Intellectual Property Rights in Nanotechnology

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Abstract

Intellectual property rights are essential in today's technology-driven age. Building a strategic IP portfolio is economically important from both an offensive and defensive standpoint. Applicable areas in Nanotechnology to which intellectual property rights can apply are presented. Some challenging issues surrounding the acquisition of IP rights in Nanotechnology are also presented.

The Importance of Protecting Intellectual Property

The value and strategic importance of protecting intellectual property cannot be overstated. The costliest example in US history of R&D is perhaps the case of Eastman Kodak vs. Polaroid begun in the 1970s, and resolved in 1990. Seven patents upheld by Polaroid led to the total destruction of Kodak's instant photography business, to the tune of more than $3 billion dollars in infringement damages, compensation and legal fees, research and manufacturing costs [1].

More recently in 1990 and 1997, the University of California filed for patent infringement against Genentech for the company's manufacture and sale of the growth hormone product Protropin[R]. A settlement agreement with a payout of $200m from Genentech was reached in November 1999, with no admission of infringement from Genentech [2].

After settling patents claims to DEC, IBM, Stac Electronics and Apple at the cost of half a billion dollars, Microsoft has to date more than a thousand patents, 250 times more than the 4 patents it owned 12 years ago [3]. Perkin-Elmer owned one hundred and sixty patents in 1976. Today it has more than seven thousand patents, an increase of more than 45-fold [4].

Clearly, both an offensive and defensive strategy can be used effectively in applying IP rights. Compared with the modest costs in building an effective IP portfolio, a huge drain on resources are involved in resolving patent disputes. With a dispute history reminiscent of David and Goliath, the enormous power of protecting intellectual property should not be overlooked.

Nanotechnology

As an emerging science in its infancy, nanotechnology promises the nano-scale manufacture of materials and machines made to atomic specifications. It is a field at the junction of chemistry, physics, biology, computer science and engineering. In the context of this paper, nanotechnology will be referred to as a manufacturing as well as a computational science, since many of tomorrow's manufactured items exist today only as models and simulations.

The impact of nanotechnology on our way of life is widely believed to reach profound and hitherto unimagined levels in the coming decades. Proposed changes include clean abundant energy, pollution-free and inexpensive production of superior defect-free materials, complete environmental restoration and cleanup, safe and affordable space travel and colonization, and quantum leaps in medicine leading to perfect health and immortality. As a result of these advances, we anticipate the obsolescence of nearly all of today's industrial and economic processes by the first half of the new century, leading to global and radical changes in life style, finance, law, and politics.

This paper presents a brief overview of intellectual property rights, and the various areas in nanotechnology to which IP rights may be applicable. Technology transfer, including licensing and business agreements, are not covered. Instead, issues related to the science of nanotechnology and the challenges surrounding the acquisition of IP rights are presented.

Types of IP Protection

- Patents
- Copyrights
- Trade Secrets
- Trademarks
- Maskworks

Patents

Patents offer protection for functional concepts, methods, apparatus, or processes that are novel, useful and non-

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obvious [5]. The Agreement in Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement) in 1994 defines patentable matter as any invention that involves an innovative step and has a potential industrial application [6].

In contrast, discoveries, diagnostic or therapeutic methods, or inventions not compatible with public order or general principles of morality are not patentable. The distinction between "discoveries" and "invention" can become somewhat blurred in nanotechnology where the principles of patent law are tested.

The purpose of the patent is to advance innovation through disclosure and teaching of the details of the invention to the public, and in exchange, the inventor or owner is rewarded the legal rights of ownership. The legal rights refer to, in particular, the right to exclude others from making, using, selling or importing into the US or offering for sale of the invention, giving the owner the exclusive rights to capitalize on the invention. The ownership rights are granted for a period of 17-20 years, depending on the date of filing of the patent.

Patents are obtained through a costly and lengthy process. In Europe, Japan, and the Pacific, the "first to file" system applies. In the U.S. however, the "first-to-invent" system applies. However, patent applications must be filed within one year of the first offer for sale of the product or the patent filing will be void.

Copyrights

Copyrights protect the original expression of an idea. By offering protection, copyright encourages the expression of original, artistic ideas into a tangible medium. Legal protection is effected instantly, when the original copyrightable subject matter is fixed into a tangible medium, e.g. on paper or in a digital storage form.

Copyrights are much more inexpensive and expediently obtained than patents, and are valid for the author's lifetime plus 50 years. A longer period of validity (75/100 years) applies if the creation was work made for hire, which is generally the case in the nanotechnology industry.

Trade Secrets

Trade secrets protect any technical or business information that gives the business a competitive advantage. It need not be completely novel or exclusive, but it must have a derived or potential economic value from being unknown. Additionally, reasonable efforts must be made to keep the information secret, e.g. through diligent and the inexpensive use of Non-Disclosure Agreements (NDA). Legal protection under trade secret no longer applies when the information is disseminated publicly. There is no formal filing procedure to register trade secrets to obtain protection.

Maskworks

In chip technology, when the chip layout includes an original circuit design, the layout is protectable. Specifically, maskworks protect against the unauthorized copying of the chip layout information. Federal registration is relatively quick and inexpensive, but filing must be done within two years of commercialization of the chip product.

Trademarks

Trademarks refer to the distinctive signature mark that can be used to protect the company, product, service, name or symbol. The trademark must not be descriptive or generic. Legal protection is not offered to the technology, rather to the company good will and quality associated with the use of the recognized name or symbol. Trademarks provide exclusive rights within a region or nation and as long as used commercially, they may be renewed indefinitely. Compared to patents, they are obtained within a moderate time period (usually under 2 years) and typically cost under $5K per registered mark.

Building an IP Strategy

The IP rights are protected under various federal and state legal laws. Without protection, the property falls into the public domain and may be used by any party without license. A sound management strategy would be to systematically build a portfolio consisting of different IP rights, with the aim of protecting the various aspects of the company's technology and commercial interests.

IP rights protect the commercial interests of a company at the various stages of design, manufacturing, and product operation. At the design and development stage, copyrights and trade secrets can be immediately enforced. Novel apparatus and methods can then be patented, a process that takes about three years and requires the investment of some funds. Once a product or service is developed, issued patents and trademarks protect the technology and associated names and symbols.

The perfection of an IP portfolio is of interest to startups and their investors, whereas licensing agreements are of interest to manufacturers and customers. Whereas strategic enforcement of IP rights can be achieved through licensing, litigation and other business means, effective acquisition of IP rights must be done legally. While copyrights and trade secrets may be obtained easily, patents, trademarks and maskworks require applicant action and response within critical filing deadlines. Generally, the first to patent will have the best chance of winning the broadest patents.

The Emerging Anatomy of Nanotechnology

Nanotechnology, more descriptively known as molecular manufacturing, involves the design, modeling, fabrication and manipulation of materials and devices at the atomic scale. It necessitates thorough spatial control of matter at the level of molecules and atoms, with capabilities to process and rearrange them into custom designs. Nanotechnology differs from traditional chemical manufacturing in that the chemical reactions are not left to statistical movements of molecules in solutions, but instead the molecules are brought into appropriate positions with appropriate speeds and orientations to cause desired reactions. Nanotechnology also differs fundamentally from micro-manufacturing of silicon chips in that the top-down approach and repeated refinement of bulk materials (e.g. etching silicon) into micro or even nano-scale designs suffers from defects inherent in the original bulk material. In contrast, nanotechnology's bottom-up approach will build essentially defect-free structures from the atoms up. Table I highlights some nanotechnology milestones [7]. In 2001 the US government invested a total $422M in nanotechnology, an increase from $270M in year 2000, while for a total investment of $519M is requested for 2002. Nanotech research has intensified in universities around the world, and degree programs are increasingly offered at the graduate and undergraduate levels. Venture capital firms are showing growing interest in nanotechnology, and significant nanotech projects have been initiated by large multi-national companies, with some of them allocating up to a third of their research budget to nanotech [7].

Table I Some nanotechnology milestones

1959	Feynman delivers "Plenty of room at the bottom" talk
1974	First molecular electronic device patent filed
1981	Scanning tunneling microscope (STM) invented
1985	Buckyballs discovered
1986	Atomic force microscope (AFM) invented "Engines of Creation" published
1987	Quantization of electrical conductance observed First single-electron transistor created
1988	First "designer protein" created
1991	Carbon nanotubes discovered
1993	First nanotechnology lab in the US
1997	DNA-based nanomechanical device created
1999	Molecular-scale computer switch created
2000	US launches National Nanotechnology Initiative
2001	Logic gates made entirely from nanotubes

At the present state of the art, only the simplest molecular structures can be built in the lab. However, the design and modeling of much larger structures is quite feasible with current computational methods and resources, hence we will distinguish between computational and manufacturing efforts in nanotechnology, with the manufacturing efforts roughly divided into the production of materials and tools. A large portion of nanotechnology's popularity lies in its applications to other already established fields. We will consider applications to electronics, sensors, aerospace, environmental cleanup and sanitation, and medicine.

Table II stratifies nanotechnology efforts. Patents, trademarks, trade secrets, copyrights and maskworks can be applied to each of these components to strategically build an IP portfolio. This is discussed in the following paragraphs.

Table II Nanotechnology efforts and some application areas

Nanotechnology

- Manufacturing
  - Materials
  - Tools
- Computational

Some Application Areas

- Electronics
- Sensors
- Aeronautics and space travel
- Environment cleanup and sanitation
- Medicine

Protectable Intellectual Property in Nanotechnology

Manufacturing Methods

One approach to building a wide range of nano-scale structures is positional assembly [8], involving the use of tiny robot arms or similar manipulating devices to precisely position molecular building blocks for bonding. Initial progress towards positional assembly has been made, for example with the use of scanning tunneling microscopes (STM) able to push atoms around with their tips in near-zero temperatures [9]. Novel methods in overcoming the difficulties of manipulating tiny molecules with instruments that are bigger and bulkier, as well as methods that deal with the tendency of molecules to adhere to the manipulating apparatus [10] will present fundamental steps towards viable manufacture of nanostructures and are IP-protectable.

Another approach to building nano-scale structures is self-assembly, involving the design of molecules which aggregate into desired structures. Although self assembly takes place all around us and produces structures ranging from crystals to life forms, we do not yet understand it in sufficient detail needed for nanotechnology [11].

Aside from techniques of molecular assembly, feasible and useful nanotechnology demands that manufacturing costs remain close to the cost of required raw materials and energy, and IP rights protect novel manufacturing methods and processes that increase yield and decrease cost. Self replicating systems have been proposed as a method for low cost molecular manufacturing, with Zyvex's "exponential assembler" [12] as a concrete theoretical proposal in which nano-sized robot arms proliferate by building replicas of themselves. Merkle's "Convergent assembly" is another proposal in which macro-objects of a given size are built recursively from parts a fraction in size [13].

Computational Techniques

While present techniques allow the manufacture of only the most basic nano-structures, the design and modeling of molecular structures is quite feasible with current computational technology. With molecular design software and computational chemistry packages, molecular materials and machines can be modeled and quickly evaluated, eliminating bad designs and keeping more promising ones. As nano-structures behave at the border of quantum mechanics and classical physics, available packages differ in the level of detail modeled and hence in the size of structures that can be modeled given realistic computational resources. For example, molecular mechanics packages that treat individual nuclei as point masses currently model structures with thousands of atoms, while more accurate quantum mechanics based packages are limited to smaller structures. Mesoscale techniques incorporating both quantum and classical mechanics are being used to model structures at the boundary. Technologies, including algorithms that model an array of inter-molecular forces appropriate to the complexity and scale of the simulated system, databases tailored for storage and annotation of molecular components, related data compression methods, graphical, virtual reality, hardware user interfaces specifically targeting the needs of nanotechnologists, and similar special purpose software and hardware tools can be protected with patents, copyrights, trademarks, trade secrets and maskworks.

Applications of Nanotechnology

Molecular Electronics

As conventional semiconductor devices follow Moore's Law to approach their physical limits, we move in the direction of hybrid circuits which incorporate conventional as well as molecular components. Today, quantum-effect nanoelectronic devices have already been fabricated in solid-state structures. These include quantum dots, which are nano-scale "boxes" holding a well-defined number of electrons that can be put together to form lattices and cellular automata [14] with special properties, as well as single-electron transistors, devices that use controlled electron tunneling to amplify current [15]. In addition, the discovery of the versatile carbon nanotubes and their ability to act as transistors and diodes promise new directions. Improvements on such novel circuits, for example large-scale clocking schemes for quantum dot cellular automata, as well as methods of integrating emerging molecular electronic components with current solid-state electronics are areas of active research and the architecture as well as manufacturing methods of such components and aggregate systems enjoy intellectual property rights protection. One important consideration is that while it is easy to design around specific patented molecules and devices, it is much harder to bypass architectural patents, hence their utility and effectiveness is arguably higher.

Nanotechnology based memory chips [e.g. 16], due to their simpler more repetitive structure compared to more elaborate chips such as CPUs, are widely believed to become one of the first components to be commercialized and integrated into existing solid-state circuits. Flat panel displays based on carbon nanotube field emitters are another application nearing commercialization.
In the future, however, it is likely that we design and fabricate electronic components as well as entire systems using only molecules, with a number of advantages. The smaller component sizes yield higher circuit densities, lower power consumption, possibly more precise component fabrication, as well as specific advantages such as higher operating temperatures for quantum dots, widening their range of application. Therefore, novel methods of efficient synthesis and inexpensive mass fabrication of molecular electronics components represent a fertile development ground and are protectable under IP rights.

Sensors

Sensors represent another area widely believed by researchers as well as investors to become one of the first commercialized applications of nanotechnology. The relation between the structural and chemical properties of carbon nanotubes and their electrical properties have led to a number of sensor designs currently on the verge of mass production. An example of a carbon nanotube carbon dioxide (CO_2) sensor is given by Ong & Grimes [17] who, by tracking the resonant frequency of a multi-wall carbon nanotube coating, determine the permittivity of the coating, which changes linearly in response to CO_2 concentration. Installation of special purpose binding sites on the tips of carbon nanotubes has been proposed to enable genome processing without the use of expensive PCR-based methods. A much needed technique is the inexpensive high yield production method of carbon nanotubes, and novel methods of synthesis and production will be protectable with IP rights. Computational models of simulating the mechanical behavior of carbon nanotubes are another active area protectable with patents, copyrights, trademarks and trade secrets.

Aerospace

The superior strength and low weight of fullerenes may open the frontier to space travel by drastically decreasing the cost of launch to orbit. Because of conditions of high temperatures, extreme pressures, hard vacuum, high radiation and so forth in aerospace applications, the development of heat-resistant polymers and other materials, miniature computers, molecular machines based on chemistry that can survive in space, and assembly methods compatible with conditions in space will greatly benefit aerospace applications [18], as will novel computational models of the operation of such devices and materials in space, with IP protection enforceable at all stages of such aerospace applications.

Nanomedicine

When nanotechnology makes the construction of micron-scale machines possible, one of the first likely applications will be medical nanomachines. Freitas' "respirocytes" [19] represent one design proposal for micron-sized diamondoid oxygen storage tanks floating in the blood stream, in effect artificial mechanical red blood cells.

One promising anti-AIDS application capitalizes on three features of the buckyball: its size, its ability to carry chemicals enabling delivery of drugs to specifically targeted sites, and its unique shape that facilitates binding with HIV infected cells, e.g. see [20]. Novel designs of nanomedical machines, methods of delivery, communication, tracking, and disposal (if needed) of such machines, as well as techniques for drug release and injection of substances into cells (for example using nanotube syringes) and nanoengineered prosthetics (such as artificial bones) all enjoy IP rights protection.

Environment and Sanitation

Self-assembled monolayers, i.e. substances spontaneously forming a one-molecule thick layer on a surface, are a technology showing promise for environmental sanitation. A layer of functional groups tailored to bind to heavy metals and assembled on mesoporous surfaces has been shown to separate and remove mercury from aqueous and organic liquids and gaseous streams [21]. Novel modeling techniques, designs, manufacture methods and applications for active and passive nanotech-based materials and machines for water-treatment, extraction of toxics, detection of pollutants, and recovery of materials before they become wastes are some examples of protectable technologies under IP rights.

Challenges to the Nanotechnology Patent Process

For small companies and startups, patents are among the only protections from infringement by large corporations. As companies grow, their ability to keep trade secrets decreases and patents again become a chief method of IP protection. However, it is important to keep in mind that a patent application gets published 18 months after filing, unless the applicant opts out, in which case a foreign patent may not be pursued for the invention. Hence, unless the applicant opts out and foregoes foreign filing, the description of the invention will end up in the public domain and accessible to competitors, whether a patent issues or not.

Furthermore, the interdisciplinary nature of nanotechnology presents a special case [22]. The USPTO houses seven different technology centers, including the biotechnology and organic chemistry center and the chemical and materials engineering center, and various art units within each center, such as the metallurgy unit and the polymer chemistry unit within the chemical and materials engineering center, but none are dedicated to nanotechnology. This lack of focused expertise combined with the understaffed state of the USPTO is likely to result in (1) the improper rejection of patents due to a mistaken conclusion that the taught matter is not new, as well as (2) overly broad patents giving the owner excessive control over a particular area, as has happened during the recent flood of information technology patents which overwhelmed the USPTO and resulted in cases such as the "one-click" Amazon.com patent criticized as too broad and stifling. Challenging an overly broad patent held by a competitor is a costly process, while in the case of an improperly denied patent the company must spend precious time appealing the USPTO's decision, time that could be spent taking advantage of the patent.

The USPTO has reached out to the nanotechnology community for solutions, and recently the Foresight Institute and the USPTO held a patent roundtable addressing these issues. Having a set of nanotechnology specialists within the USPTO and in communication with each other could unify prior art searches and ensure more accurate consideration of nanotechnology patents and increased quality of granted patents [22].

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