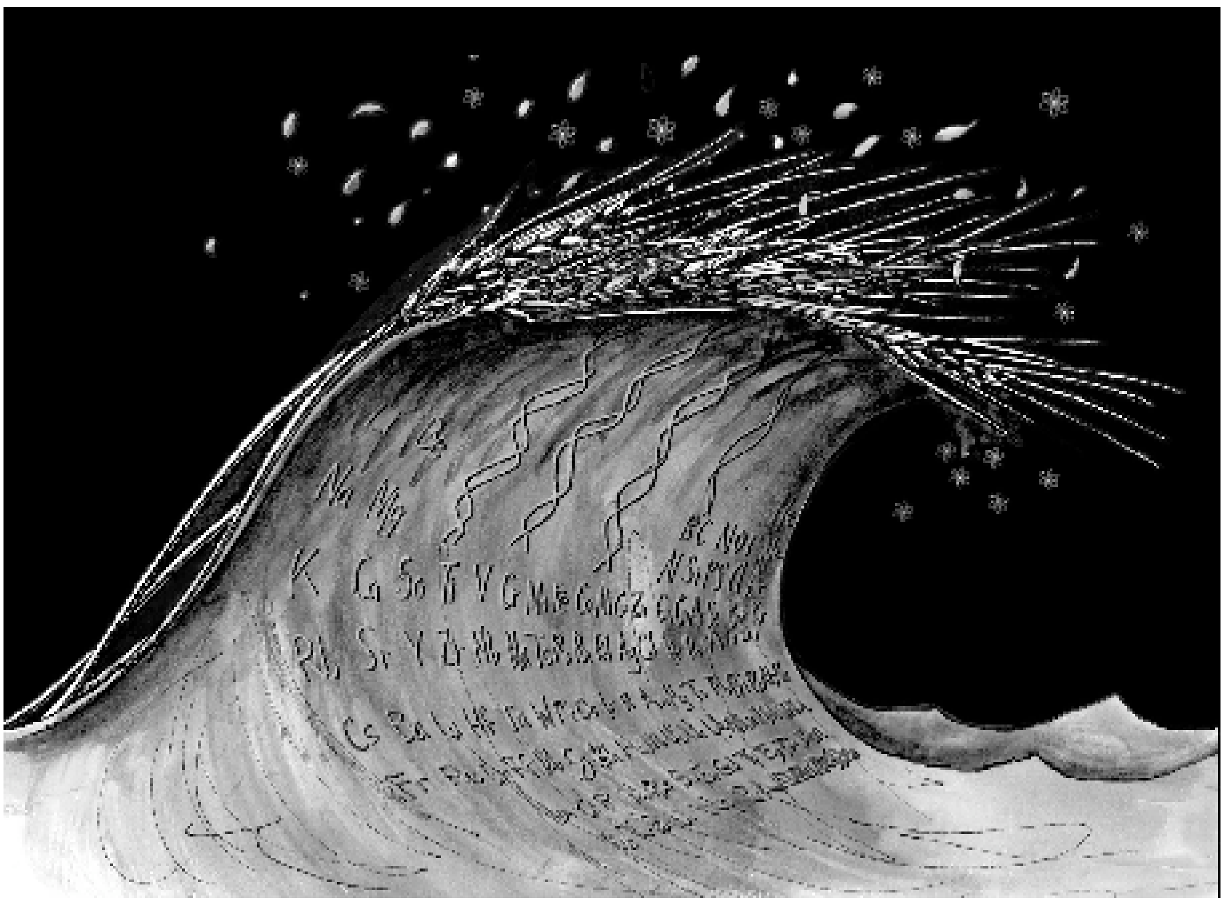
ETC Group Report

Nanotech's "Second Nature" Patents:
Implications for the Global South



The number of nanotech patents is surging, breaking across all industry sectors and sweeping up all of nature, both living and non-living.

etc group
action group on erosion, technology and concentration

March/April and May/June-2005
ETC Group Special Report – Communiqués No. 87 and 88

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June 2005

Nanotech's "Second Nature" Patents:

Implications for the Global South
Is Nanotech "Pro-Poor Science" or is the G8 Downsizing Development?

ISSUE: On the 25th anniversary of the US Supreme Court decision that opened the floodgates to the patenting of all life forms, ETC Group reports on current trends in intellectual property relating to nano-scale technologies. With nanotechnology, the reach of exclusive monopoly patents is not just on life, but all of nature. Accordingly, ETC Group refers to nanotech's "second nature" patents. Nanotech patent claims offer the South (and society) an advance look at who's likely to own nanotechnology and dominate 21st century commodity markets. Breathtakingly broad nanotech patents are being granted that span multiple industry sectors and include sweeping claims on entire classes of the Periodic Table. Yet, when the G8 nations meet this July they will be unveiling a "Pro-Poor Science" strategy to turn nanotechnology into a silver bullet antidote to social injustice. Is nanotech the solution – or just another big downer for development?

IMPACT: The race is on to win monopoly control of tiny tech's colossal market. The US National Science Foundation predicts that the immensely broad power and scope of nano-scale technologies will revolutionize manufacturing across all industry sectors – capturing a $1 trillion market within six or seven years. Although industry analysts assert that nanotech is in its infancy, "patent thickets" on fundamental nano-scale materials, building blocks and tools are already creating thorny barriers for would-be innovators. Industry analysts warn that, "IP roadblocks could severely retard the development of nanotechnology."[1] Some insist that nano-scale technologies will address the most pressing needs of the South's marginalized peoples. But in a world dominated by proprietary science, it is the patent owners and those who can pay license fees who will determine access and price. Even as South governments are grappling with confusion and controversies over biotechnology, the World Trade Organization's Trade-Related Aspects of Intellectual Property (TRIPs) obligates even "least developed" countries to enforce nanotech patents by 2006.

PLAYERS: The world's largest transnationals, leading academic labs and nanotech start-ups are all racing in the patent gold rush. Increasingly, universities are licensing on an exclusive basis. Nanotech's "second nature patents" are positioning multinational matter moguls to own and control novel materials, devices and their manufacturing processes.

POLICY: While WIPO ponders a "development agenda" in Geneva, patent offices in Washington, Munich and Tokyo are deciding who will gain exclusive monopoly over a technology that will bring profound changes in demand for raw materials and manufacturing around the globe. Despite rosy predictions that nanotech will provide a technical fix for hunger, disease and environmental security in the South, the extraordinary pace of nanotech patenting suggests that developing nations will participate via royalty payments. Accordingly, national governments must protect their sovereignty and intergovernmental agencies must move quickly to prevent multi-sector monopolies, technology barriers and the formation of a powerful new oligopoly that seeks control over the economy's 'second nature.'

"When you control the atoms, you control just about everything." – Dr. Richard Smalley, 1996 Nobel laureate for his discovery of fullerenes (buckyballs).[2]

Introduction:
Control and ownership of nanotechnology is a vital issue for all governments and civil society because nanomaterials and processes can be applied to virtually any manufactured good across *all* industry sectors. Nanotechnology refers to the manipulation of matter at the scale of atoms and molecules, where size is measured in billionths of meters (one nanometer = one-billionth of a meter). Nanotech isn't a single technology – but a range of technologies converging at the nano-scale – including biotechnology, genomics, neurosciences, robotics and information technologies. For a brief introduction to nanotechnology, please see, *A Tiny Primer on Nano-Scale Technologies* [http://www.etcgroup.org]

Worldwide, industry and governments invested more than $10 billion in nanotech R&D last year, with two-thirds coming from corporate and private funds.[3] There are an estimated 1200 nanotech start-up companies, half of which are US-based.[4] Virtually all Fortune 500 companies invest in nanotech R&D. A recent survey conducted by MIT's *Technology Review* predicts that products involving nanotech will account for over $100 billion by 2008;[5] the US government predicts that the nanotech market will explode to $1 trillion by 2012. Intellectual property (IP) will play a major role in deciding who will capture nanotech's trillion dollar market, who will have access to nano-scale technologies and at what price. At stake is control over innovations that span multiple industry sectors – from electronics, energy, mining and defense to new materials, pharmaceuticals and agriculture. As the *Wall St. Journal* put it, "companies that hold pioneering patents could potentially put up tolls on entire industries."[6]

Even industry insiders admit that current intellectual property trends related to nanotech are chaotic. Many broad patents on nanotech-related materials, tools and processes have been granted too early and too often. In 2002, the US-based industry trade group, Nanotechnology Business Alliance, was already warning in testimony before the US Congress, "…several early nanotech patents are given such broad coverage, the industry is potentially in real danger of experiencing unnecessary legal slowdowns."[7]

"…patents will cast a larger shadow over nanotech than they have over any other modern science at a comparable stage of development." – Mark A. Lemley, Stanford Law School

More recently, nanotech industry analysts observe that the "euphoria for patenting" in the US combined with the US Patent & Trademark Office's inability to handle a flood of patent applications has resulted in "the rejection of valid claims, the issuance of broad and over-lapping claims, and a fragmented and somewhat chaotic IP landscape." The writers warn, "These IP roadblocks could severely retard development of nanotechnology."[8]

This report aims to provide information to civil society and South policymakers about current trends in nanotechnology and intellectual property. What is the current IP landscape? What is being patented and by whom? What are the implications for innovation and development in the South? How will intellectual property affect the South's participation in the nanotech revolution?

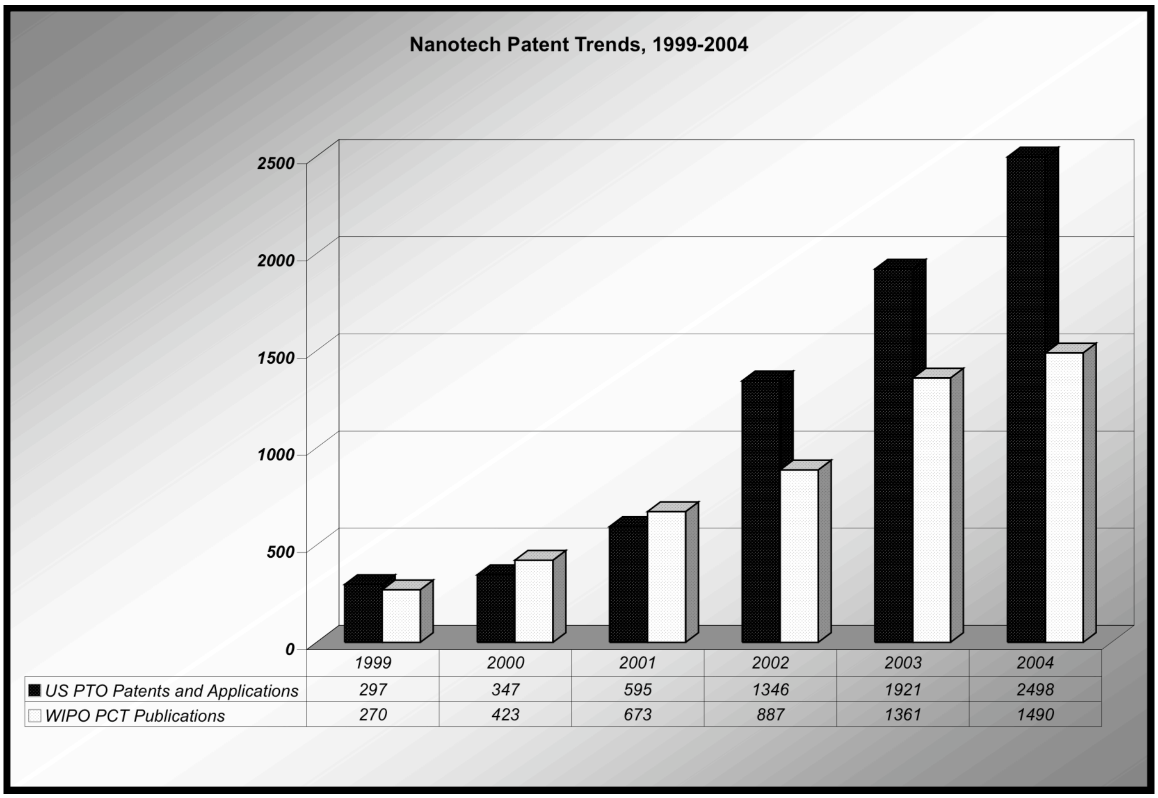
"Like biotechnology in the early 1980s, the IP landgrab mentality pays off for early pioneers. Don't bet the jockey. Don't bet the horse. Own the track." – Lux Research, Inc.[9]

How Many Nanotech-Related Patents?
Patents on nano-scale materials, tools and processes are a fair measure of the tsunami-like strength of this latest industrial revolution. Estimates vary on the number of nanotech patents issued since the early 1990s, but all agree that both companies and public sector entities are "rushing to the patent office in

record numbers to patent nanotechnology inventions."[10]

The lack of uniform definitions for nanotechnology means that identifying the number of nanotech-related patents granted over the past decade is a very imprecise science. When the US PTO announced it had created a new classification for nanotechnology patents in October 2004 it defined nanotechnology patents narrowly: Classification 977 includes only those patents 1) whose subject matter is in the scale of approximately 1-100 nanometers in at least one dimension; and 2) that involve materials, structures, devices or systems that have novel properties and functions because of their nano-scale size.

Nanotech patent searches often use broad search terms (for example, the prefix "nano"), which can result in exaggerated counts. There is wide consensus, however, that major patent offices worldwide are granting nanotech patents at an extraordinary pace. The chart below illustrates the overall trend, which is similar at the World Intellectual Property Organization's Patent Cooperation Treaty and at the US PTO.[11]



In response to the demand for nanotech patents, more than a dozen major law firms in the US have recently established nanotech patent law specialties.

Researchers from the University of Arizona and the US National Science Foundation examined nano-scale science and engineering patents at the US Patent & Trademark Office from 1976-2003. [12] They found that 8,630 nanotech-related patents were issued by the US PTO in 2003 alone, an increase of 50% over the previous three years. The top 5 countries represented were: US (5,228 patents), Japan (926), Germany (684), Canada (244) and France (183). The top 5 entities winning nanotech-related patents included four multinational electronic firms and one university: IBM (198 patents), Micron Technologies (129), Advanced Micro Devices (128), Intel (90) and University of California (89).

A new report by Lux Research, Inc. identifies far fewer nanotech patents granted by the US PTO. In April 2005 Lux announced that it had identified 3,818 nanotech-related patents issued between 1985-March 2005, with an additional 1,777 patent applications.[13]

> ***"…nanotechnology is raising fundamental questions as to what should, and should not, be patentable."*** – The European Commission, Communication from the Commission[14]

ETC Group Takes a Closer Look at Nanotech Patents Granted by the US PTO

In October 2004, the US PTO announced it had created a new classification for nanotechnology patents – Class 977 – which would serve as a cross-reference to help examiners, among others, search prior art. Before Class 977 existed, examiners relied on keyword searches to find relevant information and related patents.[15] As defined by the US PTO, nanotechnology patents in Class 977 must meet the following criteria:

- relate to research and technology development in the length scale of approximately 1-100 nm in at least one dimension
- provide a fundamental understanding of phenomena and materials at the nanoscale and create and use structures, devices, and systems that have size-dependent novel properties and functions.[16]

The US PTO is now reviewing patents issued before the classification was created and re-classifying those that meet the 977 criteria. According to Bruce Kisliuk, a patent examiner group director, the Patent Office hopes to be caught up reviewing already-issued patents within a year.[17] Until the review is complete, the PTO is referring to Class 977 as a "digest." Eventually, Class 977 will be broken down further into sub-classes.

As of May 25, 2005, Class 977 included 726 patents issued by the US PTO, dating from May 24, 2005 back to 1980. In its incomplete state, Class 977 should be seen as a sample rather than a comprehensive picture of nano-patenting in the US. (At present, Class 977 contains only six nano-patents dating from the second half of 2004, for example.) Even though the classification is incomplete, the sample is worth looking at because it offers an advantage over more random patent searches (e.g., searching for keywords such as "nano" or "quantum"): we can be reasonably confident that the patents in Class 977 are bona fide nano-patents because they have been reviewed and each was determined to meet the classification criteria – relating to the nanometer scale (1-100 nm) in at least one dimension and exploiting size-dependent properties.

A search through Class 977 reveals:

- The USPTO has issued nano-patents in the fields of electronics (including cameras, computers and other devices), instruments and tools (including scanning probe microscopes and sensors), pharmaceuticals (including drug delivery), food, agrochemicals, devices, materials (including fullerenes, nanotubes and quantum dots) and processes for creating and engineering nano-sized particles.
- More than 290 different primary patent examiners were assigned to evaluate these Class 977 patents. The extraordinarily large number of examiners raises suspicions that over-lapping and conflicting patents were granted by different examiners at about the same time; it also illustrates the multi-disciplinary and cross-sectoral nature of nano-scale science.
- Out of the 235 Class 977 patents issued in 2003 (the most complete year):[18]
- 112 (48%) are assigned to US-based companies
- 29 (over 12%) are assigned to US universities
- 70 (30%) are assigned to companies based outside the US (of these, 26 are assigned to companies based in Japan, 10 in Germany, 9 in Australia – 8 of which are assigned to one company, Silverbrook Research. Companies from Canada, Venezuela, France, Korea, Belgium, Denmark, Italy, Ireland, Netherlands, Taiwan and Antilles make up the other non-US assignees.)
- 15 (6.5%) are assigned to non-US government entities or national research agencies
- The US government has rights to 31 patents (either because it provided funding for research or through outright ownership), which represents 22% of the patents assigned to US entities

The top patent assignees in US PTO Class 977
Nano-patents, Class 977, as of May 25, 2005 (726 patents)

Company/Institution	Headquarters	Patents Issued
Canon Kabushiki Kaisha	Japan	49
IBM	USA	47
Silverbrook Research	Australia	28
The United States of America	USA	16
Hitachi, Ltd.	Japan	16
Seagate Technology	USA	16
Micron Technology, Inc.	USA	14
Eastman Kodak Company	USA	13
Olympus Optical Co., Ltd.	Japan	10
University of California	USA	9
Rohm and Haas Company	Germany	9
Polaroid Corporation	USA	9
Sony Corporation	Japan	8
Molecular Imaging Corporation	USA	8

Class 977 patents issued by the USPTO range from mundane to alarming to other-worldly. One would expect only great things from the Delphi Oracle Corporation and it does not disappoint: Delphi owns patent 6,493,910, "a shoelace with enhanced knot retention and method of manufacture." (It's a nano-patent because the shoelace makes use of nano-scale fumed silica.) On the disturbing end of the spectrum, the US government won patent 5,805,657 back in 1998 for "nuclear fuel elements made from nanophase materials," which makes one wonder in the event of infringement – will there be anyone around to sue? Zyvex Corporation owns patent 6,510,359, a "method and system for self-replicating manufacturing stations." In case anyone devises one of these in the next 20 years, it looks like Zyvex will own it. They claim a "non-biological self replicating manufacturing system" comprising:

- a translating machine capable of translating at least a first surface in relation to at least a second surface, wherein said at least a first surface comprises at least one assembly station thereon and wherein said at least a second surface comprises parts arranged thereon for use in constructing at least one other assembly station; and
- a control system for controlling the operation of said translating machine and for controlling said at least one assembly station to cause said at least one assembly station to construct at least one other assembly station from said parts on said second surface.

Patent Paradox: For most nanotech start-up companies (especially those that operate without products or profits), intellectual property is the most essential asset. In the words of one industry executive, the strength of a nanotech company's patent portfolio is what separates the winners from the losers.[19] Consider, for example: Nanogen's stock jumped over 50 percent on the day it announced it had won a patent on a technology to detect genetic variants; NVE Corporation's stock surged 41 percent when it announced its new patent on magnetic random access memory.[20]

But the transaction costs of filing for and defending patents are enormous. Competing in the high-stakes patent game requires not only winning and defending patents, but also using them as bargaining chips to cross-license other proprietary technologies. Intellectual property is one of the biggest expenses for fledgling start-ups, and nanotech industry insiders predict that long and costly patent litigation battles could inflict mortal wounds. Consider, for example:

- In the US, depending on the complexity, claims, and length of the application, filing fees can go as high as $1000.[21]

- For nanotech start-up companies, patent fees are often a major cost of doing business – sometimes second only to payroll.[22] Legal fees for winning a patent in the US can cost $25,000-$30,000, and up to $250,000 for international patent claims.[23]

- Outside the US, countries charge around $5,000 per year on each pending patent. The translation fees alone to win a patent in Japan are between $12,000 and $20,000.[24]

- The number of patent lawsuits filed in the US more than doubled over the decade of the 1990s. Based on a survey of intellectual property lawyers in 2000, the cost of defending a large (more than $25 million at risk) patent infringement suit ranges from $2 million to $4.5 million. For cases with less than $1 million at risk, the cost was $300,000 to $750,000, or about half the amount in dispute.[25]

- Most shocking of all, it is estimated that only about two percent of all issued patents end up generating more revenue than the cost of obtaining the patent. Among this small group of "profitable" patents, only some will end up being worth the price of litigation.[26]

Many intellectual property experts in the US are predicting that large-scale nanotech patent litigation is inevitable, and it's likely to be ugly. Because of the large number of over-lapping and conflicting patents being granted, nanotech companies must be prepared to vigorously defend their patents in court. It's conventional wisdom that, in most patent battles, it's the largest enterprises – not the most innovative – that will prevail. According to authors Josh Lerner and Adam Jaffe, "the firm with the best lawyers or the greatest capacity to withstand the risk of litigation wins the innovation wars – rather than the company with the brightest scientists or most original, valuable ideas."[27]

"Nobody's making any money right now, so there's no particular reason to fight the battles yet. But a lot of people are coming out with patents, and a lot of claims are certainly overlapping, if not certainly conflicting. The fights are going to be brutal." – Matthew Nordan, vice-president of research, nanotech analyst firm, Lux Research[28]

Firms can use patents as "strategic weapons to strangle competition."[29] If a larger firm believes that its dominance in a nanotechnology market is threatened, it "can slowly starve their start-up competitors into extinction by waging a protracted battle on the IP front."[30] As with biotech in the 1980s and 1990s, nanotech start-ups holding key patents may also become attractive takeover targets because it's less costly for a multinational firm to acquire the company than to litigate in court.

In part two of this report (see pages 16-27) ETC Group provides case studies of nanotech and intellectual property, focusing on some of the key nanomaterials or tools that are the subject of multiple (and likely) over-lapping patent claims. The case studies examine: carbon nanotubes, Nanosys Inc.'s patents on inorganic nanomaterials, quantum dots, dendrimers and scanning probe microscopes.

What are the major trends in Nanotech-related IP?

Patents on nanotech's fundamental building blocks and tools. Stanford University law professor Mark Lemley asserts that nanotechnology "is the first new field in a century in which people started patenting the basic ideas at the outset."[31] In contrast to most other major enabling technologies of the 20th century (such as computer hardware, software, the Internet, and even biotechnology), writes Lemley, the most basic ideas and fundamental building blocks in nanotechnology "are either already patented or may well end up being patented."[32] ETC Group does not share Lemley's view that biotech's fundamental enabling tools were not patented early on – but we do share his view that nanotechnology's most basic ideas and building blocks are being patented early and often.

In the nanotech arena, it's not just the opportunity to patent the most basic enabling tools, but the ability to patent the nanomaterials themselves, the products they are used in and the methods of making them. At the US Patent & Trademark Office there are three primary types of patent claims:[33]

1) composition of matter claims (that is, nanomaterials such as nanotubes, nanowires and nanoparticles),
2) device, apparatus or system claims (including, for example, tools used to characterize and control nanomaterials – or devices incorporating nanomaterials),
3) method claims (processes for synthesizing nanomaterials or constructing nano-scale devices).

The CEO of Nanosys, Inc., Larry Bock, explains the once-in-a-lifetime attraction of being able to get in on the ground floor by consolidating fundamental nanotech patents: "One of the key things that got me excited about this whole area three years ago is that from an IP standpoint you could control IP from things like composition of matter to the simplest functional devices to the end application all under one IP portfolio. That doesn't come around very often in one's career."[34]

Nanomaterials are chemical elements or compounds less than 100 nm in size. Taking advantage of quantum physics, nanotech companies are engineering novel materials that may have entirely new properties never before identified in nature. The "raw materials" for creating nanomaterials and devices are the chemical elements of the Periodic Table – the building blocks of *everything* – both living and non-living. Whereas biotechnology patents make claims on biological products and processes – nanotechnology patents may literally stake claim to chemical elements, as well as the compounds and the devices that incorporate them. With nano-scale technologies the issue is not just patents on life – but on all of nature. In short, atomic-level manufacturing provides new opportunities for sweeping monopoly control over both animate and inanimate matter. In essence, patenting at the nano-scale could mean monopolizing the basic elements that make life possible.

Proprietary Periodic Table: Exclusive monopoly patents on chemical elements are not new. Glenn Seaborg, the 1951 Nobel Prize-winning physicist, won US patent #3,156,523 for the chemical element *Americium* (element no. 95 on the periodic table) on November 10, 1964. Seaborg's patent is recognized for having the shortest patent claim on record: "What is claimed is Element 95." Seaborg's second patented element was Curium #96 – US patent # 3,161,462 granted on December 15, 1964.

"It is true that one cannot patent an element found in its natural form; however, if you create a purified form of it that has industrial uses – say, neon – you can certainly secure a patent." – Lila Feisee, Biotechnology Industry Organization's Director for Government Relations and Intellectual Property

It's Elemental: When Harvard University's Charles Lieber obtained a key patent (US patent 5,897,945) on nano-scale metal oxide nanorods, he didn't claim nanorods composed of a single type of metal – but instead claimed a metal oxide selected from up to 33 chemical elements. Harvard's claims on nanorods include those comprised of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten, manganese, technetium, rhenium, iron, osmium, cobalt, nickel, copper, zinc, cadmium, scandium, yttrium, lanthanum, a lanthanide series element, boron, gallium, indium, thallium, germanium, tin, lead, magnesium, calcium, strontium, and barium. In a single patent, Lieber's claims extend to nearly one-third of the chemical elements in the Periodic Table – spanning 11 of the 18 Groups. Patent lawyers have identified Harvard's patent (licensed to Nanosys, Inc.) as one of the top 10 patents that could influence the development of nanotechnology.[35]

Similarly, a key patent on semiconductor nanocrystals (quantum dots) held by the University of California (licensed to Nanosys, Inc. and Quantum Dot Corp.) claims semiconductor nanoparticles from elements in Groups III-V of the Periodic Table. The claims in US patent number 5,505,928 extend to boron, aluminum, gallium, indium, nitrogen, phosphorus, arsenic, antimony as well as those compound semiconductors that result from combining elements in Groups III-V (such as gallium arsenide).

Cross-industry Patent Claims: Nanotechnology is not only cross-disciplinary, a single nano-scale innovation may have diverse applications that span multiple industry sectors. Mark Lemley of Stanford Law School observes, "a significant number of nanotechnology patentees will own rights not just in the industry in which they participate, but in other industries as well."[36] When ETC Group examined the 700+ patents that the US Patent & Trademark Office had identified as nanotechnology patents as of May 25, 2005, it was not surprising to find that the patents had originally been assigned to *all* of the major patent classes – including electricity; human necessities; chemistry/metallurgy; performing operations and transporting; mechanical engineering (lighting, heating, weapons, blasting); physics; fixed construction; textiles and paper.

Masters of the Industrial Universe? The crucial aspect to understand about nano IP is not simply that the patents span a broad range of fields, but that a single invention can be relevant for widely divergent applications. It doesn't come as a big surprise to find an invention that is applicable to related fields (e.g., pharmaceuticals and foods), but consider the following examples from US PTO's Class 977:

- US5,874,029 – University of Kansas, 23 February 1999: Methods for particle micronization and nanonization by recrystallization from organic solutions sprayed into a compressed antisolvent: ***The invention can be used in the pharmaceutical, food, chemical, electronics, catalyst, polymer, pesticide, explosives, and coating industries, all of which have a need for small-diameter particles.***
- US6,667,099 – Creavis Gesellschaft für Technologie und Innovation mbH, 23 December 2003: Meso-and nanotubes: The invention relates to mesotubes and nanotubes (hollow fibers) having an inner diameter of 10 nm-50 μm and to a method for the production thereof …***The hollow fibers are used in separation technology, catalysis, micro-electronics, medical technology, material technology or in the clothing industry.***
- US6,641,773 – The USA as represented by the Secretary of the Army, 11 November, 2004: Electro spinning of submicron diameter polymer filaments: An electro spinning process yields uniform, nanometer diameter polymer filaments…***The filament is particularly useful for weaving body armor, for chemical/biological protective clothing, as a biomedical tissue growth support, for fabricating micro sieves and for microelectronics fabrication.***

The reason that the same invention can be used inside the human body, in clothing and in computers, as in the third example above, is that at the molecular level biological and non-biological material can be integrated – whether this is a seamless integration is a matter yet to be determined by toxicological research.

Second Nature Patents: While biotech's raw materials are biological, nano-scale technologies involve the manipulation of both living and non-living materials, sometimes in combination. When this is the case, the discipline is known as *nanobiotechnology*. A nanostructured material used inside the body as a bone replacement is one example of nanobiotechnology, but so is a hybrid organism created from living and non-living materials, such as the nano-scale silicon and muscle-tissue hybrid announced by researchers in early 2005.[37] Closely related to and sometimes overlapping nanobiotech is the new field of "synthetic biology" in which living systems are built to order and then programmed to perform specific tasks. These, too, often combine biological and non-biological parts. Patents on the products of nanobiotechnology provide the opportunity to monopolize the basic elements that are the building blocks of the entire natural world, bringing a whole new dimension to the notion of "life patenting."

The table below provides examples of the possible range of nanobiotechnology and synthetic biology patents recently issued by the US PTO. It includes, for example: hybrid devices combining a nanomaterial and muscle tissue, which generate electrical power and which the inventor has described as "absolutely alive"[38] (Montemagno [1]); membranes made from biological and non-biological materials to be used in electricity production or water purification (Montemagno [2]); a method for controlling the properties of semiconductor nanoparticles by creating them with the help of biological material (Belcher); synthetic DNA base pairs that do not occur in nature (Benner); a method for genetically modifying cells by pricking them with carbon nanotube "needles" and injecting foreign DNA (McKnight); a gene switch that uses "switching agents" to control gene expression by turning them on or off.

"Much of what we manufacture now will be grown in the future, through the use of genetically engineered organisms that carry out molecular manipulation under our digital control. Our bodies and the material in our factories will be the same...we will begin to see ourselves as simply a part of the infrastructure of industry." – Rodney Brooks, director of Artificial Intelligence Laboratory, Massachusetts Institute of Technology (MIT)[39]

A Sample of Recent Nanobiotechnology/Synthetic Biology Patents

Inventor	Patent/ Application Number	Publication Date	Description
Carlo Montemagno, UCLA, USA	US20040101819A1	27 May 2004	Self-assembled muscle-powered microdevices
Carlo Montemagno, UCLA, USA	US20040049230A1	11 March 2004	Biomimetic membranes
Angela Belcher, MIT, USA	US20030113714A1	19 June 2003	Biological control of nanoparticles
Angela Belcher, MIT, USA	US20030073104A1	17 April 2003	Nanoscaling ordering of hybrid materials using genetically engineered mesoscale virus
Steven Benner, UF-Gainesville	US6617106	9 September 2003	Methods for preparing oligonucleotides containing non-standard nucleotides
James J. Collins, Cellicon Technologies, USA	US6841376	11 January 2005	Bistable genetic toggle switch
Timothy McKnight, Oak Ridge National Laboratory	US20040197909A1	7 October 2004	Parallel macromolecular delivery and biochemical/electrochemical interface to cells employing nanostructures

Role of Public Sector Universities in Nanotech IP: One of the unique features of nanotechnology, according to Stanford Law School professor, Mark Lemley, is that universities and public research foundations hold "a grossly disproportionate share of nanotech patents" that he believes are critically important to downstream nanotech products.

In 2004 a patent attorney specializing in nanotechnology identified 10 key patents that he believed could have the greatest impact on the development of nanotechnology. Seven of the 10 patents are owned by universities.[40]

Because they conduct basic research, it's not surprising that universities are the early-stage engines for nanotechnology. But unlike early-stage researchers 25 years ago, the new generation of US public researchers has become "extremely aggressive patenters" largely because of the Bayh-Dole Act of 1980 – US legislation designed to encourage technology transfer by permitting universities to patent their federally funded research projects. Before 1980, universities worldwide were granted about 250 US patents per year. By 2003, the number of university-owned patents increased almost 16-fold, to 3,933.[41]

Because university labs aren't in the business of commercializing products, they try to re-coup their research costs by patenting their employees' early scientific innovations – in the hope of earning royalties or licensing fees. Exclusive licensing is generally the more lucrative deal – and therefore the most appealing to technology transfer offices. In general, universities are acting more and more like businesses. Not only are universities patenting nanotech early and often, they are more frequently licensing their inventions on an exclusive basis. US policymakers who favor Bayh-Dole would argue that universities are benefiting society by transferring science and technology to the private sector for commercialization. But in many cases, consumers end up paying twice – once by paying taxes to support government-financed research, and again when they purchase a new, proprietary technology developed with taxpayer funds. With the emphasis on winning exclusive monopoly patents, the traditional academic culture of open communication and exchange is also undermined and eroded.[42]

From 2003 to early 2005 the *Nanotechnology Law & Business Journal* identified 55 publicly announced nanotech patent license agreements – 20 of which involved a university or public research entity as the licensor. Of the 20 license agreements involving university or research entities as licensor, all but one was granted on exclusive terms (and its terms were not disclosed).

Publicly Announced Nanotech IP License Agreements Involving US University or Public Research Entity as Licensor

Year	License Terms	Licensor	Licensee	Technology
2003	**Exclusive**	Lawrence Berkeley Natl Lab.	Nanosys, Inc	Textile processing technique
2003	**Exclusive**	Columbia Univ.	Nanosys, Inc.	Materials and technologies of nanocomposite solar cells
2003	**Exclusive global**	Rensselaer Polytechnic	Applied Nanoworks	Crystals that can be used in medical research
2003	**Exclusive global**	Rockefeller University	Evident Technology	Water-soluble metal and semiconductor quantum dots
2003	**Exclusive**	South Carolina Research Foundation	Competitive Technologies	Nanobiomaterial for skeletal repair
2003	**Exclusive**	MIT	Nanosys	New compositions of matter relating to quantum dots or nanocrystals
2003	**Exclusive global**	Rensselaer Polytechnic	Applied Nanoworks	Fabrication of nanocrystals
2003	**Exclusive**	Unnamed research institution	NanoDynamics	Process to synthesize copper nanomaterial
2003	**Exclusive** global for biological applications	MIT	Quantum Dot Corp.	Synthesis and composition of quantum dots
2003	**Exclusive**	NYU	Nanoscience Technologies	DNA nanotechnology
2004	**Exclusive**	University of Dayton	NanoSperse	Method of distributing carbon nano-fibers
2004	**Exclusive**	Caltech	Aonex	Thin film semiconductor layer transfer
2004	**Exclusive**	MIT	Nano-C	Production of nanostructured carbon materials
2004	Terms not released	Inter-University Micro-Electronic	MEMC Electronic Materials	Silicon bulk wafers
2004	**Exclusive**	Stanford	Biotrove	Microarray to perform PCR
2004	**Exclusive**	MIT	Molecular Imprints	Moire fringe alignment technology
2004	**Exclusive**	University of Illinois	NanoInk	Nanoscale chemical surface patterning of dip pen
2004	**Exclusive**	California Institute of Technology	Nanotechnica	Microfluidics
2005	**Exclusive**	University of Texas	Applied nanotech	Next generation memory chip
2005	**Exclusive**	UCLA	Nanomix	Nanostructures for electrochemical sensing

Source: ETC Group, Based on information compiled by *Nanotechnology Law & Business Journal*, Vol. 1, Issue 1, 2004 – Volume 2, Issue 2, 2005

Itty-Bitty Biopiracy Looms Large?

The largest single holder of nanotech patents in the world is a Chinese researcher, Yang Mengjun, who is taking ancient Chinese medicinal herbs, reducing them to nano-scale formulations, and claiming exclusive monopoly over the herbs or the process used to nano-size them. He holds over 900 patents on nanoscale versions of traditional Chinese medicinal plants.[43] Similar patents are being granted in the US and Europe. For example, the Pacific Corporation (Korea) has won a European patent on nanoscale ginseng for use in cosmetic products.[44] The Pacific Corporation claims that an emulsion of ginseng at the nano-scale (reduced to small particles between 50-500nm) allows it to penetrate the skin, exerting an anti-aging effect.

Patent claims on nano-scale formulations of traditional herbal plants are providing insidious pathways to monopolize traditional resources and knowledge – one more reason why the Convention on Biological Diversity and FAO should address the implications of nanotechnology.

Diamond vs. Chakrabarty Remembered

June 16, 2005 marks the 25th anniversary of Diamond vs. Chakrabarty, the landmark US Supreme Court decision that opened the floodgates to the patenting of all life forms. The anniversary offers a timely opportunity to examine current trends in intellectual property relating to nano-scale technologies – the world's newest technological wave.

In 1971, Ananda Chakrabarty, an employee of General Electric, applied for a patent on a genetically modified, oil-eating microbe. His patent application was rejected by the US Patent & Trademark Office (US PTO) on the grounds that animate life forms were not patentable. When Chakrabarty won his case on appeal, the PTO Commissioner, Sidney Diamond, took the case to the US Supreme Court.

On June 16, 1980 by a narrow 5-4 margin, the US Supreme Court ruled that Chakrabarty's oil-eating microbe was not a product of nature; living organisms could be seen as human made inventions and are therefore patentable subject matter. An ironic footnote to the saga is that the "invention" didn't work.

The monumental importance of the Chakrabarty decision did not register with the Court – or the public – at the time. (Some environmentalists were eager to embrace life patenting if it meant microbes could devour oil spills.) In 1980 the Supreme Court specifically noted that the Chakrabarty decision was a narrow case that would not affect the "future of scientific research."[45] The Court got it wrong. According to lawyer and activist Andrew Kimbrell, "The complete failure by the Court to correctly assess the impacts of the Chakrabarty decision may go down as among the biggest judicial miscalculations in the Court's long history."[46]

As a result of Chakrabarty, the slippery slope of IP on living organisms became a patent landslide, and a bonanza for the biotech industry. Over the course of a single decade, the US government re-interpreted intellectual property laws to allow for exclusive monopoly control over *all* biological products and processes. After Chakrabarty, the once unthinkable patenting of genes, plants, animals, microorganisms and human genetic material would become common practice in the US – positioning industry and the US government to set the precedent for IP regimes worldwide via the World Trade Organization and through bilateral and regional trade agreements.

The Chakrabarty "Life Patenting" Timeline

1980 – Diamond v. Chakrabarty – US Supreme Court case establishes precedent for the patenting of living organisms.
1980 – US Bayh-Dole Act allows businesses, universities and non-profit organizations to retain title to patents that result from federally-funded research, and to exclusively license them.
1984 – University of California wins US patent on a cell line developed from cancerous tissue of John Moore, a leukemia patient whose cancerous spleen cells were patented and commercialized without his knowledge.
1985 – US PTO rules that genetically engineered plants, seeds and plant tissue are patentable subject matter.
1986 – Uruguay Round of General Agreement on Tariffs and Trade (GATT) begins with Trade-Related Intellectual Property (TRIPs) on the table.

1987 – US PTO rules that genetically modified animals are patentable subject matter.
1988 – US PTO issues first patent on a living animal – a transgenic mouse. Harvard licenses the "OncoMouse" to Dupont.
1993 – Patent claim by the US Secretary of Commerce on the cell line of a 26-year old Guaymi indigenous woman from Panama. Following worldwide controversy, the US government abandoned its patent claim on the Guaymi cell line in November 1993.
1994 – EPO issues species-wide patent on all genetically modified soybeans to Agracetus (later acquired by Monsanto).
1995 – WTO comes into force at the conclusion of the Uruguay Round of GATT.
1995 – Civil society organizations and social movements in Europe defeat European Patent Directive that aims to harmonize patenting of genetic material within the EU.
1995 – US Supreme Court rules in Asgrow vs. Winterboer that farmers no longer have the right to harvest and re-sell proprietary seed for reproductive purposes (that is, proprietary seed protected by Breeders' Rights – plant variety protection – may be saved only for the purpose of re-planting the farmers' own acreage).
1995 – US PTO issues patent to US National Institutes of Health for an unmodified human cell line from an indigenous person from Papua New Guinea. Due to the international controversy, the US government is forced to disclaim the patent in December 1996.
1998 – European Parliament gives final approval to a controversial biotechnology "patent directive" that aims to harmonize national legislation on the patenting of genetic material within the EU. The Directive creates, for the first time in European history, an explicit legal right to patent higher organisms such as plants and animals.
2002 – Canadian Supreme Court rules against patenting of higher life forms – rejects patenting of genetically modified mouse.
2004 – Canadian Supreme Court (Monsanto v. Schmeiser) affirmed Monsanto's right to prosecute farmers who are found to have proprietary GM crops growing on their land – whether they wanted them or not.
2004 – US Patent & Trademark Office establishes nanotechnology patent class.

Lessons learned from Chakrabarty:

- Historic decisions allowing exclusive monopoly control of all biological products and processes involved no public input or wider societal debate; these decisions were made by a handful of individuals in the courts and patent offices – not by the US Congress. In essence, it was the courts and not citizens who gave biotech the green light in the US. Similarly, at the international level, intellectual property rules have been crafted by and for a narrow group of corporate interests.

- Following Chakrabarty, the US government's aggressive life patenting policies set the bar for the rest of the world – especially at the World Trade Organization.

- The slope is slippery indeed. The history of patent monopoly (see below) demonstrates that patent holders typically seek wider patentability, more expansive scope of patent claims, longer patent terms and greater harmonization of patent rules worldwide.

- For many developing nations the rationale for accepting stronger IP regimes has been the argument that their economies would prosper from increased technology transfers and foreign direct investment. In the case of biotechnology, however, the vast majority of key enabling technologies are proprietary products and processes, tightly concentrated in the hands of multinational gene giants. Under these conditions, stronger levels of IP obligate developing countries to make a massive transfer of resources to the North, in order to acquire licenses for proprietary technologies.[47] A new study by the World Bank concludes that the effects of stronger intellectual property regimes in creating greater trade flows to developing countries are "theoretically ambiguous."[48] The authors conclude, however, that stronger levels of intellectual property in developing countries are not a factor in spurring high-technology trade flows.[49]

From Dust to Dust: A concise history of patent monopoly

The rallying cry "no patents on life" has become a line in a technological and legal sandstorm. Although the notion of intellectual monopolies can be traced back to early Greece, patents did not come into their own until Britain's Industrial Revolution when the inventors of textile machinery demanded "protection." Recognizing that patents would make technology accessible only to well-heeled manufacturers, smaller enterprises protested. The response: "Don't worry. We only seek to patent the machines we invented."

In the 1920s and 30s, when rose and chrysanthemum breeders demanded intellectual property for their flowers, they argued that it was unfair to grant patents to machine inventors but to deny equal rights to ornamental inventors. Although some were repelled by the idea that living things could be patented, the flower companies replied, "Don't worry. These patents protect only decorative plants – not food crops."

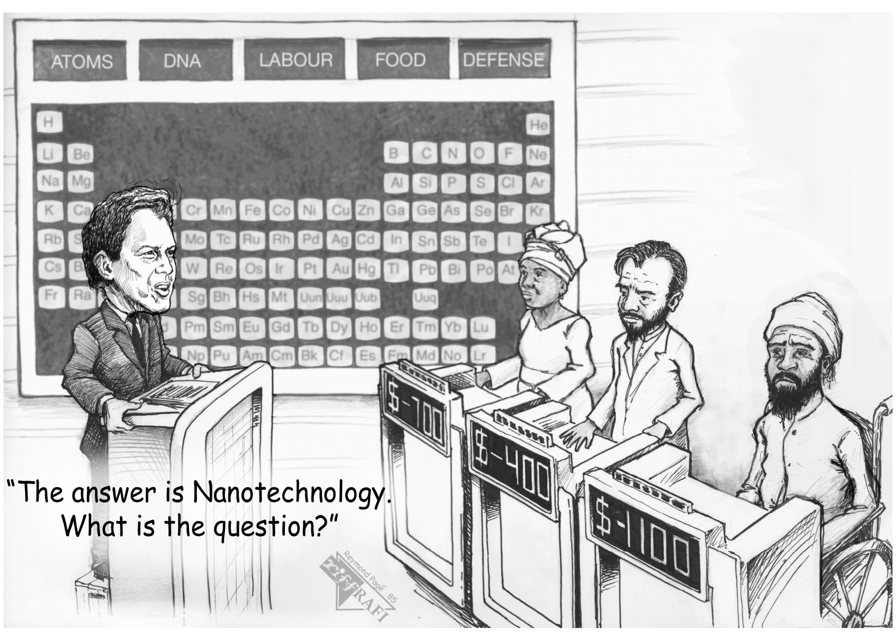
In the 1960s, when plant breeders called upon governments to grant them intellectual property over food crops, they said it was unfair to recognize the minor contributions of ornamental breeders without recognizing the contributions of the breeders of crop varieties. The companies chided their critics by saying, "Don't be alarmed. We just want breeders' rights to protect plant varieties; we're not patenting plants, animals or human genetic material, and we would never stop farmers from saving seed."

In 1980, the Gene Giants won patents on genetically modified microbes. A few years later they applied for patents on plants and animals. When civil society protested, industry responded, "Why all the fuss? If you allow the patenting of micro-organisms, why not plants and lab rats?"

In the 1990s, corporations and governments began to patent genes, snippets of DNA, and entire human cell lines. When indigenous peoples protested, patent offices responded, "Don't worry. Human cell lines are just microorganisms."

Meanwhile, patents made it illegal for farmers to save and re-use proprietary seed. The seed/biotech industry denounced the 12,000-year old right of farmers to save harvested seed as patent infringement.

With the advent of nano-scale technologies, corporations are patenting essential building blocks of all living and non-living things. Industry is redefining life to create hybrid organisms that will take on machine functions. When we tell them they have gone too far, they will reply, "Don't worry. We're all just machines."



Downsizing Development:
The Impact of Nanotech IP in the Global South

Over the past two decades the role of intellectual property in all areas of science and technology has exploded globally – primarily due to rules prescribed by the World Trade Organization's Trade-Related Aspects of Intellectual Property (TRIPs) and by bilateral/regional trade agreements. The TRIPs agreement obligates all WTO member countries to adopt and enforce minimum standards of intellectual property. WTO has 150 members, and claims that it accounts for over 97% of all world trade.[50] In 1996 the World Intellectual Property Organization (WIPO) and WTO established a collaborative relationship in order to implement the TRIPs Agreement. (WIPO has 182 member states, which represents over 90% of the world's countries.)

Among other IP rules, WTO members must allow patenting in *all* fields of technology. The initial grace periods and flexibility allowed by TRIPs for developing country members have nearly expired. By 2006, the so-called "least developed countries" are required to adopt the WTO/TRIPs standards.

Over the past decade, civil society, social movements, the UN Human Rights Commission and some governments have warned of the inequities of IP for the global South. Recently, even at WIPO – the UN body whose mission is to promote and protect intellectual property – the uneven IP playing field and the negative impacts of TRIPs have become undeniable and untenable for many developing nations. In September 2004 the "Geneva Declaration on the Future of the World Intellectual Property Organization" warned that current IP regimes are having negative impacts in the developing world, resulting in lack of access to essential medicines, anticompetitive practices that hinder innovation and the misappropriation of social and public goods.[51] At WIPO's General Assembly meeting (September 27-October 5, 2004), Brazil and Argentina, supported by 14 developing country co-sponsors, proposed that WIPO adopt a "development agenda," stating that

> Intellectual property protection cannot be seen as an end in itself, nor can the harmonization of intellectual property laws leading to higher protection standards in all countries, irrespective of their levels of development. The role of intellectual property and its impact on development must be carefully assessed on a case-by-case basis. IP protection is a policy instrument the operation of which may, in actual practice, produce benefits as well as costs, which may vary in accordance with a country's level of development. Action is therefore needed to ensure, in all countries, that the costs do not outweigh the benefits of IP protection.

WIPO's General Assembly adopted the decision to welcome a development agenda. But the US, UK and other industrialized nations are balking at the decision to give development concerns a higher profile within WIPO, acknowledging only that WIPO should give greater technical assistance to developing countries.[52] Reports will be prepared and the issue will be considered at WIPO's General Assembly meeting in September 2005.[53]

Meanwhile, developing nations are now facing a new technology wave – and the requirement to accommodate nanotechnology-related inventions – even while still grappling with unresolved controversies over biotechnology and information technologies. By next year, ready or not, most of the world's developing nations will be obligated to evaluate and enforce nanotech patents.

Conclusion:

ETC Group is not suggesting that nanotech, unencumbered by patents, will provide solutions for the South's most pressing needs. On the contrary, ETC Group believes that a technological fix can never right social wrongs. However, much ink has been spilled of late on the benefits nanotech will bring to developing nations while ignoring the realities of technology transfer and intellectual property.[54]

Multinational corporations, universities and nanotech start-ups (primarily in the OECD countries) have already secured numerous patents on essential nanotech tools, materials and processes. To the extent that these are "foundational" patents – that is, seminal breakthrough inventions upon which later innovations are built, researchers in the developing world could be shut-out. Nanotech patent thickets are already causing concern in the US and Europe. Researchers in the global South are likely to find that participation in the proprietary "nanotech revolution" is highly restricted by patent tollbooths, obliging them to pay royalties and licensing fees to gain access.

Ultimately, nanotech will profoundly impact the South's economy, regardless of its level of direct participation or its handling of intellectual property. Nano-scale manufacturing platforms could make geography, raw materials, as well as labour, irrelevant. By employing nanotech to build from the bottom-up rather than processing down, the quantity of raw materials required could be sharply reduced. In short, nano-scale technologies are poised to become the strategic platform for global control of materials, food, agriculture and health in the immediate years ahead. Intellectual property monopoly is a crucial and powerful tool for realizing that strategy. As a starting place for further debate, ETC Group offers the following recommendations related to nanotech IP.

Six "Pro-South Science" Policy Proposals:

1. **Poor applause:** When the G8 meets in July to discuss its dubious "Pro-Poor Science" strategy, leaders of rich nations shouldn't ignore the restrictions implicit in intellectual property that make it difficult or impossible for the South to develop its own independent technology solutions and to have access to the useful technologies of others. A truly "Pro-South" science policy would establish a global ten-year sunset clause on all monopoly patents.

2. **Patent pause**: WIPO should initiate a global suspension of patent approvals related to any applications that meet the US PTO's Class 977 standard (the criteria for nanotechnology patents) until further social review, including wide public debate, is undertaken on the impacts of nanotech IP.

3. **Technology flaws:** In close cooperation with social movements, including trade unions, the Food and Agriculture Organization (FAO) and the United Nations Conference on Trade and Development (UNCTAD) should cooperate with WIPO in producing a study on the impact of nanotech-related intellectual property on monopoly practices, technology transfer and trade. The UNCTAD Commission on Science and Technology for Development, also in conjunction with social movements, should examine the implications for technology transfer and the needs and interests of developing countries.

4. **TRIPs clause**: South governments and countries-in-transition should suspend any Class 977 equivalent patent grants or applications pending a full evaluation of their impacts. In particular, governments should determine whether or not such patents compromise access to the basic elements of nature or contravene national legislation or international agreements, such as WTO TRIPs, concerning intellectual property over living material.

5. ***Ordre public* laws**: National governments and relevant international organizations such as WIPO and UNCTAD should examine the social and *ordre public* significance of Class 977 equivalent patents that could compromise access to the fundamental components of nature.

6. **Diversity laws:** With input from indigenous peoples and peasant farmers' organizations, the Convention on Biological Diversity (CBD), the Commission on Sustainable Development (CSD) and FAO should consider the impact of intellectual property on fundamental elements of nature with respect to biodiversity and national sovereignty over genetic resources (especially in such fields as synthetic biology or nanobiotechnology). In a wider context, either the CBD or the CSD should adopt a permanent agenda item to monitor developments in nano-scale technologies.

Case Studies:
A Closer Look at Nanotech Patent Activities
Is There Plenty of Room at the Bottom?

Why Case Studies? Nano-scale technologies are broadly defined and their potential applications are vast. As a result, it is difficult to measure the impacts of nanotech patent activity without examining specific nano-scale materials and tools. In the following pages, ETC Group examines patent activity involving some of nanotech's "hottest" and potentially most lucrative nanomaterials and one essential tool – scanning probe microscopes. Our case studies include:

- Carbon nanotubes
- Nanosys, Inc. and inorganic nanostructures
- Quantum Dots
- Dendrimers
- Scanning Probe Microscopes

Each case study includes a general introduction to the molecular material or tool, why it is important, potential applications and a profile of the companies/institutions that are most active in commercializing and/or seeking patents. Based on US Patent & Trademark Office (US PTO) patent searches we also provide an overview of recent patent activity (numbers of issued patents and patent applications by year) and the top patent assignees in each area.

Take Note – Limitations of Patent Searches: Unfortunately, the ranking of top patent assignees is not always a true reflection of the number of patents held by each company/institution or the overall level of concentration in patent activity. (More details are provided in each case study.) In some cases, patent databases do not provide updated information on corporate mergers and acquisitions, so it is difficult to provide a completely accurate picture of the concentration in patent ownership or control. More importantly, when publicly funded research institutions in the US grant exclusive licenses on their patented technology to a private sector entity, there is no requirement under patent law that the identity of the exclusive licensee be disclosed.[55] In other words, there is no public accountability – and no public record that allows us to easily monitor who is staking a dominant position in nanotech IP. (US government funding of nanotech is substantial. As legal scholar Ted Sabety points out, "nanotechnology occupies a peculiar dichotomy: it is publicly funded, but the results of the R&D are privately held.")[56]

In the following case studies, ETC Group's patent searches are limited to the (US PTO). While this does not provide a complete snapshot of nanotech patent activity worldwide, the US PTO is the world's largest national patent office and it attracts applicants from all over the world.[57]

We also note that, despite enormous hype and investment, there is no guarantee that the patented nanomaterials highlighted in our case studies will be commercially successful. As one industry analyst notes, "likely uses for nanomaterials have historically not been accurately predicted."[58] It is also important to remember that there are big question marks about the potential toxicity of certain nanomaterials such as carbon nanotubes and quantum dots.

Finally, readers must be cautious when relying on company-generated information/hype that aims to attract investors and customers. In today's environment, many nanotech start-up companies depend on intellectual property as their primary asset.

Nanotech's "Miracle Molecules" Monopolized? A Case Study of Patents on Carbon Nanotubes

> *"Patents concern me greatly, particularly in nanotubes. There are so many patents being issued. I fear that we are setting ourselves up for many years of IP lawsuits. This will have a chilling effect on innovation."* – James R. Von Ehr II, founder and chairman of Zyvex Corporation[59]

What are carbon nanotubes? Carbon nanotubes are large molecules of pure carbon that are long and thin and shaped like tubes, about 1-3 nanometers (1 nm = 1 billionth of a meter) in diameter, and hundreds to thousands of nanometers long. As individual molecules, nanotubes are 100 times stronger-than-steel and one-sixth its weight. Some carbon nanotubes can be extremely efficient conductors of electricity and heat; depending on their configuration, some act as semi-conductors.

Why are they important? Some people believe that nanotubes are one of nanotech's most promising molecular building blocks because they exhibit unique properties with a wide range of potential commercial applications. Industry enthusiasts believe that carbon nanotubes will radically improve the performance of tiny sensors, electronic and optical devices, catalysts, batteries, fuel cells, solar cells and drug delivery vehicles. Currently 50% of all lithium batteries incorporate carbon nanofibers (wires spun from carbon nanotubes), which double their energy capacity. Some predict that nano-scale carbon transistors will replace silicon transistors within the next decade. Nanotubes are already used in tennis rackets to make them stronger and lighter. Fortifying a bulletproof vest with a small quantity of nanotubes could double its ability to absorb the energy of a bullet.[60] One company is developing carbon nanotubes to make plastics fire retardant. Carbon nanotubes are capable of storing up to 65 percent of their weight in hydrogen – a capacity that could someday make hydrogen fuel cells a cheap and efficient alternative to fossil fuels.[61] Scientists at Rice University are developing a new type of wire made of carbon nanotubes that conducts electricity much better than copper, and could transform the electrical power grid.

The huge potential market for carbon nanotubes hinges on industry's ability to figure out how to produce large quantities of carbon nanotubes more cheaply and uniformly. Today, there are at least three major processes for producing carbon nanotubes, but most companies measure output in only grams per day.

According to a 2005 report from nanotech industry analysts, Cientifica, the nanotube market is poised for big changes. "Massive improvements in capacity are now such that demand for nanotubes will no longer be constrained by production," predicts Cientifica. A total of 65 tons of nanotubes and nanofibers were produced in 2004 with a market value of roughly €144 million. Cientifica predicts that by 2010 carbon nanotube prices will decrease by a factor of 10-100, the global market for nanotubes will surpass €3 billion and Korea will be the major supplier of all types of nanotubes.[62]

Nano Hazards? Despite the huge amount of interest and investment in carbon nanotubes, the toxicological impacts of these and other engineered nanoparticles are still unknown. A handful of toxicological studies reported thus far indicate that there is reason for concern. In 2005 researchers at the US National Aeronautic and Space Administration (NASA) reported that when commercially available carbon nanotubes were injected into the lungs of rats it caused significant lung damage.[63] (The researchers indicated that the nanotube dosage applied to rats was roughly equivalent to worker exposure levels over a 17-day period.) In a separate study, researchers at the US National Institute of Occupational Safety and Health reported in 2005 substantial DNA damage in the heart and aortic artery of mice that were exposed to carbon nanotubes.[64]

The Nanotube Patent Thicket: Although nanotech is often described as a nascent industry – patent offices have already granted hundreds of patents on carbon nanotubes. As a result, in those countries where the patents are recognized, it is virtually impossible to make or use materials, devices and systems based on carbon nanotubes without infringing a swarm of existing patents – whose claims are often broad, overlapping and conflicting.

The quagmire is known as a "patent thicket" and it means that any researchers hoping to develop new technology based on carbon nanotubes must first negotiate licenses from multiple patent owners. (And there's no guarantee that a company will agree to license its patent – especially if it aims to curb competition.)

A 2004 review of US patents related to carbon nanotubes conducted by John Miller et al. uncovered 306 patents on nanotubes and the methods used to produce them.[65] The survey identified at least 10 patents claiming nanotubes, 38 patents on nanotube production methods, 20 patents on general-purpose tools and processes, and over 238 patents on various applications of carbon nanotubes. The authors point out that, even if a company developed a revolutionary new product or process involving carbon nanotubes, the new innovation would undoubtedly infringe existing patents. The authors conclude, "As nanotechnology continues to develop, the minefields of patents will become more difficult to traverse."[66]

Who Owns Patents on Nanotubes? Single-wall carbon nanotubes were discovered in 1991 by Sumio Iijima of Japan, a researcher for Japanese computer giant, **NEC Corporation**. In 2004, the company asserted that any company that wants to manufacture or sell carbon nanotubes must first negotiate a license on NEC's two seminal patents.[67] NEC is expected to license its carbon nanotube patents widely; last year, Japan's **Sumitomo Corporation** was the first company to negotiate a license.[68]

IBM also holds an early and fundamental patent on single-wall carbon nanotubes. US Patent No. 5,424,054 has been identified by patent lawyers as one of the ten most important patents that could have an impact on the future development of nanotech. IBM's patent was licensed to Carbon Nanotechnologies, Inc.

Carbon Nanotechnologies Inc. (CNI) is the self-described "preeminent world producer" of carbon nanotubes. The Houston, Texas-based company was founded in 2000 by Rice University Nobel Laureate and entrepreneur, Richard Smalley. According to CNI's president, Bob Gower, the company holds a portfolio of 30 patents related to carbon nanotubes, and about 12 of them give CNI a lock on the nanotube market. In addition, CNI has 70 patent applications pending that include 4,000 claims on nanotube compositions, methods of production and end-use applications.[69] "We expect to be the supplier in this arena," Gower told the *Houston Chronicle*.[70]

The company sees its patent portfolio as the key to the company's survival. CNI's chief financial officer told *Small Times,* "IP protection is critical for everything we've done. IP gives us the freedom to price appropriately and keep others from nipping at the door."[71]

CNI's strategy is to stake claims on the dominant methods used to manufacture carbon nanotubes. CNI founder Richard Smalley asserts that his company has "an exceptional intellectual property position in all the process routes" that are considered practical for large-scale commercial production of single-wall carbon nanotubes.[72]

While most of its competitors produce just grams of nanotubes per day, CNI claims that it's the only manufacturer that can crank out 25 lbs. or more of nanotubes per day, with plans to scale-up to 100 lbs. per day in 2006.[73] In early 2005 the company also began to manufacture double-wall carbon nanotubes in gram to multiple kilogram quantities.[74] (While 25 lbs. per day seems almost negligible, it's important to keep in mind that CNI sells its tubes by the gram with a one-gram minimum. That means, in theory, that 25 lbs. of nanotubes could represent over 11,000 one-gram orders!)

CNI has about 500 customers, including many commercial firms that are purchasing tiny amounts of nanotubes to test in products ranging from plastics, batteries, water purification systems to aerospace, defense and space exploration. One corporate client, Korean electronics titan, Samsung, is using CNI's carbon nanotubes to create a new generation of energy-saving, flat-screen televisions.

Hyperion Catalysis based in Cambridge, Massachusetts (USA) claims that its multi-wall carbon nanotubes were first synthesized in 1983, and the company holds a seminal patent issued in 1985.[75] The company sells multi-wall nanotubes dispersed in a range of plastics for commercial automotive and electronics applications.

Worldwide, there are less than 20 companies making commercial quantities of carbon nanotubes.[76]

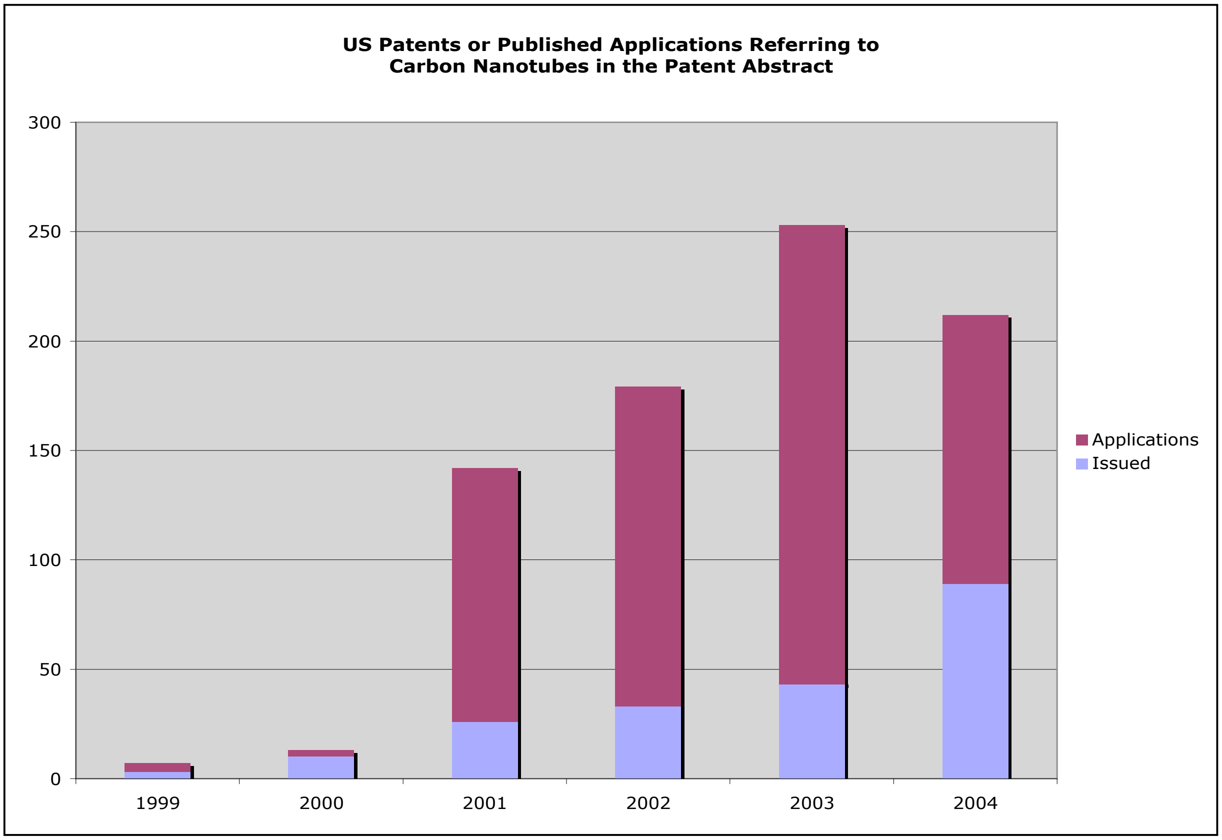
Nanocyl S.A. (Belgium) is the leading manufacturer and developer of carbon nanotubes in Europe. Other players include, for example: **Nanoledge** in France, **Rosseter Holdings** in Cyprus; South Korea's **ILJIN**; Moscow's **Nanocarblab**; **Shenzhen Nanotech Port Co.** in China and Tokyo's **Carbon Nanotech Research Institute**.

Carbon Nanotube patents issued by US PTO (1999-2004) **Top Assignees – 257 patents total**		**Number of patents**
Samsung Electronics and Samsung SDI Co., Ltd.	Korea	23
Rice University	USA	14
Hyperion Catalysis International, Inc.	USA	10
The United States of America	USA	9
Univ. of Kentucky Research Foundation	USA	8
Industrial Technology Research Institute	Taiwan	8
NEC Corp. and Research Institute, Inc.	Japan	7
Intel Corporation	USA	6
Iljin Nanotech Co., Ltd.	Korea	5
Battelle Memorial Institute	USA	4
The Regents of the Univ. of California	USA	4
Agency of Industrial Science and Technology	Japan	4
Hitachi, Ltd.	Japan	4
LG Electronics, Inc.	UK	4
Stanford University	USA	4
The Regents of the Univ. of California	USA	4

The nanotube patent search was conducted on 25 April 2005.

The Bottom Line:

- To the extent that carbon nanotubes represent an important component in nanotech-related materials, they will affect traditional commodity markets and demands for raw materials. Concerns about ownership and control of carbon nanotubes are especially relevant to the global South.
- ETC Group's list of top patent assignees (see chart) of US patents related to carbon nanotubes reveals that ownership of carbon nanotube patents is highly fragmented – there are numerous players in diverse industries.
- There were 140 different primary patent examiners for the 257 patents on nanotubes issued by the US PTO. The lack of uniform handling increases the likelihood that different examiners in different departments reviewed different prior art and this could result in overlapping patent claims.
- ETC Group agrees with analysts who conclude that there currently exists a nanotube patent thicket. A swarm of existing patents, whose claims are often broad, overlapping and conflicting, means that researchers hoping to develop new technology based on carbon nanotubes must first negotiate licenses from multiple patent owners.
- Lux Research, a nanotechnology consulting firm, recently conducted its own study of the IP nanotech landscape. The Lux report concludes that "nanotube patents look messy in electronics," but they found that carbon nanotube patents are not a problem in all areas (especially energy, healthcare and cosmetics).[77]
- Since patent databases do not always reveal the current ownership of patents or disclose assignees, our list of leading carbon nanotube patent assignees is not a true reflection of a company or institution's dominant position. CNI claims that it has an exceptional IP position in all the process routes for producing carbon nanotubes, for example, but it is not immediately apparent by conducting patent searches. However, CNI has licensed nanotube patents from Rice University. (Richard Smalley is both a Rice faculty member and founder of CNI.)
- The number of US patents already granted relating to carbon nanotubes is considerable, but the number of patent applications received by US PTO from 2001-2004 is far greater – suggesting that there could be increased activity in the nanotube patent area in the immediate years ahead. US PTO patent applications do not always reveal patent assignees – so it is impossible to predict which companies/institutions are most actively seeking patents in this area, or by whom the patents, if granted, will be controlled.



Nanosys, Inc. – A Case Study of Patents on Inorganic Nanostructures

> *"Thus, all of the important intellectual property in inorganic semiconductor nanostructures is consolidated in one place – Nanosys – enabling the creation of a single, industry-dominant position."* – Larry Bock, CEO, Nanosys[78]

Nanosys, Inc.: Founded in 2001, California-based Nanosys, Inc. is one of the most talked about nanotech start-up companies in the United States. The creation of venture capitalists, the company was scheduled to make its debut as a public company in 2004 – but yanked its initial public offering (the sale of stock to the public) when the market for tech stocks looked uncertain. The company's much-heralded debut was a dud.

Nanosys doesn't sell a single product and admits that it won't have any profits for years to come, but it does have a star-studded scientific advisory board, big-name corporate partners (**Dupont**, **Intel**, **Sharp**, **Matsushita Electric Works**, etc.), US government grants and a CEO who is a seasoned entrepreneur – having started some 14 biotech firms with venture capital. Nanosys has something else that makes it the envy of every fledgling nanotech business – a patent portfolio that virtually corners the market on inorganic nanostructures.

For Nanosys, Inc., the name of the game is proprietary nanomaterials – inorganic nanostructures the company believes will be the fundamental molecular building blocks for a wide range of commercial products – ranging from solar cells, electronic circuits, LEDs, chemical and biological sensors, etc. **DuPont** is partnering with Nanosys to use nanostructures as the basis for thin, flexible display screens. **Matsushita** and Nanosys are working on nanotech-enabled solar panels, and Intel is teaming up with Nanosys to develop memory chips for permanent data storage.

What are inorganic nanostructures?
Nanostructures include all shapes – wires, rods, "tetrapods," dots – formed from all of the industrially important semiconductor materials (such as silicon). Because they are under 100 nanometers, Nanosys seeks to exploit their quantum properties – new and unique electronic, optical, magnetic, interface and integration properties. But nanostructures are not just materials, they are molecular-scale devices grown from the bottom-up. Nanosys CEO Larry Bock explains:

"Nanosys is focused on high-performance inorganic nanostructures. These are nanostructures made out of commercially important materials like silicon, gallium arsenide, indium phosphide but grown from the bottom-up instead of traditional down processing. When we grow these structures we can literally define where each and every atom is in these structures on the atomic scale. And as a consequence of that we can very finely tune their electronic, optical, magnetic-thermal properties. So when we grow these structures we are integrating a lot of functional complexity into these structures as we grow them – so now they are no longer materials, they now become devices. So, for example, we can engineer things like high-performance transistors, LEDs, solar cells, little lasers and so forth into these nanostructures as we grow them.[79]

Nanosys emphasizes that – in stark contrast to carbon nanotubes – its nanostructures are uniformly synthesized and well-defined building blocks. The company claims that its proprietary semiconductor nanostructures are the only class of nanomaterials whose structure and properties can be predicted and controlled based on computer models with "a precise synthetic recipe that produces the exact structure in high-purity and high-yield, with every particle identical to every other."[80]

Nanosys' Patent Strategy: Nanosys' executives realized a few years ago that the patents it wanted to control on inorganic nanostructures were held by a few leading academic institutions. The company acted quickly to sign broad, exclusive licensing agreements with leading universities such as Columbia, Harvard, Hebrew University, Lawrence Berkeley National Laboratories, MIT, UCLA and University of California-Berkeley. Nanosys also persuaded a "dream team" of nanotech academic researchers to affiliate with the company – including nanoscience super stars like Charles Lieber (Harvard), Paul Alivisatos (UC-Berkeley), Moungi Bawendi (MIT) and Peidong Yang (UC-Berkeley). The goal was to consolidate key talent and key patents at Nanosys.

Today, Nanosys claims to hold "one of the broadest technology platforms in the industry" with more than 350 US and international patents and patent applications covering fundamental areas of nanotechnology.

The Bottom Line:

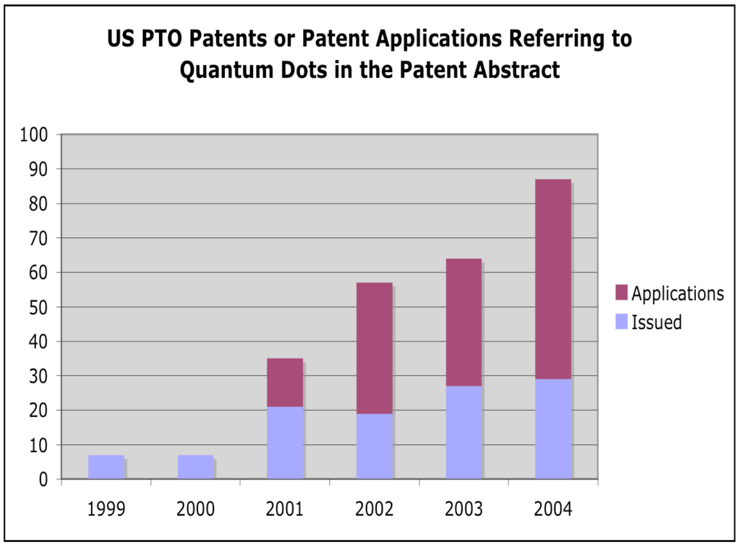
- By all accounts, Nanosys has amassed an extensive patent portfolio with ownership of key nanoparticle patents – especially in the area of nanowires.
- A detailed patent search of inorganic nanostructures, however, would not reveal or confirm Nanosys' dominant position in this area (many of Nanosys' key patents were obtained by exclusive license agreements with public sector institutions). In fact, Nanosys is listed as the assignee for only two patents issued at US PTO, and 15 patent applications.

A Case Study of Patents on Semiconductor Nanocrystals
Who is Queen of the Quantum Dots?

> ***"If you want to look for a place where there will be an intellectual property battle, this is it."*** – Matthew Nordan, vice president of research for Lux Research, commenting on 'quantum dot' patents granted by the US PTO[81]

What are quantum dots? Semiconductor nanocrystals, or "quantum dots," are another of nanotech's "miracle molecules" whose quantum properties promise a wide range of applications across several industrial sectors.

Why are they important? Companies are



exploiting the unique optical effects that occur when semiconductor nanomaterials change size – as the particles are reduced in size, they emit distinctly different colors. The particles can be attached to or incorporated in materials, including biological materials, to act as a kind of barcode or tracking device. One project underway aims to incorporate quantum dots in inks or polymers used in the manufacture of paper money as a way to combat counterfeiting.[82] Currently, quantum dots are used for labeling live biological material *in vitro* and *in vivo* in animals (other than humans) for research purposes – they can be injected into cells or attached to proteins in order to track, label or identify specific biomolecules.

In January 2004, Carnegie Mellon University researchers – collaborating with scientists from **Quantum Dot Corporation (QDC)** – announced that quantum dots injected in animals circulated in the blood for hours and continued emitting their distinctive colors for eight months.[83] (Once they stopped circulating, the nanocrystals collected in the liver, spleen, lymph nodes and bone marrow, suggesting that the particles were picked up by immune cells whose job it is to sweep up circulating debris.[84]) The hope is that one day quantum dots will be used in humans to treat and monitor diseases such as cancer. Researchers will have to proceed with caution because the core material in most semiconductor nanocrystals is highly toxic cadmium and "formal or systematic studies" to determine toxicity of quantum dots have not been conducted.[85] Comprehensive toxicological data on quantum dots are crucial and will determine the likelihood of extensive *in vivo* applications in humans.

Who Controls Patents on Quantum Dots? According to Lux Research's Matthew Nordan, two companies – **Nanosys** and **QDC** – claim to have divvied up exclusive licenses to all key patents on quantum dots, with QDC laying claim to biological applications and Nanosys claiming everything else.[86] Founded in 1998, QDC develops and sells semiconductor nanocrystals for biological, biochemical and biomedical applications. QDC has licensed 22 patents and owns or has licensed over 90 US and international patent applications currently under examination.[87] QDC asserts that "only QDC can provide…licensed water-soluble nanocrystal-linker compounds for biological uses."[88] Nonetheless, **Evident Technologies** of Troy, NY (USA) markets proprietary water-soluble semiconductor nanocrystals for biomolecule detection. Evident says they are not infringing

Quantum dot patents issued by US PTO (1999-2004) **Top Assignees – 146 patents total**		**Number of patents**
MIT	USA	15
University of California	USA	12
Quantum Dot Corporation	USA	10
Technology & Devices Intl.	USA	7
IBM	USA	7
Sony Corporation	Japan	7
University of Illinois	USA	6
Texas Instruments	USA	6
Electronics and Telecommunications Research	Korea	6
Matsushita Electric Industrial Co., Ltd.	Japan	5
Fujitsu Limited	Japan	5

The patent search was conducted on 2 May 2005.

QDC's patents, but as Lux's Nordan points out, "one of these two standpoints is wrong."[89] The lack of standardized terminology may have led to the granting of over-lapping patents, with claims that read very differently but do in fact describe the same processes or products. For example, a broad patent search using keywords (including *semiconductor* *nanocrystals*, *quantum dot*, *nanodot*) brings up only one of Evident's five patents, all of which refer to prior art related to the optical effects of nanocrystals.

The Bottom Line:

- ETC Group's list of top quantum dot patent assignees reveals that university labs have actively pursued patents on quantum dot related research. The concentration in ownership of key quantum dot patents (especially the dominant positions of **Nanosys** and **Quantum Dot Corporation**) is obscured, however, partly because patent assignees are not disclosed.

- There is enormous potential for overlapping and conflicting patents in the quantum dot arena. The 146 patents issued by the US PTO from 1999-2004 on quantum dots technology had 71 different patent examiners. Different examiners in different departments may have reviewed different prior art, leading to the issuance of patents that might otherwise be rejected.[90]

- While the number of US patents related to quantum dots did not experience dramatic growth from 2001-2004, patent applications in the area of quantum dots are increasing every year. The trend suggests that patent activity in this area will be even more crowded, and complex, in the immediate future.

Nanomaterials Branching Out
A Case Study on Dendrimer Patents

> ***"Dendrimers pose the biggest question mark…A large number of relevant claims have been assigned from pioneer Dow to one start-up company, Dendritic Nanotechnologies."*** – Lux Research, April 2005, on the prospects for the commercial development of dendrimer technologies, based on their analysis of the intellectual property landscape[91]

What are dendrimers? Dendrimer, from the Greek word (*dendron*) for tree, refers to a synthetic, three-dimensional molecule with branching parts. Dendrimers are formed using a nano-scale, multi-step fabrication process. Each step results in a new "generation" that has twice the complexity of the previous generation – a first generation dendrimer is the simplest; a tenth generation dendrimer is the most complex and can take months to engineer.[92] Donald Tomalia, a researcher working for chemical giant **Dow**, first synthesized and named dendrimers in 1979.

Why are they important? Dendrimers are "stealth molecules" that have many potential applications, including diagnostic and therapeutic applications. By customizing and controlling dendrimer "architecture," nanotechnologists are developing dendrimers for drug delivery, diagnostic imaging and as carriers of genetic material. Dendrimers can easily move across biological membranes and they can store a wide range of metals, organic or inorganic molecules among their branches. Companies developing these synthetic molecules claim that most dendrimers don't trigger the immune system when injected or used topically, and have low cytotoxicity (that is, toxicity to cells).[93] However, some forms of dendrimers can induce clotting in the bloodstream – a potential concern for *in vivo* applications.[94]

Dendrimers could also be used in coatings and materials, electronics and photonics. A look at the patent assignees for dendrimer technology reveals the wide range of potential applications – patents are assigned to chemical, petroleum, tire, cosmetics and pharmaceutical companies, among others.

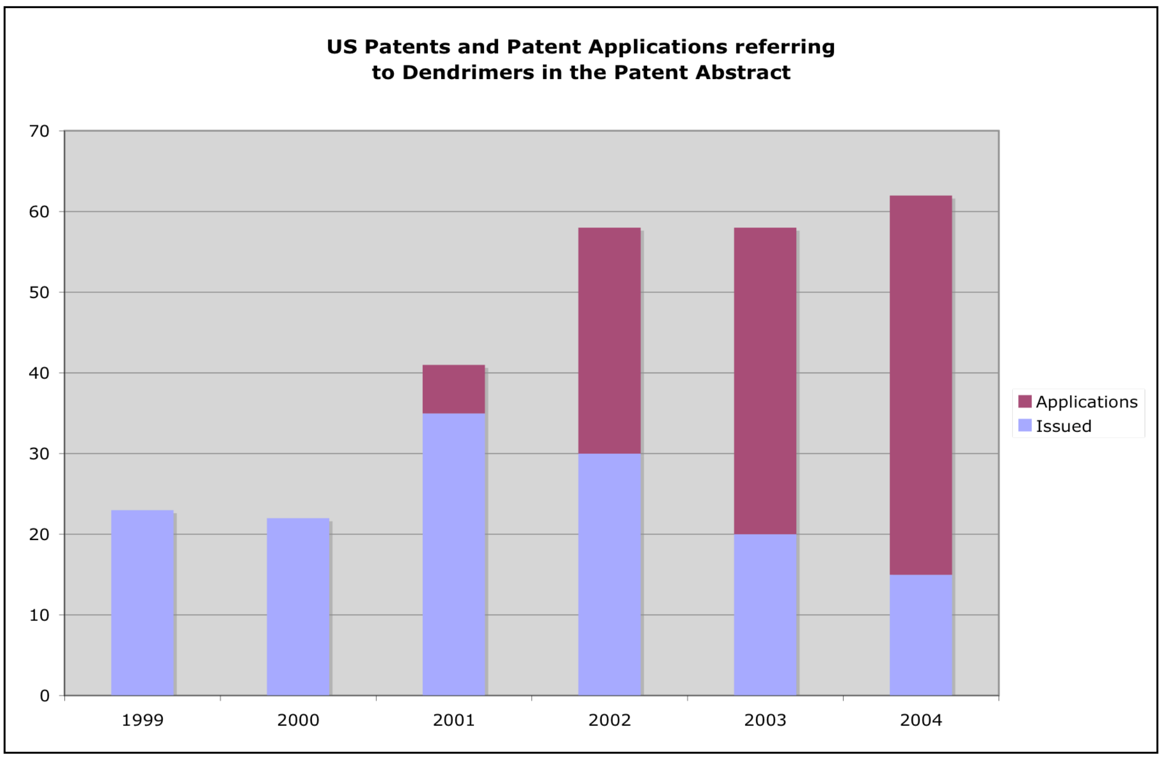
Commercial development of dendrimers has been slow because of the difficulty of scaling-up production and because their cost is prohibitively high. Diagnostic-grade, tenth generation dendrimers go for US$1,650/100mg.[95] A new, copper-catalyzed process for dendrimer synthesis announced in 2004 has reportedly increased yields.[96] Dendritic Nanotechnologies has reportedly filed for patents on a new, one-step process to synethesize dendrimers, which could potentially drive down the cost of production.[97]

Dendrimer-based products (and those in the pipeline) include, for example.

- A dendrimer-based tool for detecting cardiac damage is being developed by **Dade Behring**, one of the world's largest medical diagnostic firms.
- The world's first drug based on dendrimers, developed by Australian-based **Starpharma**, is a topical gel for use as a "liquid condom" to reduce the risk of HIV infection in women. StarPharma's "VivaGel" microbicide has gone through initial animal testing and phase-one safety trials in humans.
- The **US Army Research Laboratory** is developing a dendrimer-based anthrax detection agent, dubbed "Alert Ticket.
- **ExxonMobil** owns patent 5,906,970 on a "flow improver" based on dendrimer technology – an additive that will increase the flow of oil in cold temperatures.

Who Controls Dendrimer IP?

The Dendrimer IP shuffle: Dendrimer IP is a "hot potato" because the potential for profit is enormous but commercialization is slow and uncertain – everyone wants to be holding key dendrimer patents at just the right time. **Dendritech**, a private company spun off from **Dow** and founded by Tomalia in 1992, sold its dendrimer patents back to Dow in 2000. Then Tomalia left Dendritech and founded a new company, **Dendritic NanoTechnologies Inc. (DNT)**. In January 2005, DNT acquired the mother lode of dendrimer patents when Dow turned over its entire intellectual property portfolio on dendrimers (196 patents worldwide) to DNT in exchange for owning a significant stake in the company.[98] A third company, **Starpharma** (Melbourne, Australia), which already owned a chunk of DNT, increased its



financial stake in the company to 49.9% and also gained exclusive rights to DNT's and Dow's intellectual property for dendrimer-based pharmaceutical applications. The flip-flopping dendrimer patent portfolio is now in the hands of DNT which claims to control "the world's broadest intellectual property position in dendrimer science." Today, DNT sells and licenses more than 200 variations of dendrimers to pharmaceutical, biotechnology and diagnostic companies.

Dendrimer patents issued by US PTO **Top Assignees – 272 patents total**		**Number of patents**
Dow Chemical* - these patents are now owned by Dendritic NanoTechnologies Inc.	USA	39
Bayer AG	Germany	9
Phillips Petroleum Company	USA	9
Xerox Corporation	USA	7
DSM N.V.	Netherlands	6
Dendritech, Inc.	USA	6
Ford Motor Company**	USA	6
University of California	USA	6
ExxonMobil Chemical Patents Inc.***	USA	6
Bridgestone Corporation****	Japan	6

Search conducted on 2 May 2005.

*includes Dow Corning Toray Silicone Co., Ltd. And Dow Corning Corporation
**includes Ford Global Technologies
***includes Exxon Research and Engineering Co.
****includes Bridgestone Tire Company

The Bottom Line:

- Dendritic Nanotechnologies, Inc. clearly holds a dominant position in the dendrimer patent arena.
- The 272 dendrimer patents issued between 1999-2004 were examined by 120 different patent examiners. The lack of uniform handling could result in overlapping and conflicting patents.
- The list of top assignees reveals a particularly broad area of potential industrial applications for dendrimer technology, ranging from oil, pharma, rubber, automotive and even cosmetics.
- While there is uncertainty about the future commercial value of dendrimer IP, there is little room for new, would-be innovators to enter the field without seeking multiple licenses – which may or may not be available from companies seeking to dominate the field.
- The number of issued patents relating to dendrimers has declined every year since 2001. However, the number of dendrimer patent applications at US PTO is rising steadily.

Windows on the Nano-World: Scanning Probe Microscopes and Beyond

> ***"One frequently repeated nugget of wisdom in the nanotechnology business at the moment is that the real money is in making the picks and shovels, as it was in an earlier Californian gold rush. The pick-and-shovel manufacturers in nanotechnology are making tools such as microscopes, manipulators and instruments for working at the nanoscale."*** – *The Economist*, January 1, 2005.[99]

Note on terminology: In this case study ETC Group examines one of nanotech's fundamental and indispensable tools – scanning probe microscopes. We use the general term to refer to a new generation of microscopes (including scanning tunneling microscopes, atomic force microscopes) that enable nano-scale imaging and molecular measurement.

What is a scanning tunneling microscope? On August 10, 1982, IBM won US patent 4,343,993 for the invention of the Scanning Tunneling Microscope (STM), the first microscope that allowed researchers to "see" at the atomic scale. The invention earned its creators a Nobel Prize in 1986 and opened the door to understanding and manipulating nano-scale phenomena. As physicist Richard Feynman said in his now-famous lecture in 1959: if you want to make atomic-level manipulations, first you must be able to *see* what's going on. The STM is, quite simply, a fundamental tool indispensable to the development of nanotechnology.

How does the STM work? The STM doesn't work the way a conventional microscope does – it doesn't magnify a sample until it is big enough to see with an unaided eye. Instead, a fine needle-like tip that is electrically conductive is scanned just above the surface of an electrically-conductive sample. The distance between the tip and the sample is only a few Angstroms (a nanometer is 10 times *bigger* than an Angstrom). When a tiny voltage is applied, the rules of quantum mechanics allow electrons to jump – or "tunnel" – across the space between tip and sample. Though very small, the flow of electrons can be detected easily. As the tip moves along the surface of the sample, the tip's position is constantly adjusted to make sure the distance (and hence, the electrical current) remains constant. These adjustments trace the surface features of the sample. When the features are graphically displayed on a computer screen, it is possible to "see" the individual atoms and molecules that make up the sample.

What is an atomic force microscope? Because the prototype STM relied on electrical flow between tip and sample, it could only be used to examine materials that would conduct at least a small electric current. Since the early 1980s, STMs have evolved into Atomic Force Microscopes (AFMs) that are able to see a wider range of nano-scale samples. The process resembles the original one where a needle-like tip scans across a surface whose topography is "read" and then translated into a graphic image, but the AFM is able to see samples that are not highly conductive, such as biological samples. Rather than maintaining a constant distance between tip and sample, the tip of an AFM is attached to the end of a highly sensitive cantilevered arm and actually touches the surface of the sample to trace it and generate an image.

Beyond SPMs: Coming soon is a tool to view the nano-realm in *three* dimensions, which would dramatically increase our understanding of how things work at the molecular level – such as the complex patterns of protein folding.[100] The idea is to combine magnetic-resonance imaging (MRI) with an AFM – the resulting tool is called a magnetic-resonance force microscope (MRFM). The technology is in the earliest stages, but there are already six granted patents referring to MRF Microscopy. Another development achieved by a research team at Zhejiang University in China is an AFM that can be completely immersed in liquid, facilitating imaging of biological samples.[101] The microscope works in a wide range of corrosive solutions as well, which allowed the researches to measure the corrosion of a sample of lead in real time.[102]

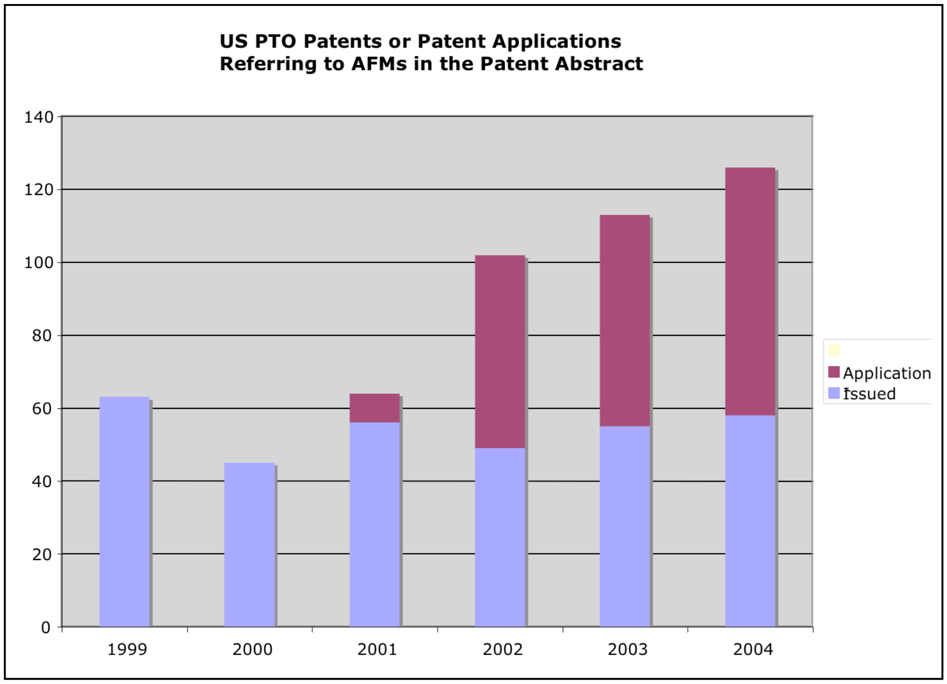
Who Holds Patents on SPMs? The SPM patent landscape is densely populated because the tool is still evolving and inventors tend to seek intellectual property protection on every modification and variation. Since IBM's pioneering patent in 1982, the US PTO has issued 735 patents that refer to AFMs/SPMs in their abstracts.[103] 214 additional patent applications referring to AFMs are pending. As the following chart makes clear, AFM patent activity is still robust, doubling over the last six years.

AFM/SPM patents – top 10 patent assignees

Institution	# of patents	%
Veeco*	82	11%
IBM	61	8%
Olympus Optical Co.	34	5%
Seiko Instruments	32	4%
University of California	26	3%
Hitachi	25	3%
Molecular Imaging	24	3%
Canon Kabushiki Kaisha	21	3%
Stanford University	19	3%
Advanced Micro Devices	17	2%
Jeol Ltd.	17	2%

Search conducted on 22 April 2005.
*includes patents assigned to Digital Instruments, Wyko, Topometrix, Park Scientific and ThermoMicroscopes – all acquired by Veeco

The top 10 patent assignees account for 47% of the total AFM/SPM patents issued at US PTO from 1999-2004.



Veeco considers itself a world leader in nano-scale metrology equipment. Although the company's total sales were only $390 million in 2004, Veeco is the world's leading seller of atomic force microscopes, and dominates the global AFM market. According to Lux Research, Veeco sells between 80 and 100 AFMs/SPMs to the scientific research community every quarter.[104] Veeco has sold over 7,000 research AFMs in addition to more than 120 AFMs used in semiconductor and data storage factories.[105] Veeco's business strategy has been to develop microscopy tools internally and to acquire companies that are already in the AFM business. Veeco's acquisition of the **Wyko Corporation** in 1997 gained Veeco a position in the metrology business; Veeco's acquisition of **Digital Instruments** the following year brought Veeco into the world of Scanning Probe Microscopes. Since 1998, Veeco has continued acquiring metrology companies, including **Topometrix**, **Park Scientific** and **ThermoMicroscopes** as well as technology from IBM. Veeco now holds approximately 150 patents worldwide related to AFMs/SPMs.[106] Veeco is currently involved in a patent dispute with **Asylum Research** – an AFM manufacturer founded by former Digital Instruments employees. Veeco sued Asylum for patent infringement in 2003; in early 2004, Asylum countersued Veeco for failing to pay royalties on a technology developed by Asylum researchers. Dr. Jason Cleveland, Asylum Research's Chairman, stated, "We believe the Veeco lawsuit is an attempt to stop competition and deprive the AFM market of leading edge products."[107] The cases have not been decided.

The Bottom Line:

- Veeco and IBM clearly dominate in the area of IP related to AFMs/SPMs. Through strategic acquisitions of companies and patents, Veeco is the industry leader and holds approximately 150 patents worldwide related to AFMs/SPMs.[108]

- AFM/SPM technologies are not static – they are constantly being refined and advanced. Veeco is a relatively small company – and could be acquired by a larger competitor.

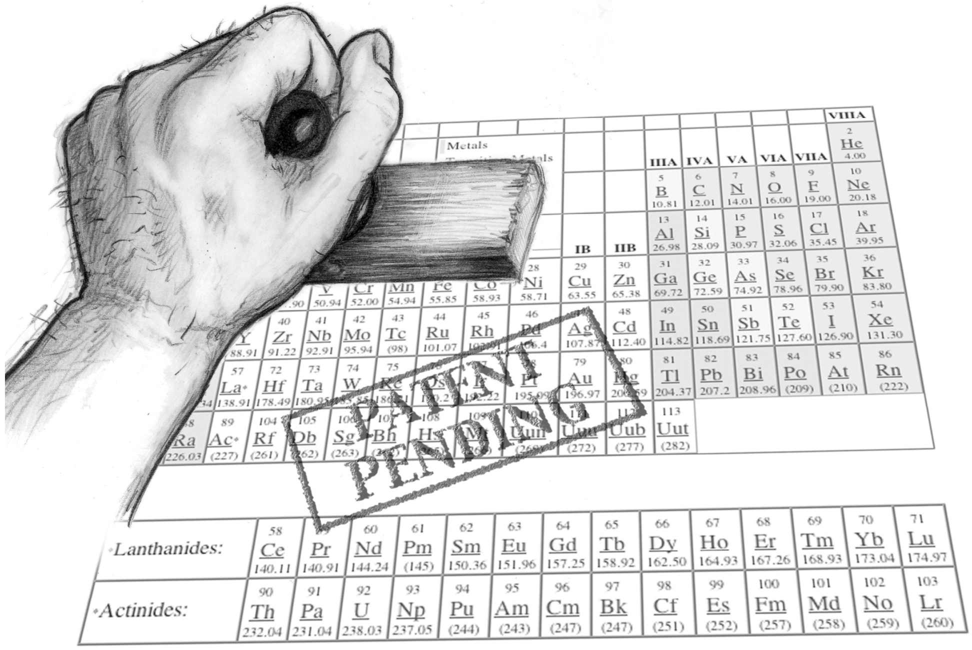
- At this early stage, the concentration in ownership of one of nanotech's key enabling tool should be closely monitored, and poses special concerns for researchers in the global South.

[1] John C. Miller, Ruben Serrato, José Miguel Represas-Cardenas, Griffith Kundahl, *The Handbook of Nanotechnology: Business, Policy and Intellectual Property Law*, John Wiley & Sons, 2005, p. 65.
[2] Smalley is quoted in interview with Sonia E. Miller, "Measuring Nanotechnology's Effect on the Law," *New York Law Journal*, 02-04-2005 (online).
[3] Stacy Lawrence, "Nanotech Grows Up," *Technology Review*, June 2005.
[4] Ann M. Thayer, "Nanotech Investing," *Chemical & Engineering News*, Vol. 83, No. 18, May 2, 2005, p. 17. The estimate comes from Lux Research, Inc.
[5] Stacy Lawrence, "Nanotech Grows Up," *Technology Review*, June 2005, p. 31.
[6] Antonio Regalado, "Nanotechnology Patents Surge as Companies Vie to Stake Claim," *Wall Street Journal*, June 18, 2004, p. 1.
[7] Mark Modzelewski, Executive Director, NanoBusiness Alliance, September 17, 2002, in testimony to US Congress.
[8] John C. Miller, Ruben Serrato, Jose Miguel Represas-Cardenas, Griffith Kundahl, *The Handbook of Nanotechnology: Business, Policy and Intellectual Property Law*, John Wiley & Sons, 2005, p. 65.
[9] Lux Research, Inc., *The Nanotech Report 2004*, Volume 1, p. 186.
[10] Mark A. Lemley, William H. Neukom Professor of Law, Stanford University, "Patenting Nanotechnology," unpublished manuscript sent to ETC Group by the author, March 2005, p. 1.
[11] The search was conducted using the search term "nano" in the patent abstract. The search was conducted on 18 May 2005 and was meant to provide only a general overview of the nanotech patenting trend at WIPO and US PTO.
[12] Zan Huang, et al., "International nanotechnology development in 2003: Country, institution, and technology field analysis based on US PTO patent database," *Journal of Nanoparticle Research* 6: 325-354, 2004.
[13] Charles Q. Choi, "Nano World: Nano Patents in Conflict," UPI, Published April 25, 2005.
[14] Anonymous, The European Commission, Communication from the Commission: Towards a European strategy for nanotechnology, May 12, 2004, COM (2004) 338, p. 17.
[15] Juliana Gruenwald, "Patent office struggles to stay ahead of nanotech industry," *Small Times* on-line, April 20, 2004. Available on the Internet: http://www.smalltimes.com/document_display.cfm?document_id=7743
[16] The USPTO class definition is available online: http://www.uspto.gov/web/patents/classification/uspc977/defs977.htm
[17] Email communication with Bruce Kisliuk, April 1, 2005.
[18] Of course, more nano-patents may be added, but as it stands now, 2003 is the most complete year, with all months represented. The following breakdown adds up to greater than 235 because some patents are owned jointly and assigned to more than one entity – a corporation and a university, for example.
[19] Susan J. Ainsworth, *Chemical & Engineering News*, Volume 82, Number 15, April 12, 2004, pp. 17-22. Available on the Internet: http://pubs.acs.org/cen/coverstory/8215/8215nanotech.html
[20] Tyson Winarski and Elizabeth Stoker-Townsend, "Nanotechnology Thriving on Patents," *Intellectual Property Today*, April 2005, p. 27.
[21] Handbook, p. 212.
[22] Antonio Regalado, "Nanotechnology Patents Surge as Companies Vie to Stake Claim," *Wall Street Journal*, June 18, 2004, p. 1.
[23] Ibid.
[24] D. Harris et al, "Strategies for Resolving Patent Disputes Over Nanoparticle Drug Delivery Systems," *Nanotechnology Law & Business Journal*, Vol. 1, 4, 2004, article 1, p. 7.
[25] Adam B. Jaffe and Josh Lerner, *Innovation and its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It*, Princeton University Press, Princeton, 2004.
[26] D. Harris et al, "Strategies for Resolving Patent Disputes Over Nanoparticle Drug Delivery Systems," *Nanotechnology Law & Business Journal*, Vol. 1, 4, 2004, article 1, p. 17.
[27] Adam B. Jaffe and Josh Lerner, Innovation and its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It, Princeton University Press, Princeton, 2004, p. 6.
[28] Matthew Nordan was interviewed by Charles Choi, UPI. Source: UPI, Charles Q. Choi, "Nano World: Nanotech Patent Wars May Come," October 1, 2004.
[29] John C. Miller, et al., *The Handbook of Nanotechnology: Business, Policy and Intellectual Property Law*, p. 65.
[30] Ibid.
[31] Mark A. Lemley, William H. Neukom Professor of Law, Stanford University, "Patenting Nanotechnology," unpublished manuscript sent to ETC Group by the author, March 2005, p. 1.
[32] Ibid., p. 14.

[33] Lux Research Inc., *The Nanotech Report 2004*, Volume 1, 2004, p. 242.
[34] From an audio interview with Larry Bock, November 9, 2004. Available on the Internet: http://www.nanotechnologyinvestment.com/Companies/ViewDocument.asp?ID=2339
[35] Steve Maebius, "Ten Patents that Could Impact the Development of Nanotechnology," an article appearing in Lux Research, Inc., *The Nanotech Report 2004*, p. 242-247.
[36] Lemley, p. 1.
[37] Roland Pease, "'Living' robots powered by muscle," BBC News, January 17, 2005. Available on the Internet at http://news.bbc.co.uk/go/pr/fr/-/1/hi/sci/tech/4181197.stm
[38] Ibid.
[39] Rodney Brooks, "The Merger of Flesh and Machines," *The Next Fifty Years: Science in the First Half of the Twenty-First Century*, ed. by John Brockman, 2002, p. 191.
[40] Steve Maebius, "Ten Patents that Could Impact the Development of Nanotechnology," an article appearing in Lux Research, Inc., *The Nanotech Report 2004*, p. 242-247.
[41] Mark A. Lemley, p. 19.
[42] Jonathan King and Doreen Stabinsky, "Life Patents Undermine the Exchange of Technology and Scientific Ideas," in *Rights and Liberties in the Biotech Age*, ed. by Sheldon Krimsky and Peter Shorett, Rowman & Littlefield, 2005, p. 52.
Between 2003 and February 20, 2005
[43] To view a sample of the patents, go to: http://v3.espacenet.com/results?sf=a&CY=ep&LG=en&DB=EPODOC&TI=&AB=nano&PN=&AP=&PR=&PD=&PA=&IN=Yang+Mengjun&EC=&IC=&PGS=10&FIRST=31
[44] EP1327434A1: Nanoemulsion comprising metabolites of ginseng saponin and a skin-care composition for anti-aging containing the same.
[45] Andrew Kimbrell, *The Human Body Shop: The Engineering and Marketing of Life*, Harper Collins, 1993, p. 195.
[46] Ibid.
[47] Carlos Maria Correa, "How intellectual property rights can obstruct progress," SciDev.Net, 4 April 2005. On the Internet: http://www.scidev.net
[48] Carsten Fink and Carlos A. Primo Braga, "How Stronger Protection of Intellectual Property Rights Affect International Trade Flows," in *IP and Development: Lessons from Economic Research*, World Bank, January 2005, p. 34. On the Internet: www.worldbank.org/research/IntellProp_temp.pdf
[49] Ibid.
[50] From "The WTO in brief," available on the Internet at http://www.wto.org/english/thewto_e/whatis_e/inbrief_e/inbr00_e.htm
[51] The Declaration, translated into six languages, can be found on the Consumer Project on Technology website at http://www.cptech.org/ip/wipo/genevadeclaration.html.
[52] William New, "Nations Clash On Future Of WIPO Development Agenda," *Intellectual Property Watch*, April 11, 2005. Available on the Internet: http://www.ip-watch.org
[53] WIPO's decision is available on the Internet: http://www.cptech.org/ip/wipo/wipo10042004.html
[54] Salamanca-Buentello F. et al., "Nanotechnology in the developing world," PloS Med 2 (5): e97, May 2005.
[55] Ted Sabety, "Nanotechnology Innovation and the Patent Thicket: Which IP Policies Promote Growth?" *Nanotechnology Law & Business*, Vol. 1, Issue 3, 2004.
[56] Ibid.
[57] Angela Hullmann describes the special relevance of US PTO searches in her article: A. Hullmann and M. Meyer, "Publications and patents in nanotechnology," *Scientometrics* 58 (2003), pp. 515-516.
[58] A team of legal and business analysts presents a summary of the findings of a new report by Lux Research, Inc. on the nanotech intellectual property landscape: Ruben Serrato, Kirk Hermann, Chris Douglas, "The Nanotech Intellectual Property ("IP") Landscape," *Nanotechnology Law & Business Journal*, Vol. 2, Issue 2, 2005, Article 3.
[59] Sonia E. Miller, Measuring Nanotechnology's Effect on the Law**,** *New York Law Journal*, 02-04-2005 (online).
[60] John Roper, "Houston Company Poised to be Nanotech Force," *Houston Chronicle*, March 10, 2005.
[61] Lux Research, p. 206.
[62] Cientifica, "Nanotubes for the Energy Market," (Executive Summary) April 18, 2005, www.cientifica.com
[63] Janet Raloff, "Nano Hazards: Exposure to minute particles harms lungs, circulatory system," Science News Online, Week of March 19, 2005; Vol. 167, No. 12.
[64] Ibid.
[65] John C. Miller, Ruben M. Serrato, Jose Miguel Represas-Cardenas, Griffith A. Kundahl, *The Handbook of Nanotechnology: Business, Policy, and Intellectual Property Law*, John Wiley & Sons, 2005, p. 72.

[66] John C. Miller, et al., *Handbook of Nanotechnology*, p. 74.
[67] Anonymous, "NEC makes carbon nanotube patent claim," *Electronicsweekly.com*, 4 March 2004. On the Internet: http://www.electronicsweekly.com/Article5033.htm
[68] Ibid.
[69] Business Wire, Inc., "Carbon Nanotechnologies Inc. Achieves Major Milestone With 30 Patents Issued or Allowed Relating to Use of Small-Diameter Carbon Nanotubes," February 16, 2005.
[70] John Roper, "Houston Company Poised to be Nanotech Force," *Houston Chronicle*, March 10, 2005.
[71] Candace Stuart and David Forman, "Nano startups consolidate IP positions," *Small Times*, Feb. 17, 2005. On the Internet: www.smalltimes.com
[72] Carbon Nanotechnologies, Inc., News Release, "Carbon Nanotechnologies, Inc. (CNI) Announces Availability of Double-Wall Carbon Nanotubes," February 1, 2005. On the Internet: http://www.cnanotech.com/ (CNI's patents cover four production processes, including: growing carbon nanotubes on a supported catalyst; using an electric arc to form a carbon vapor or plasma; forming plasma by using a laser beam on carbon surface; and a gas-phase process.)
[73] John Roper, "Houston Company Poised to be Nanotech Force," *Houston Chronicle*, March 10, 2005.
[74] Carbon Nanotechnologies, Inc., News Release, "Carbon Nanotechnologies, Inc. (CNI) Announces Availability of Double-Wall Carbon Nanotubes," February 1, 2005. On the Internet: http://www.cnanotech.com/
[75] Telephone conversation with Patrick Collins, Director of Marketing, Hyperion. April 8, 2005. See Hyperion website: http://www.fibrils.com/index.htm
[76] Rocky Rawstern, ed., "Nanotube Surveys," *Nanotechnology Now*, last updated November 2004. On the Internet: http://www.nanotech-now.com/nanotube-survey-april2003.htm#Survey3
[77] The Lux Research report, "The Nanotech IP Landscape," is written primarily for nanotech investors, and costs $3500. For more information: http://www.luxresearchinc.com/ ETC Group did not purchase the Lux report. A team of legal and business analysts summarizes the report's findings and analyzes its data and conclusions in the following article: Ruben Serrato, Kirk Hermann, Chris Douglas, "The Nanotech Intellectual Property ("IP") Landscape, *Nanotechnology Law & Business Journal*, Vol. 2, Issue 2, 2005, Article 3.
[78] Larry Bock, "Following Mr. Robinson's Advice: The Story of Nanosys," *Nanotechnology Law & Business Journal,* Vol. 1, Issue 1, 2004, Article 10, p. 6.
[79] Interview with Larry Bock, CEO, Nanosys Inc. NanotechnologyInvestment.com Exclusive Interview with Nanosys Inc. "Company Develops Small Tech with Big Vision," November 10, 2004. On the Internet: http://www.investorideas.com/Forums
[80] Larry Bock, "Following Mr. Robinson's Advice: The Story of Nanosys," *Nanotechnology Law & Business Journal,* Vol. 1, Issue 1, 2004, Article 10, p. 6.
[81] Charles Q. Choi, "Nano World: Nano patents in conflict," United Press International, April 25, 2005; available on the Internet at http://www.wpherald.com/print.php?StoryID=20050425-095053-7324r
[82] http://www.evidenttech.com:80/applications/quantum-dot-ink.php
[83] Anonymous, Carnegie Mellon news release, "Carnegie Mellon Enhances Quantum Dot Corp. Technology For Long-term, Live-animal Imaging," January 19, 2004; available on the Internet at http://www.sciencedaily.com/releases/2004/01/040119081813.htm
[84] Anonymous, Carnegie Mellon news release, "Carnegie Mellon Enhances Quantum Dot Corp. Technology For Long-term, Live-animal Imaging," January 19, 2004; available on the Internet at http://www.sciencedaily.com/releases/2004/01/040119081813.htm
[85] www.qdots.com/live/render/content.asp?id=46
[86] The Lux report on intellectual property is available for $3500 but ETC Group did not purchase the report. Reference to the report is based on Charles Q. Choi, "Nano World: Nano patents in conflict," United Press International, April 25, 2005; available on the Internet at http://www.wpherald.com/print.php?StoryID=20050425-095053-7324r
[87] John C. Miller, Ruben M. Serrato, Jose Miguel Represas-Cardenas, Griffith A. Kundahl, *The Handbook of Nanotechnology: Business, Policy, and Intellectual Property Law*, John Wiley & Sons, 2005, p. 74.
[88] http://www.qdots.com/live/render/content.asp?id=37
[89] Matthew Nordan quoted in Charles Q. Choi, "Nano World: Nano patents in conflict," United Press International, April 25, 2005; available on the Internet at http://www.wpherald.com/print.php?StoryID=20050425-095053-7324r
[90] Serrato et al., "The Nanotech Intellectual Property ("IP") Landscape, Nanotechnology Law & Business Journal, Vol. 2, Issue 2, 2005, Article 3.
[91] Anonymous, Lux Research news release, "Nanotechnology Gold Rush Yields Crowded, Entangled Patents," April 21, 2005; available on the Internet at http://www.nanotech-now.com/news.cgi?story_id=09134

[92] Tom Henderson, "What are dendrimers good for? Dow Chemical is eager to find out," *Small Times* Online, November 12, 2001; available on the Internet at www.smalltimes.com
[93] Eric J. Lerner, *Medicine at Michigan*, "'Nano' Is Now at Michigan – And James Baker is Leading the Way," Summer 2000. On the Internet: http://www.medicineatmichigan.org/magazine/2000/summer/nanonman/default.asp
[94] Lux Research, Inc., Nanotech Report 2004, p. ___.
[95] http://www.dendritech.com/pricing.html
[96] Maureen Rouhi, "High-Yield Path to Dendrimers," *Chemical and Engineering News*, Vol. 82, No. 28, p. 5.
[97] Lux Research, Inc., Nanotech Report 2004, vol. 2.
[98] Dendritic NanoTechnologies, Inc., *News Release*, "Dendritic NanoTechnologies, Dow and Starpharma Sign Major Three-Way Deal to Commercialize Nanotechnology," January 25, 2005. On the Internet: http://dnanotech.com/news.php
[99] Anonymous, "Downsizing," *The Economist*, January 1, 2005.
[100] David Rotman, "Magnetic-Resonance Force Microscopy: The promise is a 3-D view of the molecular world," *Technology Review*, May 2005.
[101] Belle Dumé, "Atomic force microscopes reach new depths," *PhysicsWeb*, May 11, 2005; available on the Internet at http://physicsweb.org/articles/news/9/5/6/1
[102] Ibid.
[103] The search was conducted on April 22, 2005 on Delphion's patent database, using the following search terms appearing in the patent abstract: atomic AND force AND microscope; scanning AND tunneling AND microscope; scanning AND tunnelling AND microscope [to reign in maverick spellers]; scanning AND probe AND microscope
[104] Lux Research, Inc., *Nanotech Report 2004*, vol. 2.
[105] Ibid.
[106] Email correspondence with Kevin Kjoller, Veeco, May 12, 2005.
[107] Anonymous, Asylum Research news release, "Asylum Research Files Counterclaims in Veeco Patent Suit," January 26, 2004; available on the Internet at http://www.asylumresearch.com/News/News.shtml#pat
[108] Email correspondence with Kevin Kjoller, Veeco, May 12, 2005.



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