A GLOBAL ASSESSMENT OF NANOTECHNOLOGY ACTIVITIES PART 2: A LOOK AT PATENTS

Patrick U. [a]Akpan, Chidubem V. [b]Egeonu and Obinna C. [c]Okoye.
[a,b]Department of Mechanical Engineering, University of Nigeria, Nsukka.
[c]Department of Mechanical Engineering, Federal University Oye-Ekiti. Nigeria.
[a]patrickakpan@unn.edu.ng: +2348102475639; [b]egeonuvictor2@gmail.com; +2347032926135; [c]obinna.okoye@fuoye.edu.ng , +2348039338658

Abstract

A study on the state of nanotechnology in the world on the basis of a Scientometric indicator was done. The volume and distribution of patents is reported in this paper. The analysis was carried out by using data published from databases produced by Thomson Reuters– The Derwent World Patent Index ™. The period under review was 1995 – 2012. The analysis shows that a total of 78, 585 nanotechnology inventions were recorded for the period under consideration. Africa, North America, South America, Europe, Asia, Australia and Eurasia contributed 0.052%, 26.85%, 0.17%, 6.69%, 61.15%, 0.25% and 1.09% of the world's total number of patent. The top seven most-patented areas of nanotechnology inventions were: Nanotubes and Nanowires (35%), Nanofabrication and Processing (26%), Nanoparticles and Quantum Dots (11%), Water Purification, Desalination and Decontamination (11%), Composite Materials (4%), Quantum Devices (4%), Nanocatalysts (4%). It is therefore recommended that countries within the latter group of continents should enforce policies to ensure the fast-tracking and maintenance of growth in this field of technology.

***Keywords**: Nanotechnology, Patents, Nanoparticles, Quantum Dots, Nanofabrication.*

1. Introduction

1.1 Concept of Scientometry

Scientometrics is the quantitative study of the disciplines of science based on published literature and communication. This could include identifying emerging areas of scientific research, examining the development of research over time, or geographic and organizational distributions of research [1].

In practice, Scientometrics is often done using bibliometrics which is a measurement of the impact of (scientific) publications [2 - 4]. The use of Scientometric indicators for decision making is constantly on the rise resulting in the rapid growth of scientometric studies [5].

There are six indicators that could portray the value of investments in nanotechnology development. These are: People (primary workforce), SCI papers, Patent applications, Final products market, R & D funding (public and private), Venture capital [6].

1.2 Nano-related Scientometric Studies

Xuan *et. al.* studied the trends for nanotechnology development in China, Russia and India from 1976 to 2007 [7]. Their studies involved the use of Thomson's Citation Index (SCI) database on publications and the United States Patent and Trademark Office (USPTO) database on patents for the period of interest. Bibliographic, content map and citation network analyses were used to evaluate country productivity, dominant research topics, and knowledge diffusion patterns. There was significant and consistent growth in nanotechnology papers for the three countries according to their study. China, Russia and India respectively had an average annual growth rate of 31.43%, 11.88% and 33.51% between 2000 and 2007. Growth pattern for the patent publications for the same period was less consistent, the average rates being 31.13%, 10.41% and 5.96% respectively.

Elangoet. al. embarked on a scientometric analysis of the global nano tribology research output between the periods

1996 and 2010 [8]. They made use of the SCOPUS to retrieve the records related to nano tribology for the period so considered. The research indicated that Nano-tribology increased at a tremendous rate from 34 papers in 1996 to 161 papers in 2010 with an average of 88 papers per year. It was clear, from their results, that 2008 recorded the highest number of publications with 177 papers. The average number of authors increased as well from 2.41 in 1996 to 3.66 in 2010 with an average of 3.52 authors per paper. Out of the total number of publications, 70% of the papers received one or more citations. In all, 11,913 citations were received by 1,321 papers with an average of 9 per paper. Citations per paper per year were 1.36 from their studies.

Akpan worked on the Scientometric analysis of publications and patents in Africa for 1995-2011 [9]. The analysis was carried out using data published from databases produced by Thomson Reuters- the Derwent World Patent Index (DWPI) and the Web of Science (WOS). The results showed that Africa produced 1779 and 41 publications and patents respectively. It also showed that nano-related research was concentrated in just five countries which are Egypt, South Africa, Tunisia, Algeria and Morocco. The top seven most published areas of nanotechnology in Africa were Nanoparticles and Quantum Dots, Nanofabrication and Processing, Nanocatalyst, Nanotubes and Nanowires, Quantum Devices, Photovoltaic and Solar Cells and Functionalization of Nanotubes, Nanowires and Nanoparticles. Patents were concentrated in three African countries which are South Africa, Morocco and Egypt. The most patented areas of nanotechnology in Africa were only three and they were Water Purification, Desalination and Decontamination, Nanofabrication and Processing and Photonic Crystals.

Related studies have been done globally and for some countries for different time periods [2, 10 -13].

This research work is interested in assessing the nanotechnology status in the world by performing a Scientometric analysis of Patents received from 1995 -2012. The outcome of this work has potential benefit for decision and policy makers and the research community.

2. Methodology

The data used for this study were extracted from data published by Thomson Reuters [12]. Derwent World Patent Index™is a Thomson Reuters database and it is the world's most comprehensive database of enhanced patent documents for both patent applications and granted patents. Subject experts from Thomson Reuters correct, analyze, abstract and manually index every patent record, making it easy to quickly find information needed to make informed decisions. It obtains its patents records from 47 patent jurisdictions around the world [14].

The collection of patent used for this study was produced using 44-sub technology search strings (see Table 1) in areas of relevant interest.

3. Results and Discussions

3.1 Nanotechnology Patents in various Continents by Source:

The total number of nanotechnology inventions from 1995-2010 was 78,585. The total number of inventions in Africa, North America, South America, Europe, Asia, Australia and Eurasia were 41, 21,100, 132, 5,261, 48,023, 197 and 863 respectively (see Figure 1). Against the world total number of inventions, the percentage of inventions are 0.05%, 26.85%, 0.17%, 6.69%, 61.11%, 0.25% and 1.09% for the respective continents. The average percentages for the International Bureau, the European Patent Office and the Eurasian Patent Organization are respectively 0.51%, 3.27% and 0.0013% approximately. Analysis (see Figure 1) shows that nanotechnology patents were also concentrated in three continents; Asia, North America and Europe in that order. These three continents also produced about 94.70% of the world's total nanotechnology patents. The other continents had relatively low volumes of inventions with Eurasia taking the lead followed by Australia, then South America and Africa. The European Patent Office had the highest volume of inventions when compared with other such autonomous bodies namely: the International Bureau and the Eurasian Patent Organization.

Table 1: Sub-Technology Categories of Interest by Source [12].

MEMS Sensors	Nanofabrication & Processing	Nanotubes & Nanowires	New Material & Nanostructure Modelling
MEMS Actuators	Displays	Material enhancement using Nanotubes, Nanowires & Nanoparticles	Photovoltaic & Solar Cells
RF MEMS	Nano Sensors	Nanoparticles & Quantum Dots	Photonic Crystals
Drug Delivery	Functionalization of Nanotubes, Nanowires & Nanoparticles	Textile: Fire/Water Resistant	Spintronic
Imaging	Semiconductor Laser & Devices	Adhesives	ASIC
Bio-MEMS Devices	Quantum Devices	Energy Harvesting	Radiation Protection
Laser & Detection	Nanocatalyst	Fuel Cells	Nano filtration
LEDs	Fuel Additives	High Performance Batteries	Composite Materials
Integrated Optics	Fuel Extraction	Lubrication	Thermal Insulation
Optical Components	Anti-corrosion	Water purification, Desalination & Decontamination	Nano devices & Modeling
Optical Sensors	Self-cleaning	Water Quality Monitoring	Nano toxicity & Safety

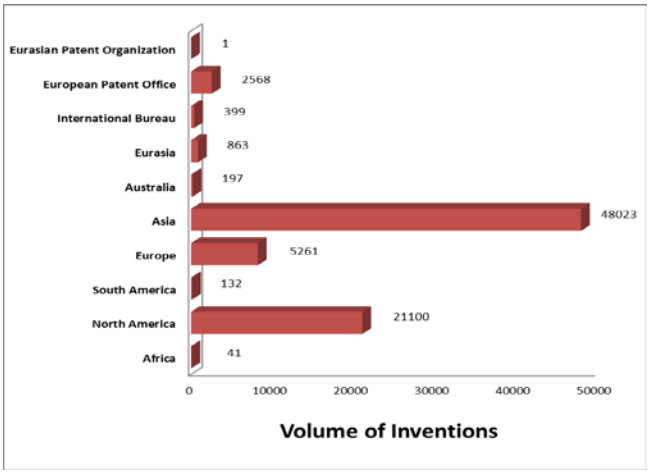

Figure 1: Amounts of Nanotechnology Patents from each Continent (1995-2012).

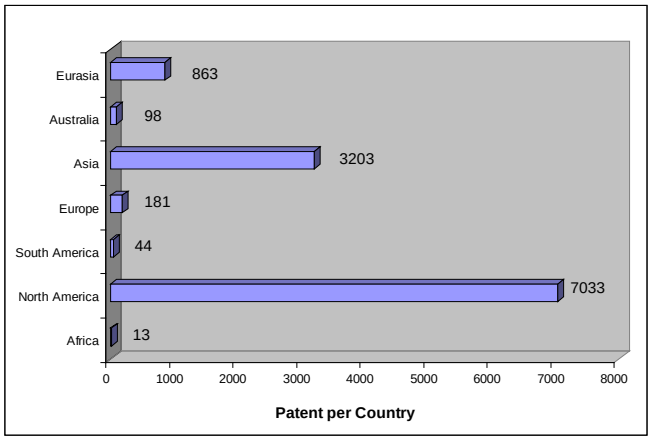

Figure 2: Nanotechnology "Patent Density" in each Continent (1995-2012).

The "patent density" in each continent is the ratio of the total volume of patents from a continent divided by the total number of participating countries from the continent. Figure 2 gives an indication that the "patent density" is highest in North America. The value is ~7,033 publications per country during the period. This is followed by those of Asia (~3,203 publications per country), Eurasia (863 publications per country), Europe (~181 publications per country), Australia (~98 publications per country), South America (44 publications per country) and Africa (~13 publications per country).

Even though Asia was clearly seen to dominate in the total number of nanotechnology patents, when compared with the number of participating countries, North America is seen to take the lead since the number of participating countries is just three. Asia followed after North America, and Eurasia came third.

The major contributors in each continent are presented in Figure 3 (a) - (g). In Africa; South Africa was the major contributor with an output of 88% of the total continental patents. In North America; it was the United States contributing 99% of the total continental patents. In South America; it was Brazil contributing 97% of the totalcontinental patents.

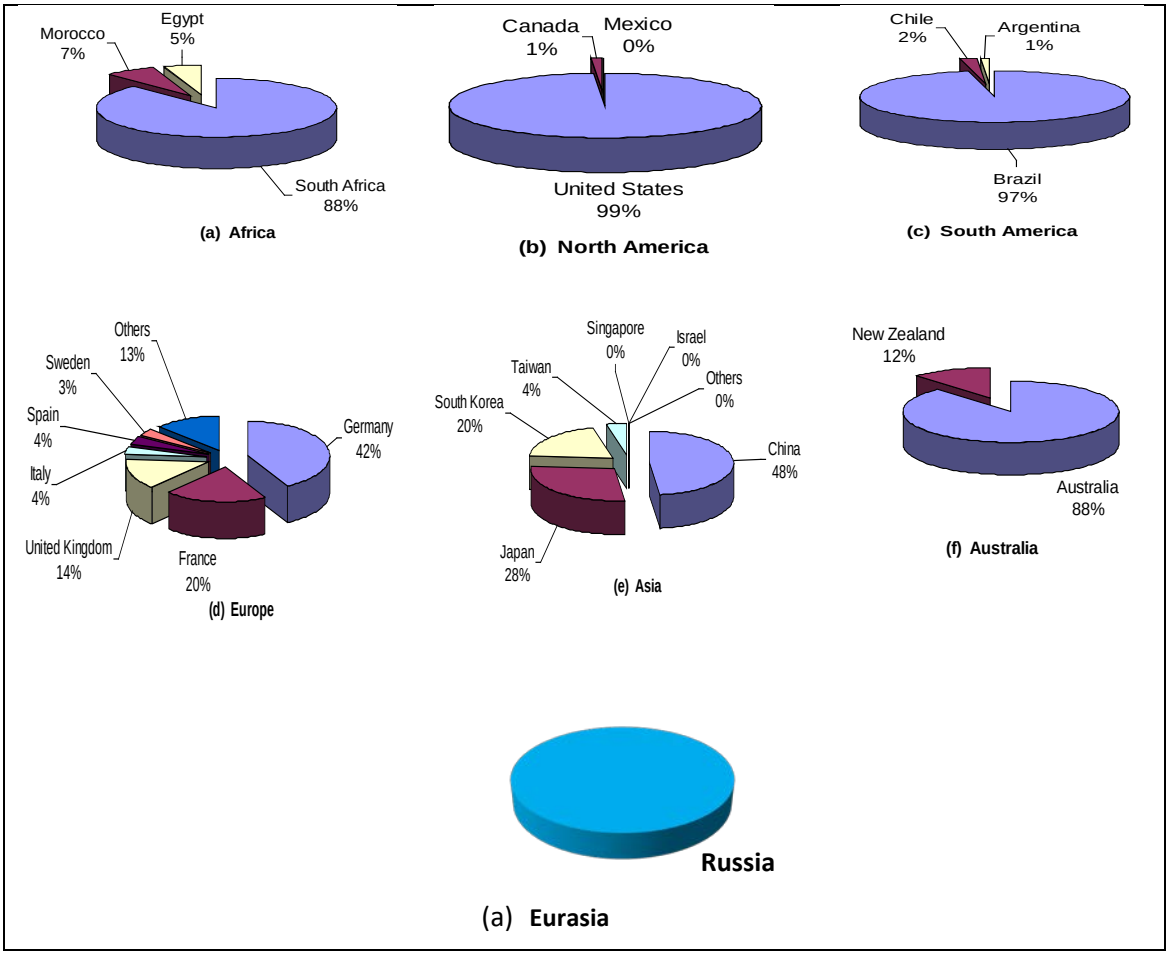

Figure 3 Major Contributors to Nanotechnology Patents in various Continents (1995-2012).

In Europe; Germany, France and the United Kingdom were the major contributors with a combined output of 76% of the total continental patents. In Asia; China, Japan and South Korea were the major contributors with a combined output of 96% of the total continental patents. In Australia; Australia was the major contributor with an output of 88% of the total continental patents.

3.2 Trends of Nanotechnology Patents in various Continents:

The annual trend for nanotechnology patents for the period under review is presented in Figure 4. Asia had the highest rate of annual growth as regards nanotechnology patents followed by North America, then Europe, Eurasia, Australia, South America and Africa. Between 1995 and 1996, Asia, North America and Europe were at par with each other, and grew at the same rate. However, Asia and North America left Europe behind between 1998 and 1999 and continued growing at par with each other until 2000 when Asia spear-headed the annual growth rate. Growth for the Asian continent was generally sharp, high and consistent until 2010 when there was an equally sharp and consistent decline. This was between 2010 and 2012. The decline was rather higher than the increment (as indicated by the very steep slope in Figure 4). North America had a lower annual growth rate than Asia generally and the rate of growth was not as sharp too (as indicated by the smoother curve in Figure 4). Growth was consistent until 2006 when it started fluctuating. This continued till 2010 when a sharp decline was also recorded dropping further downward than Asia. Europe experienced an even lower annual growth rate than either of the two preceding continents. Growth was generally consistent too until 2010 when a decline in growth set in. The decline was sharp between 2010 and 2011, but there was a reduction in the rate of decline between 2011 and 2012.

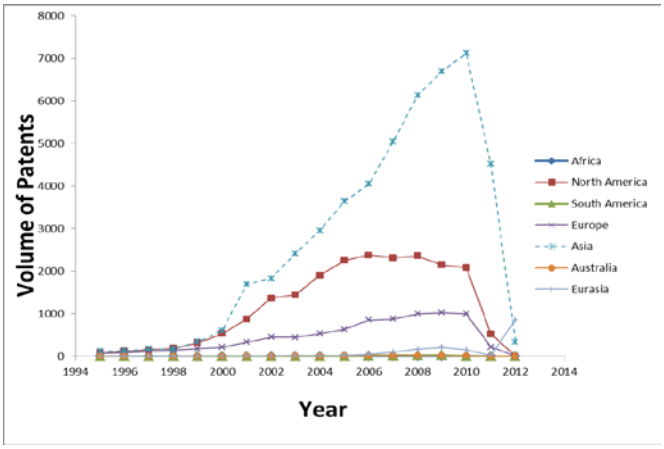

Figure 4: Annual Nanotechnology Patent Trend in the World (1995-2012).

3.3 Nanotechnology Patents by Research Area:

Figure 5 shows the top seven most-patented areas of nanotechnology globally. In decreasing order they are: Nanotubes and Nanowires (NTNW), Nanofabrication and Processing (NFPR), Nanoparticles and Quantum Dots (NPQD), Water purification, Desalination and Decontamination (WPDD), Composite Materials (COMA), Quantum Devices (QUDE), Nanocatalysts (NACA).

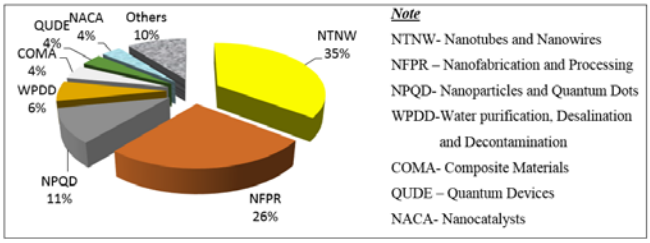

Figure 5Top seven Areas of Nanotechnology Patents (1995-2012).

At the continental level (see Fig 6 (a) – (g)), Patents from Nanotubes and Nanowires (NTNW) technology sub-sector dominated in Asia, North America and Europe. This probably explains the reason why NTNW is the most predominant area of patents globally. The situation is slightly different for the remaining continents. In Africa and Eurasia, Patents from Nanoparticles and Quantum Dots (NPQD) dominated. In South America and Australia, Patents from Nanotoxicity and Safety (NTSF) dominated.

One common thing that can be observed in all the continents is that among

the top three patents in each continent, NPQD and NFPR featured in all the continents except for Australia. In similar vein, NTNW featured in the top three areas for most of the continents except Africa and South America.

4. Conclusions

Results from the study indicate that a total of 56 countries were in participation globally. 3 were from Africa, 3 from North America, 3 from South America, 29 from Europe, 15 from Asia, 2 from Australia and 1 from Eurasia for the same period. The total volume of inventions was 78,585. The volumes corresponding to the respective continents 0.05%, 26.85%, 0.17%, 6.69%, 61.11%, 0.25% and 1.07%.

The top seven most-patented areas of nanotechnology inventions were: Nanotubes and Nanowires (35%), Nanofabrication and Processing (26%), Nanoparticles and Quantum Dots (11%), Water purification, Desalination and Decontamination (11%), Composite Materials (4%), Quantum Devices (4%), Nanocatalysts (4%).

Figure 6: Top Seven Areas of Nanotechnology Patents at the Continental Level (1995-2012).

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Acronyms

BMDE Bio-MEMS Devices
COMA Composite Material
ENHA Energy Harvesting
FNNN Functionalization of Nanotubes, Nanowires and Nanoparticles
FUAD Fuel Additives
FUEX Fuel Extraction
HPBA High Performance Battery
IMAG Imaging
NFPR Nanofabrication and Processing
NDMO Nanodevices Modeling
NTSF Nanotoxicity and Safety
NPQD Nanoparticles and Quantum Dots
NTNW Nanotubes and Nanowires
NACA Nanocatalyst
NASN Nansensors
NAFL Nanofiltration
PHCR Photonic Crystals
PVSC Photovoltaic and Solar Cells
QUDE Quantum Devices
THIN Thermal Insulation
WPDD Water Purification, Desalination and Decontamination