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Trends in Intellectual Property and Nanotechnology: Implications for the Global South

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The race is on to win exclusive monopoly patents on nano-scale materials, devices and processes. 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, tools and processes are already creating thorny barriers for would-be innovators. Industry analysts warn that, 'IP roadblocks could severely retard the development of nanotechnology.'[1] After a decade of confusion and controversy over biotech patents, South governments are now facing a newer, bigger technology wave. By 1 July 2013 even 'least developed' countries will be obligated by the World Trade Organization's Trade-Related Aspects of Intellectual Property (TRIPS) to accommodate nanotechnology-related inventions. Despite rosy predictions that nanotech will provide a technical fix for health, sustainable energy and environmental security in the South, researchers in the developing world are likely to find that participation in the proprietary 'nanotech revolution' is highly restricted by patent tollbooths, obliging them to pay royalities and licensing fees to gain access.

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

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). Nanotechnology is not a single technology – but a range of technologies converging at the nano-scale – including biotechnology, genomics, neurosciences, robotics and information technologies. Nanotechnology has been described as 'the transformational technology of the 21st century.'[3] Experts predict that nanotech will revolutionize manufacturing across all industry sectors and eventually 'impact the production of virtually every human-made object.'[3]

Worldwide, public and private spending on nanotech R&D in all sectors was approximately $9.6 billion in 2005.[4] According to industry analysts, Lux Research, in the year 2005, over 1,300 companies in 76 industries invested $3.2 billion in nanotech R&D and sold $32 billion in products that incorporate some form of nanotechnology.[5] By 2008, Lux predicts that private sector nanotech R&D spending will be more than triple, reaching $12 billion.[5]

Some advocates of nanotechnology maintain that this technology will address the South's most pressing needs. According to the UN Millennium Project's Task Force on Science, Technology and Innovation, 'nanotechnology is likely to be particularly important in the developing world, because it involves little labour, land or maintenance; it is highly productive and inexpensive; and it requires only modest amounts of materials and energy.'[6]

Control and ownership of nanotechnology is a vital issue for all governments because a single nano-scale innovation (materials, devices and processes) can be relevant for widely divergent applications across multiple industry sectors. As the *Wall Street Journal* put it, 'companies that hold pioneering patents could potentially put up tolls on entire industries.'[7] The current nanotech patent rush is reminiscent of the early days of biotechnology – 'it is like biotech on steroids' in the words of one patent attorney.[7]

Nano-scale engineering provides new opportunities for sweeping monopoly control over both living and non-living matter. Intellectual property (IP) will play a major role in deciding who will capture nanotech's

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trillion dollar market, who will gain access to nano-scale technologies, and what price they will pay. According to Stanford University Law professor, Mark Lemley, '…patents will cast a larger shadow over nanotech than they have over any other modern science at a comparable stage of development.'[8]

Nanotech Patents and TRIPS

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 TRIPS and by bilateral/regional trade agreements. The TRIPS agreement obligates all WTO member countries to adopt and enforce minimum standards of intellectual property.

The TRIPS Agreement requires member countries to make patents available for inventions, whether products or processes, in all fields of technology without discrimination, subject to the standard patent criteria (novelty, inventiveness and industrial applicability).[9] However, during the negotiations on the TRIPS Agreement, consensus was not reached on the controversial area of biotechnological inventions. The United States and some other developed countries pushed for no exclusions to patentability, while some developing country members preferred to exclude all biological diversity-related inventions from IP laws. For many developing countries the patenting of life forms and exclusive monopoly protection on biological products and processes that originate in developing countries (or that are based on traditional knowledge) continues to be controversial. Article 27.3(b) of the TRIPS Agreement is the text that ultimately prevailed on biological products and processes. It states that plants and animals as well as essentially biological processes may be excluded from patentability. However, WTO members must offer protection for plant varieties either by patents and/or by an effective *sui generis* system. Developing countries were given until 2000 to pass laws in this direction, and least developed countries (LDCs) were given until 2006 (The transitional period for LDCs has now been expanded until 1 July 2013. By that date, even 'least developed' countries will be obligated by the World Trade Organization's TRIPS to recognize and enforce nanotech patents.)[10] Because of the difficulty in reaching consensus, it was agreed that the controversial sub-paragraph TRIPS Article 27.3(b) would be reviewed in 1999. The review has not happened.

The controversy and debate surrounding the patentability of biotechnological inventions at WTO is relevant to a discussion on nanotechnology patents because nano-scale materials and processes – especially those inventions that claim both living and non-living matter – raise many of the same fundamental questions (nanobiotech patents). Broad nanotech patents are already being granted that span multiple industry sectors and include sweeping claims on entire classes of the Periodic Table. Should exclusive monopoly patents be granted on the fundamental building blocks of nature? Does the TRIPS Agreement obligate all developing countries to recognize and enforce patents on nanotechnology inventions, even those that incorporate plants and animals as well as essentially biological processes? Will overly broad patents or 'patent thickets' on emerging nano-scale materials, processes and devices prevent researchers in the global South from participating in the nanotech revolution?

Over the past decade, some governments, the UN Human Rights Commission as well as civil society and social movements 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 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.[11] At WIPO's General Assembly meeting (27 September – 5 October 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 have objected to proposals that would give development concerns a higher profile within WIPO, acknowledging only that WIPO should give greater technical assistance to developing countries.[12] Despite ongoing debate in 2005 and 2006, talks on WIPO's Development Agenda have ended in stalemate as of June 2006.[13]

Nanotech Patent Trends

The world's largest transnational companies, leading academic labs and nanotech start-ups are all 'rushing to the patent office in record numbers to patent nanotechnology inventions.'[11] A study conducted by the University of Arizona and the US National Science Foundation found that 8,630 nanotech-related patents were issued by the US Patent & Trademark Office (USPTO) in 2003 alone, an increase of 50% between 2000 and 2003 (as compared to about 4% for patents in all technology fields). The top 5 countries represented were: USA (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).[14]

According to industry analysts, 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.'[15]

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 nanotech 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.'[1] Many intellectual property experts in the US are predicting that large-scale nanotech patent litigation is inevitable. 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. In most patent battles, it is the largest enterprises – not the most innovative ones – 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'.[16]

In October 2004, the USPTO created a new classification for nanotechnology patents – Class 977 – which serves 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.[17] As defined by the USPTO, 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 nano-scale and create and use structures, devices, and systems that have size-dependent novel properties and functions.[18]

In January 2006, the European Patent Office began publicly classifying nanotechnology patents. The nanotechnology subclass (Y01N) covers:

- entities with a controlled geometrical size of at least one functional component below 100 nanometers (nm) in one or more dimensions susceptible to make physical, chemical or biological effects available which are intrinsic to that size.
- equipment and methods for controlled analysis, manipulation, processing, fabrication or measurement with a precision below 100 nanometers (nm).[19]

According to Christian Kallinger of the EPO's Nanotechnology Working Group, from 1993-2003, the US accounted for 57 percent of all published nanotech patents, followed by Japan (24 percent), EPO member states (16 percent), Korea (2 percent), and the rest of the world (1 percent).[20] EPO data also reveals that large multinational corporations, primarily electronic companies, are the dominant players in nanotech patent applications. The top 10 companies are IBM, Matsushita, Hitachi, Canon, NEC, Toshiba, Fujitsu, Mitsubishi, Sony and Philips.[21]

Patents on Nanotech's Fundamental Building Blocks and Tools

Mark Lemley asserts that nanotechnology 'is the first new field in a century in which people started patenting the basic ideas at the outset.'[8] 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.'[8]

In the nanotech arena, it is 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 USPTO, for example, there are three primary types of patent claims:[21]

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

Nanomaterials are chemical elements or compounds less than 100 nm in size or that incorporate nanoparticles 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.

Exclusive monopoly patents on chemical elements are not new. Glenn Seaborg, the 1951 Nobel Prize-winning physicist, won US Pat No 156,523 for the chemical element *Americium* (element no. 95 on the periodic table) on 10 November 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 no.96 – US Pat No 3,161,462 granted on 15 December 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

When Harvard University's Charles Lieber obtained a key patent (US Pat No 5,897,945) on nano-scale metal oxide nanorods, he did not 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.[22]

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 Pat No 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

A single nano-scale innovation may have diverse applications that span multiple industry sectors. Mark Lemley observed that, a significant number of nanotechnology patentees will own rights not just in the industry in which they participate, but in other industries as well.[8]

Consider the following examples from USPTO's Class 977 (patents identified as nanotechnology patents):

- US Pat No 5,874,029 – 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.
- US Pat No 6,667,099 – Creavis Gesellschaft für Technologie und Innovation mbH, 23 December 2003: Meso-and nanotubes: The invention relates to mesotubes and nanotubes (hollow fibres) 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.
- US Pat No 6,641,773 – 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 illustrated 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.

Nanobiotech 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.[23] 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 1 provides examples of the possible range of nanobiotechnology and synthetic biology patents recently issued by the USPTO. It includes: Hybrid devices combining a nanomaterial and muscle tissue, which generate electrical power and which the inventor has described as 'absolutely alive'[26] (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

Table 1— Recent nanobiotechnology/synthetic biology patents

Inventor	Patent/application number	Publication date	Description
Carlo Montemagno, UCLA, USA [1]	US20040101819A1	27 May 2004	Self-assembled muscle-powered microdevices
Carlo Montemagno, UCLA, USA [2]	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

Source: ETC Group

'switching agents' to control gene expression by turning them on or off.

Role of Public Sector in Nanotech IP

One of the unique features of nanotechnology, according to 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.

Because they conduct basic research, it is 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.[8]

Publicly funded research organizations in the US are increasingly licensing their nanotech patents on an exclusive basis. Legal scholar Ted Sabety observes that, 'nanotechnology [in the US] occupies a peculiar dichototmy: it is publicly funded but the results of the R&D are privately held.'[24] From 2003 to May 2006 the *Nanotechnology Law & Business Journal* identified 87 publicly announced nanotech patent license agreements – 23 of which involved a university or public research entity as the licensor. Of the 23 license agreements involving university or research entities as licensor, all but one was granted on exclusive terms (and its terms were not disclosed).[25]

In 2004, a patent attorney specializing in nanotechnology identified 10 key US patents that he believed could have the greatest impact on the development of nanotechnology. Seven of the 10 patents are owned by universities.[24]

Conclusion

Early assessment of nanotech patent trends indicate that it will be important for developing countries to monitor control and ownership of nanotechnology and its potential impacts on the transfer of technology and trade. Although industry analysts frequently assert that nanotech is in its infancy, 'patent thickets' on fundamental nano-scale materials, tools and processes are already creating thorny barriers for would-be innovators. 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. Researchers in the global South are likely to find that participation in the 'nanotech revolution' is highly restricted by patent tollbooths, obliging them to pay royalties and licensing fees to gain access.[26]

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