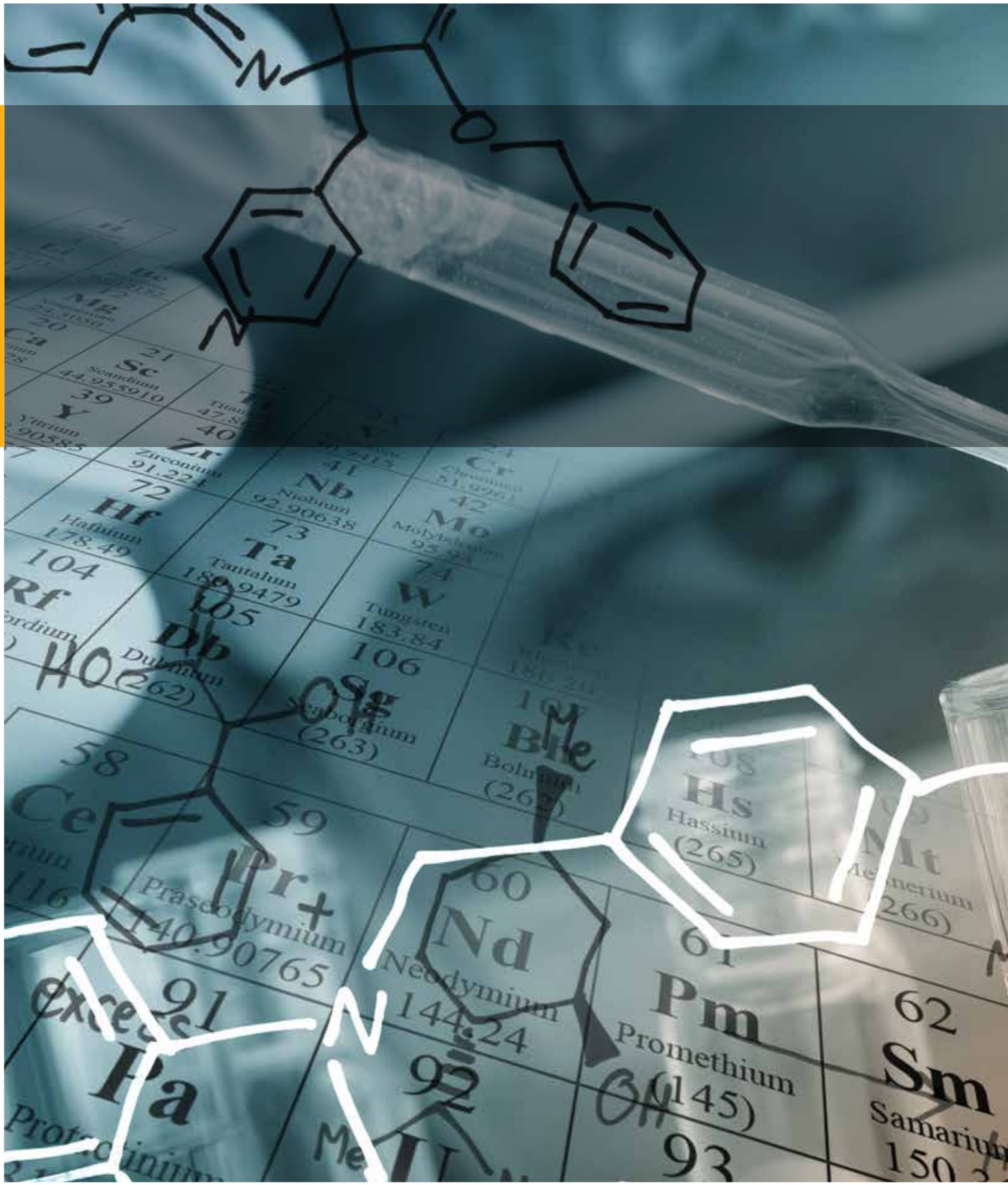
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Ta
Tantalum
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Tungsten
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Rf
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Dubnium
(262)
Sg
(263)
Bh
Bohrium
Hs
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Ce
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Pr
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Nd
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144.24
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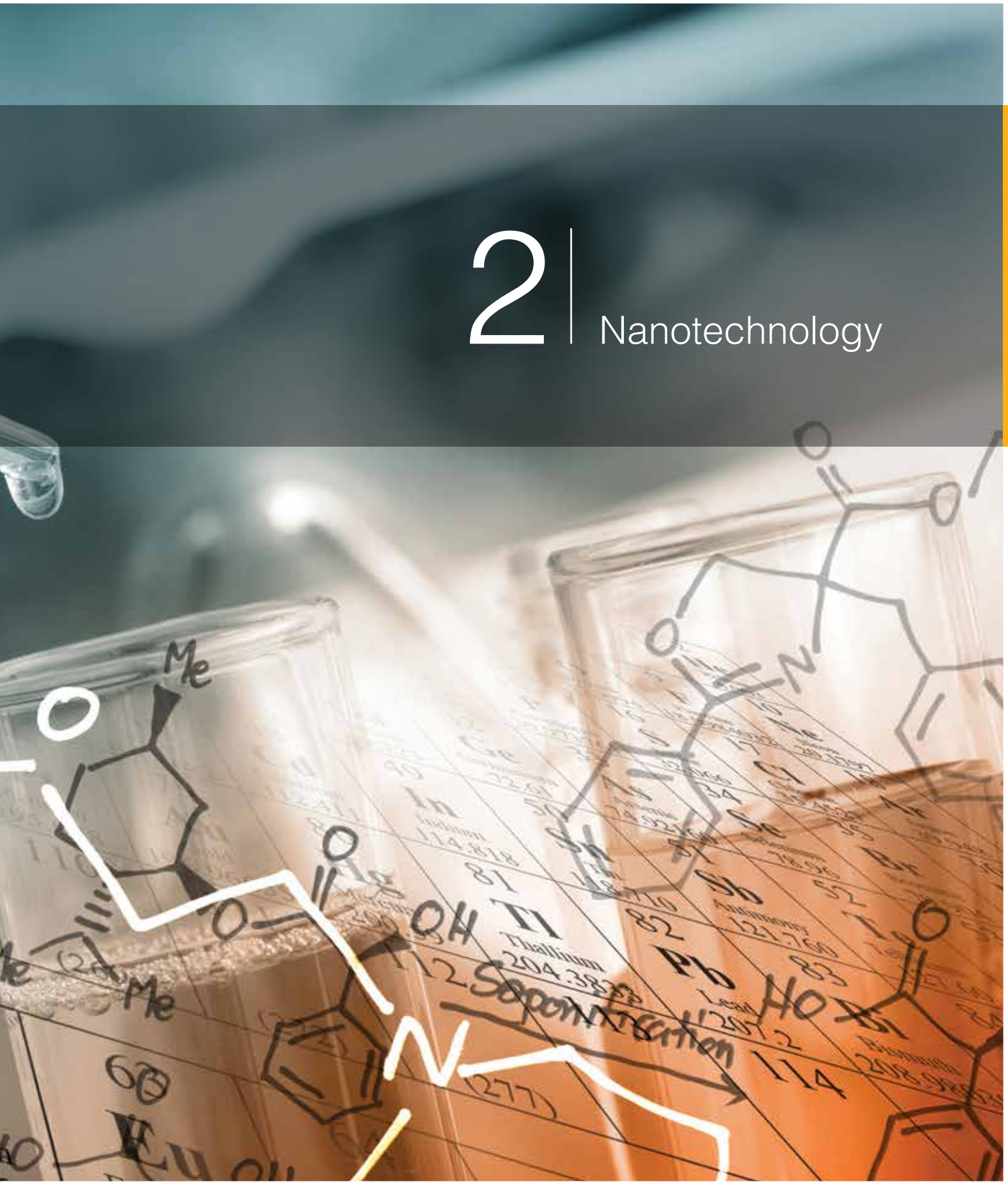
2 Nanotechnology



Nanotechnology

I. History and Background

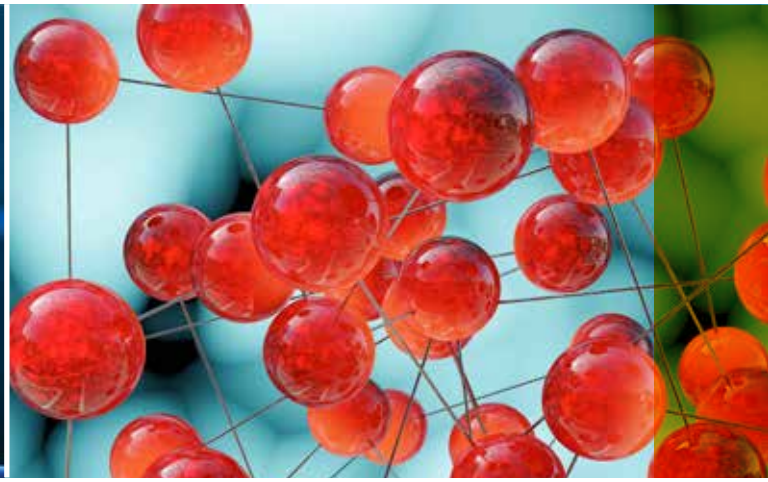
Islamic Republic of Iran has adopted a comprehensive approach in nanotechnology development aiming at creating wealth relying on this emerging technology. As a result, Iran has been able to achieve a sizable share in local and international markets. Timely entrance into the field accompanied with a focus on an endogenous development model in science and technology development has also prepared the grounds for actualization of this objective. Nanotechnology has had, and will have a great impact on all industries worldwide through improving the existing products and creating new ones. Contribution to the global advancements in this field is possible for Iranian scientists through enhancing their technological knowledge, being focused, and continuing their efforts.

Policymaking for nanotechnology development in Iran was initiated in 2001. Iran Nanotechnology Initiative Council (INIC) was established in 2003 to ensure coordination and synergy among all institutions and agencies involved in nanotechnology development.In August 2005, “Future Strategy Plan”(ten -year strategy for nanotechnology development in Iran 2005-15) was approved by the government. With the implementation of the future strategy plan and its three supplementary phases until 2015, Iran was ranked seventh in the world in nano-science production and nowadays, this industry enjoys over 29 thousand researchers. On the other hand, more than 460 thousand students are trained in nanotechnology development. Also,157 companies produce 361 nanotechnology-related products and equipment. 60 companies are also providing business development services to diffuse nanotechnology into industry.

After the implementation of the “Future Strategy Plan”, the second plan for ten-year nanotechnology development (2015-25) was prepared in 2015 and operated since the second half of the same year.

II. Policies and Strategies

Nanotechnology development policymaking and planning is focused on designing a practical and applicable model. In this line, it is tried to provide the structured programs for all rings of the value chain from science and technology development towards commercialization and market development. In addition, operational programs are continuously kept up-to-date based on contingencies and requirements of different time periods.

Some of the programs implemented during the past decade are as follows:

- Networking more than 75 research laboratories from academia and private sector in the form of Nanotechnology Laboratory Network. In this network over 1280 advanced laboratory services were provided to researchers and engineers;
- Hosting more than 100 nanotechnology startups in incubators and technology parks;
- Hosting technology development service providers in the Tech-Market Services Institute (Corridor);
- Creating student laboratories network (TAVANA network) containing 66 labs located in student research institutes across the country;
- Supporting intellectual property service provider companies;
- Establishing the Expert Committee on Food and Drug Administration to assess nanohealth products including pharmaceuticals, medical equipment, cosmetics and hygiene products, foodstuff, and beverages.

Some nanotechnology achievements in priority areas including health, water and environment, energy, and construction are as follows:

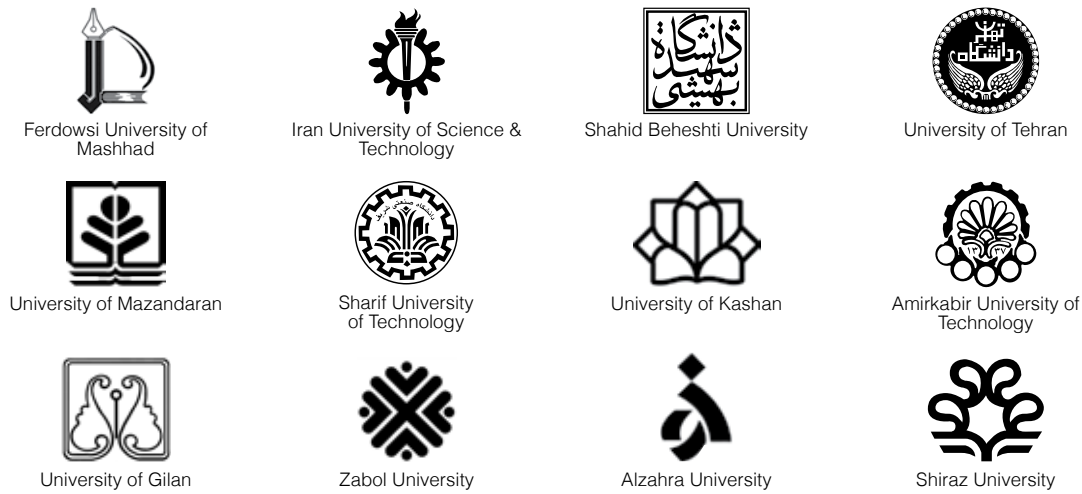
- Karun river water treatment to produce drinking water;
- Removing heavy metals from water;
- Sugarcane industry wastewater treatment plants;
- Producing industrial power plant filters to improve productivity in power industry;
- Producing nano-medicine, especially anti-retroviral ones;
- Producing materials and equipment used in construction industry such as concretes, paints, pipes, and resistant plastics.

III. Capacities and Capabilities

A. Human Resources

According to a study conducted in 2000 on the country's human resource status, the number of researchers involved in nanotechnology was not more than a dozen and just eight papers were published in a year. After the formation of Iran Nanotechnology Initiative Council, nanotechnology sector witnessed a dramatic increase in the number of researchers, publication of more than 29000 ISI articles, and involvement of 2600 active faculty members.

Also, during the last decade, 263 universities or research centers have been involved in the field of nanotechnology.



Some Universities Involved in Nano-science and Nanotechnology

B. Scientific Productivity

Iranian universities and research institutes conducted over 3300 nanotechnology-related doctoral dissertations and more than 16,000 master's theses (see figure 1).

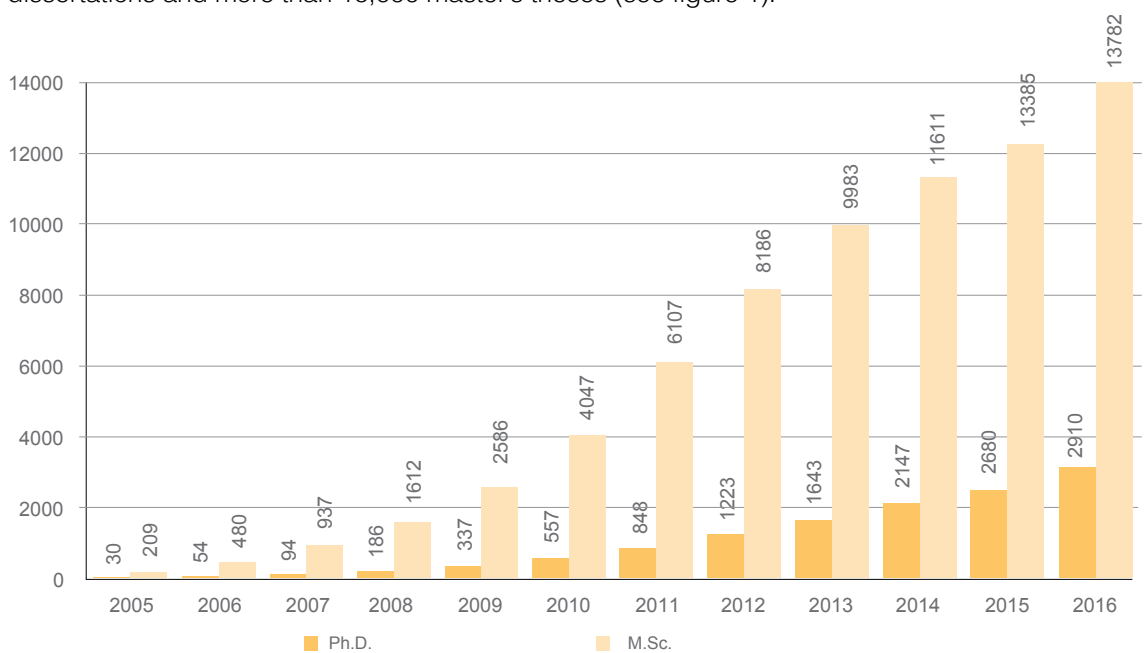


Figure 1: *Iranian Nanotechnology Graduates per year (Nov. 2016)*

Figure 2 displays the number of articles published by contribution of Iranian researchers in the Web of Science ISI database from 2001-2016.

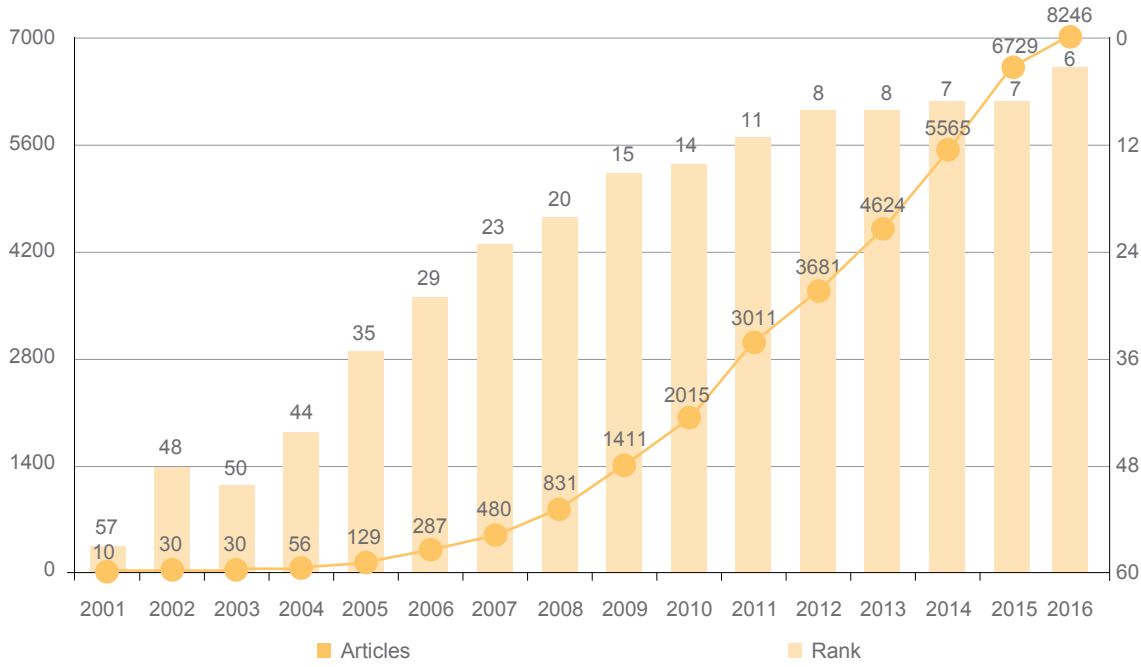


Figure 2: *The Number & Rank of Iranian Nanotechnology ISI Articles in the World (2001-2016)*

Table 1

The Number & Rank of 30 Top Countries in Nanotechnology ISI Articles (2016)

Rank	Country	Number of Articles	Rank	Country	Number of Articles
1	China	51384	16	Saudi Arabia	2721
2	USA	24487	17	Brazil	2685
3	India	12055	18	Poland	2507
4	South Korea	9065	19	Singapore	2348
5	Germany	8679	20	Turkey	2233
6	Iran	8246	21	Swiss	1989
7	Japan	7518	22	Malaysia	1884
8	France	5796	23	Netherlands	1811
9	United Kingdom	5496	24	Sweden	1705
10	Russia	4777	25	Egypt	1551
11	Spain	4477	26	Belgium	1321
12	Italy	4267	27	Pakistan	1306
13	Australia	3666	28	Czech Republic	1133
14	Canada	3291	29	Mexico	1114
15	Taiwan	3096	30	Israel	1067

Source: statnano.com

C. Some Achievements

The below chart shows the increasing trend of Nano-based products developed in Iran in the past 7 years.

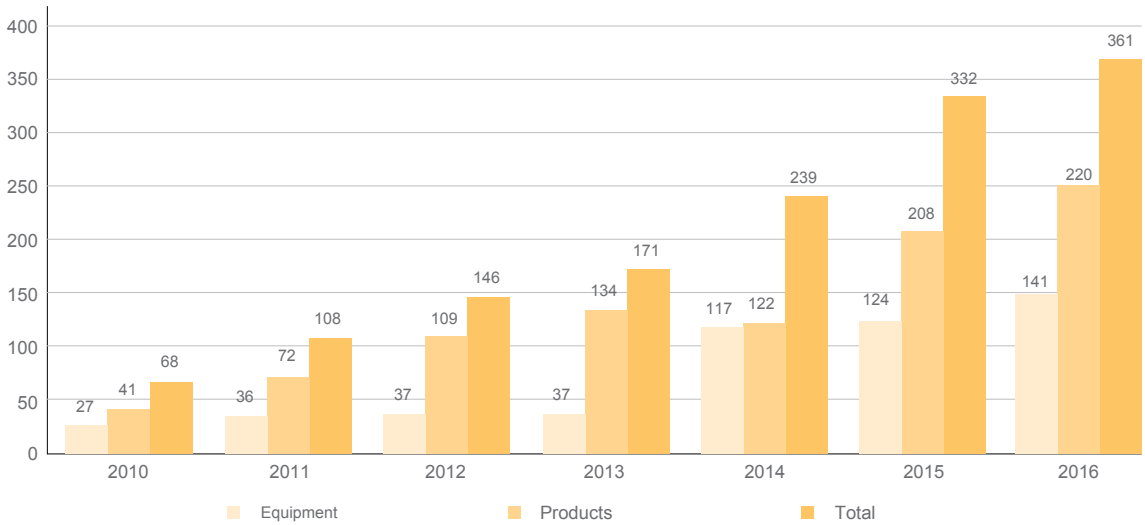


Figure 3: *Nanotechnology Products and Equipment*

Here, some leading products and equipment are introduced as follows:

• Electro Spinning Unit (Nano Fiber Production)

Applications of electro spinning units include filtration, ballistic resistant coatings, biomedical, medical prostheses, wound dressing and drug delivery and pharmaceutical compounds. The product advantages compared to other available samples include reliability, user-friendliness, and sustainability, as well as higher accuracy, performance and production rates.

Industrial Equipment for Nanofibers Production Line

• Nano Cavitation System

The device has a unique technology with a variety of applications in the areas of water and wastewater treatment such as water disinfection, removal of chemical contaminants, heavy metals, etc. Cavizone technology works based on advanced oxidation process. This technology has employed ozone injection methods, hydrodynamic cavitation and electrochemical oxidation to kill bacteria and remove biofilm, organic matter and heavy metal oxide from different water and wastewater.

Nano-Masterbatch *Nano Composite Profiles*

When water is in the cycle of cavizone process, the cell walls of bacteria decompose and heavy metals are oxidized and prepared for final treatment. Cavizone technology consists of three efficient oxidation processes that introduce an affordable and efficient technology compared to other alternative technologies. Hydrodynamic nano cavitation, injection of nano-ozone and electrochemical oxidation are these three processes. Some product highlights are as follows:

- Oxidation without utilization of chemicals;
- Ability to increase capacity in various industrial scales;
- Portability;
- High efficiency;
- Eco-friendly;
- Affordability.

• Nanoliposome Producer

Nanoliposome or submicron bilayer lipid vesicle is a new technology to encapsulate and deliver bioactive agents. Nanoliposomes can enhance the performance of bioactive agents by improving their solubility and bioavailability, in vitro and in vivo stability, as well as preventing their unwanted interactions with other molecules.

Due to their biocompatibility and biodegradability, nanoliposomes can be potentially applied in a vast range of fields including pharmaceutical, food, cosmetics and agricultural industries.

• Rebar Spot Welding Electrode, Welding Nozzles and Copper - Alumina Fittings

These products are made of copper-alumina nanocomposites through cold forging process and are applied to automotive industries, tubing, aerospace and home appliances. Key features of this product are as follows:

- Mechanical strength of low-carbon steel (4 times the pure copper due to homogeneous distribution of aluminum oxide nanoparticles within copper matrix);
- Electrical and thermal conductivity in the range of 82% pure copper to retain these properties at high temperatures;
- Higher durability of parts compared with the similar products.

The material is unique due to the homogeneous distribution of alumina nanoparticles in copper matrix. Due to the stability of these particles at high temperatures, all properties of this material

SinaDoxosome

SinaCurcumin

(unlike other alloys such as Cu- Cr- Zr) are maintained up to 1000 °c while there is no loss of properties. Resistance at high temperatures, lack of phase transitions (structural), competitive price and superior quality are among some advantages of this product compared to other available ones.

• SinaDoxosome (Doxorubicin Hydrochloride Liposome Injection)

SinaDoxosome is a liposomal drug delivery system containing doxorubicin hydrochloride applicable to treat cancers of breast, ovary, AIDS-related Kaposi, leukemia, etc.

Heart attack is one of the dangerous side effects of doxorubicin. Therefore, a 100 nm nanoliposomes is used to reduce its side effects. Nanoliposomes also increase the durability of the drug in the body and leave the immune system intact due to the use of polymer coatings on the surface of the particles.

Product benefits include high efficacy and low side effects, especially, reduced cardiotoxicity compared with doxorubicin hydrochloride usage.

• SinaCurcumin (Soft Gelatin Capsules Containing Curcumin Nanomicelles)

Curcumin (Diferuloylmethane) is a polyphenol of category D Aryl Heptanoid. This substance is the active part of Curcuma Longa, a perennial plant known as turmeric. Generally, anti-oxidant, cancer prevention and anti-inflammatory properties are among the biggest biological effects of turmeric and curcumin. As a potent anti-inflammatory product, it is used in the following conditions:

- Arthritis (osteoarthritis and rheumatoid arthritis);
- Gastrointestinal inflammation (Crohn's disease, gastritis, irritable bowel syndrome and ulcerative colitis);
- Inflammation of the mouth (gingivitis, stomatitis, etc.);
- Inflammation of the skin (psoriasis, eczema and ulcers, etc.);
- Prevention and Reduction of cancers;
- Side effects of chemotherapy and radiotherapy;
- An effective supplement in patients with depression;
- Powerful antioxidants and beneficial supplement for healthy cardiovascular system (anti-platelet aggregation, lowering cholesterol, LDL, etc.);

Welding Nozzle and Copper Alumina

Alumina-Copper Bar

- Improved liver function (fatty liver adjuvant therapy and prevention of progressive liver disease, etc.);
- Treatment and prevention of diabetes complications (diabetic neuropathy and retinopathy, etc.).

Advantages compared to similar products include absolute absorption of curcumin by spherical nanomicelles which increase curcumin solubility in water.

• SinaAmpholish (NanoLiposomal Amphotericin B Topical Gel)

The size of NanoLiposomal amphotericin B is about 100 nm which in cases of *cutaneous leishmaniasis*, after topical application, can pass through the horny layer and reach the macrophages in epidermis and dermis. Since liposomes are foreign particles for body, they will be swallowed by macrophages (which have phagocytic properties). Then, the vesicles fuse with the membrane of lysosomes in macrophages and contents of vesicles are transferred into lysosomes. Inside the lysosomes, the liposomal phospholipids are decomposed in acidic pH of lysosomes by lysosomal hydrolase enzymes and release the drug in the liposome. Thus, the encapsulated highly concentrated drugs in liposomes are released in the vicinity of *Leishmania* and destroy it.
Amphotericin B is the most effective medication to treat fungal and protozoan infections such as *Leishmania*. Therefore, its topical form is used in the following cases:

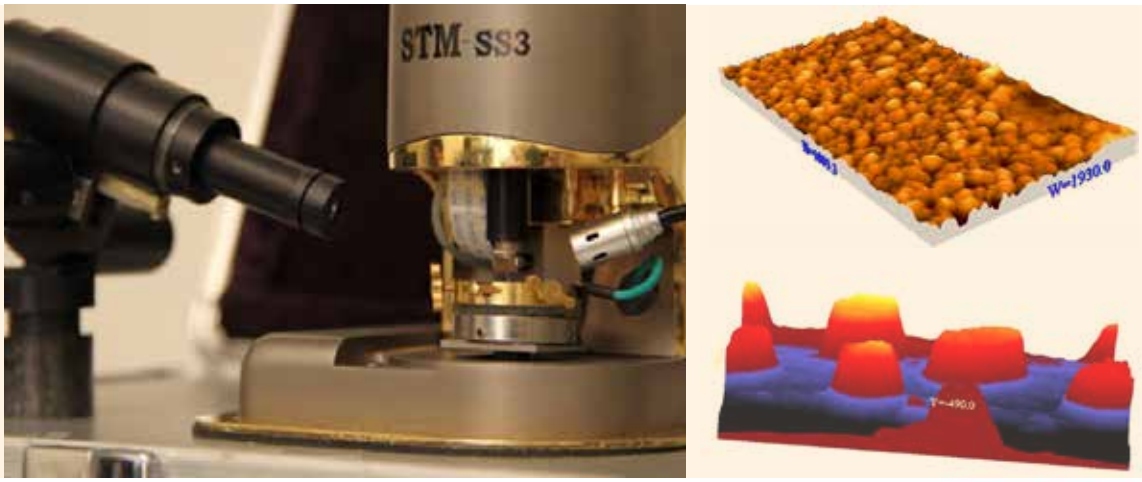
- Treatment of cutaneous *leishmaniasis (cutaneous leishmaniasis)* caused by various species of *Leishmania*;
- Topical chronic recurrent fungal infections such as dermatophytes;

Advantages compared to the similar products include more efficiency (above 90%) compared with conventional treatment and the use of antimony compounds (40%-70%), shorter treatment duration, painless and easier usage compared to the injectable treatment, and fewer side effects compared to systemic treatments.

IV. Authorities

A. Iran Nanotechnology Initiative Council

Iran Nanotechnology Initiative Council (INIC) is responsible to determine and supervise the implementation of the general policies to develop nanotechnology in the country. INIC's main mission is to enable Iran to achieve a proper place among the 15 advanced countries in nanotechnology as



Scanning Tunneling Microscope (STM) & Results

well as leveraging nanotechnology in economic development of the country. By providing facilities, creating market and removing the impeding obstacles, the Iran Nanotechnology Initiative Council aims to pave the road for the private sector activity and generation of wealth in the country. In summary INIC tasks include:

- Setting goals, strategies, macro-scale policies and national initiatives to develop nanotechnology in the country;
- Assigning general tasks to governmental bodies, determining missions for each sector and making coordination among them within the framework of a long term national plan;
- supervising actualization of goals and programs.

Various institutions with defined strategies and working plans follow the targets of INIC as summarized in the next sections.

B. Other Authorities

• Tech-Market Services Institute (Corridor)

The Tech-Market Services Institute (Corridor) was established with the aim of accelerating commercialization process and developing new technologies. The corridor already includes the following sections:

• Evaluation Department for Nanotechnology Products and Companies

Assessing nanotechnology companies' eligibility, evaluating nanoproducts in terms of stability of the nanomaterial structure and its properties, and granting certificates are among the main missions of this department.

• Commercialization Service Development Department

This department aims to identify technology development services, expand links with brokers and institutions, and monitor the quality of the provided services.

• Iran Patent Office

Having focused on importance of intellectual property as one of the important infrastructure of technology development, the Intellectual Property Department affiliated to the "Iran Nanotechnology Initiative Council" started its activity in 2005, and since 2014 as the "Iran Patent Office" has undertaken the responsibilities related to the field of intellectual property in all areas of science and technology under supervision of the "Vice-Presidency for Science and Technology".

Desalination Unit (Cap. 5000m³/day)

Nitrate Removal Unit (Cap. 5000m³/day)

Arsenic Removal Unit (Cap. 10,000m³/day)

• Tech-Export Services Corridor

This office supports companies to reach international export markets by providing export development services. It also backs firms by direct supervision on the quality of services provided by specialized firms (brokers) in each field.

• Iran Nanotechnology Standardization Committee

Recognizing the importance and role of standardization in nanotechnology development and commercialization and in line with objectives of the National Nanotechnology Program including wealth creation and life quality improvement, the "Iran Nanotechnology Standardization Committee (INSC)" was established by the Iran Nanotechnology Initiative Council (INIC) in 2006. INSC consists of three specialized working groups and serves as mirror committee of ISO/TC229.

Its main objectives include sustainable, safe and responsible development of nanotechnology while enjoying its benefits and protecting human health and environment. INSC has successfully accomplished to:

- Develop 46 national standards;
- Publish 3 international standards in ISO/TC229;
- Establish Iran Nanosafety Network (INSN);
- Implement National Nanometrology System;
- Promote nanotechnology standardization and nanosafety.

• Iran Nanosafety Network

Focusing on health, safety and environment in the field of nanotechnology and making collaboration platform for researchers and the related institutions, the "Iran Nanosafety Network" was founded to convoke the researchers and their activities in nanosafety within the framework of the network programs. For more information, see www.nanosafety.ir.

• Joint Nanometrology Strategic Committee

This committee was established in close collaboration with the Institute of Standards and Industrial Research of Iran (ISIRI) and they jointly published national nanometrology plan. The National Nanometrology System was implemented to institutionalize dynamic and continuous development of nanometrology and secure national and international credibility in nano-measurements.

C. Companies

There are more than 250 nanotech-based startups and more than 150 companies with nanotechnology product manufacturing activities. The following figures display activity areas of nanotechnology startups and nanotechnology products, respectively.

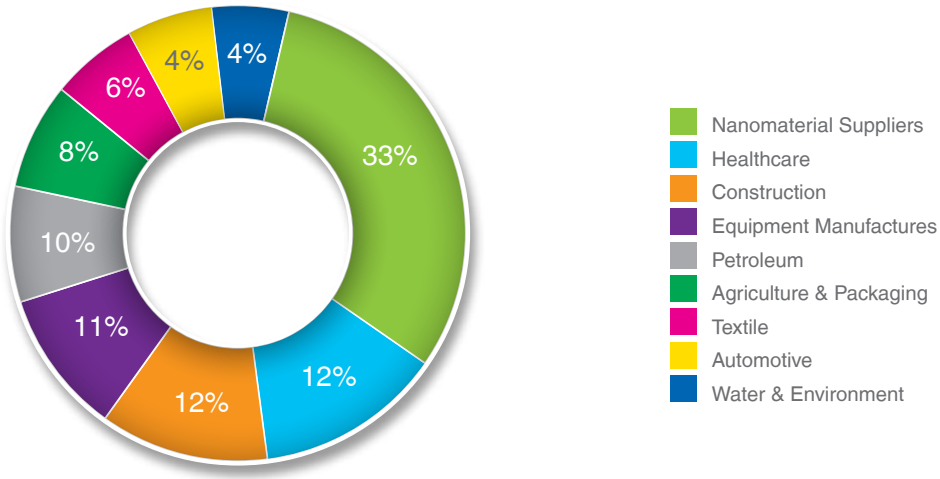


Figure 4: *Activity Areas of Nanotechnology Startups*

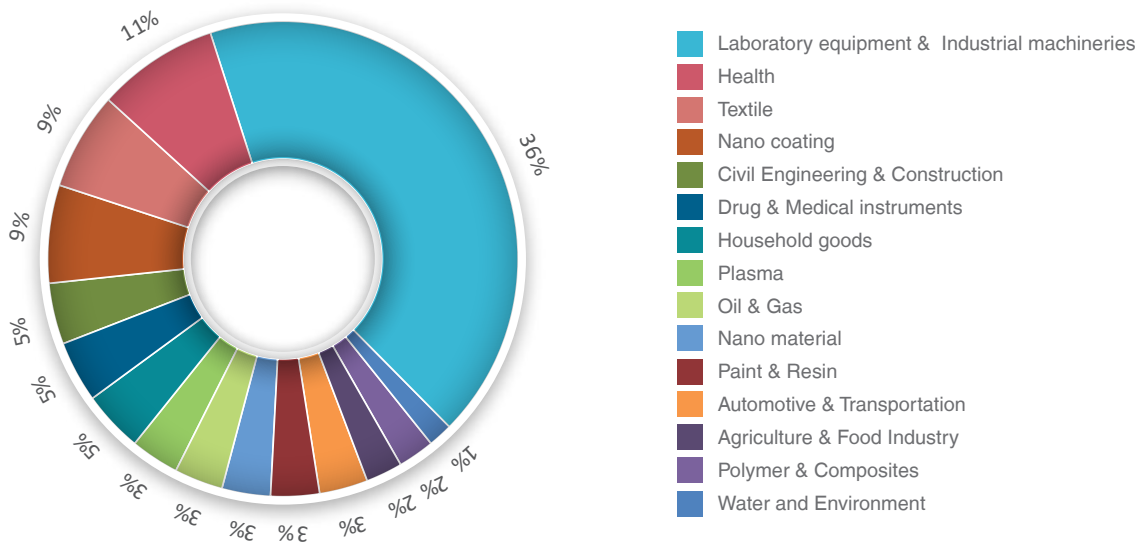


Figure 5: *Nanotechnology Products [Source: nanoproduct.ir (Dec. 2016)]*

V. International Cooperation

Active participation of Iran's nanotechnology companies in credible international exhibitions has paved the way for them to develop technological and commercial interactions with international partners. Currently, several Iranian nanotechnology companies are successfully exporting their knowledge-based products to other countries. On the other hand, active presence of the country in local and regional networks such as Asia Nano Forum (ANF) has made it possible for Iranian companies to collaborate with international nanotechnology community at policymaking and public sector levels. Also, at high decision-making levels, one can refer to bilateral cooperation agreements with countries such as China, Thailand, South Korea and Russia in the areas such as education, standards, certification, joint research and development as well as commercial interactions. The Iran's Nanotechnology Community, led by INIC, fiercely pursues bilateral or multilateral international collaborative initiatives in the following areas:

- Running international cooperation in scientific, educational, technological, and commercial levels as well as standardizing and policymaking;
- Cooperating in nanotechnology training at different levels, joint research and development (R&D), researcher exchange, knowledge and experience exchange, joint standard development, technology transfer, and joint investment with international companies and institutions;
- Making mutual commercial agreements to certify nanotechnology products and facilitate their transactions.