NANOTECHNOLOGY INITIATIVES IN NATIONS: THE CHALLENGES, OPPORTUNITIES AND PROSPECTS FOR AFRICAN NATIONS

Ikechukwu C. Ezema [(a)*], Peter O. Ogbobe[(b)] and Augustine D. Omah[(a)]

(a) Department of Metallurgical & Materials Engineering, University of Nigeria, Nsukka
(b) Technology Incubation Centre Enugu, Federal Ministry of Science & Technology, Abuja Nigeria
*Corresponding author: *e-mail: ikeezema@gmail.com: Tel: +234-8148320961*

ABSTRACT

Most countries in the continent of Africa seem to ionbelieve that the journey towards nanotechnology is a pathway that can only be walked on by the developed nations. But this is not supposed to be so, because even smaller countries such as Sri Lanka, Malaysia and Thailand have become global players of repute in nanotechnology. Materials age existed in history such as stone age, bronze age, iron and steel age, advance materials and now nanomaterials age. It is however regrettable that most nations in African are yet to embrace this emerging technology with the very urgent attention it deserves. This paper tried to survey some nations of the world that have had their initiatives launched under national activity nations and current R/D empowerment nations. In Africa, it is only South Africa that is a member of the R/D empowerment nations. This study highlighted a number of steps to be taken by African nations willing to develop a robust nanotechnology programme. The aim is to stir seriousness in these African nations to embrace and be part of this global revolution in science and technology at the level of global importance and recognition. This investigation was simply based on scientific literatures in electronic articles via internet. The review showed that nanotechnology is new globally and that most countries are adopting networking among her agencies and collaboration with private and international donor agencies. The very aim is to bring about new materials and systems that can impact positively on their economy and ensure their global competitiveness and sustainability.

***Key words**: Nanotechnology, Global initiative, Africa nations, applications, Challenges, action plans.*

1.0 INTRODUCTION

Within the last decade, nanoscience has become an emerging discipline with fundamental and applied components encompassing the physical, life, and earth sciences as well as engineering and materials science. Nanoscience simply bridges the dimensional gap between the atomic and molecular scale of fundamental sciences and the microstructural scale of engineering and manufacturing. Because of its broad multidisciplinary scope, nanotechnology is projected to increase the level of technological advances at a significantly higher rate than ever experienced in human history. As a result, the technical, educational, and societal implications of nanoscience are considered highly important, as attested by the major economic investment and the numerous national initiatives of developed and developing countries alike[1].

Nanotechnology can simply be defined as the study, understanding and control of atoms, molecules or particles at dimension between 1-100 nanometers [2]. Nanotechnology is not a subject on its own by rather the most current way in which subjects are studied similar to studies on microstructure. It essentially involves imaging, measuring, modeling, synthesis and manipulating atoms at the nanoscale. A nanoscale is about $1x10^{-9}$m (i.e. one billionth of a meter). Studying materials at this level requires high powered equipment with unique techniques and features to achieve functionality for novel applications. In the very recent past (before 1980), scientist have been seeing objects at near nanoscale using Scanning Electron Microscope (SEM), Optical Microscopes and Transmission Election Microscope (TEM), but today, High Resolution Transmission Electron Microscope (HTEM), Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM) exhibiting more powerful results are in use.

Humanity existence from generation to generation has been characterized by different materials under their use. This divide accordingly include the stone age, bronze age, Iron age, steel age, semiconductor age, advanced materials (composites; ceramics, polymers and metals) and now nano-materials[3] **.** Transformation in the materials world has been the bane of technological advancement worldwide. Dr Butt [3], reported that "between 1900 -1950, radio, television and other electronic devices were manufactured using analog inputs, while semiconductor and micro chips in use today were introduced between 1951 – 2000 to produce more sophisticated television, radio and small size computers, and internets. Since 2000, nanodevices have been in use as technological advancement for manufacture of more robust products.

The major difference between materials on a nanoscale and that on either micro or macro scale is that they have better chemical reactivity due to relatively larger surface area to mass ratio[4], which makes them poses better strength and properties. Again at nanoscale, classical physics law give way to quantum mechanics such that opaque substances becomes transparent ; example copper, inert metals become catalyst; example gold and platinum, while insulators such as silicon and polyamide become conductors [4] .

The very objective of this paper is to highlight when and how other successful nations of the world started their nanotechnology program through a launch of their National Nanotechnology Initiatives (NNI). The paper raised a number of challenges that must be addressed first and foremost and cited opportunities readily available for African Nations to utilize and be part of the abundant benefits therein in this global science and technology drive. This investigation was simply based on scientific literatures in electronic articles via internet. The study showed that nanotechnology is new globally and even the developed countries are at their early stages and as such African nations can learn from them and impact same positively on their economy and ensure their global competitiveness and sustainability. The global scenario suggests multidisciplinary cooperation approach and collaboration/partnership between major stakeholders

2.1 Nations Actively Engaged in Nanotechnology

TERI classified global nanotechnology developments in relation to advancements made from country to country such that nations are grouped on a global scale [5] as (i) National activity nations (ii) Current R/D empowerment nations and (iii) Demonstration of interest nations. These ranking is based on a number of indicators such as (i) legislated policies and legal frame work (ii) funding and investments provisions (iii) human resources capabilities (iv) Industries scenario and its socio-economic impact. Most of the countries in Africa are at the third category while some have not specifically demonstrated any interest..

The national activity nations with proficiencies in the indicators cited above and have developed a robust nanotechnology program include; Japan, China, United States of America, United Kingdom, Russia, Germany, France, Spain, among others.

Japan the electronic and automobile giant of the world had her basic research program in nanotechnology launched in 1995 with various ministries participating. This is headed by the Ministry of Science and Technology. They had a basic plan that is re-launched in every five years [6]. By 2011, about 300 public and private institutions and over 1200 researchers were involved in nanotechnology activities [7]. Their major area of focus is on production of electronic nanomaterials, nano-devices, and biomaterials. Japan had by 2011 spent about € 2.8471 billion on bottom top and top-down research categories. [8, 7]. China national nanotechnology programs have existed since 1990 [7]. Currently China appears to be leading the world in the number of nanotechnology companies [6]**.** The major products of China's nanotechnology are nanomaterials such as nanometal oxides, nanometal powders and nano compound powders. China in 2011 only spent about €1.8 billion and has instituted her 12th five year plan (2011-2015) rated the most holistic plan anywhere in the world [9] which is a target of practical shift from basic research to applied research – mobilizing over 1000 companies mainly SMEs. China had state level participation such as Suzhou industrial park and Jiangsu Shanghai [10]

USA- NNI was launched in 2001 and it is under the supervision of National Science and Technology Council with more than 25 Federal agencies with specific nanotechnology budgets participating. USA has invested about US$15.6 billion for nanotechnology (2001 – 2012. Private company participation helped USA to achieve her feet such as Hewlett Packard, Motorola, IBM and Intel in their collaborations with universities. The economic impact is growing speedily with almost over 100 companies in every region of USA focusing on nano-electronics, semiconductors, and pharmaceuticals, military devices among others [11]. These achievements have helped create millions of employment and maintain US sustainability and global competitiveness.

Other countries that have had a successful launch of their nanotechnology initiatives with attendant results include European nation. Most countries in Europe have their investments at about 100million – 350 million Euros per year [8]. They all have well tailored targets to achieve their interest and maintain global competitiveness and sustainability. In excess of this budget are Germany for instance, with over 750 companies and over 1000 researchers and 50,000 jobs already created spending about 500million Euro per year in funding. Germany is focusing on carbon nanofuel, nanomaterials, textile, with their industrial partners such as Bayer, EADS, BASF, VARITA and SIEMENS [8]. Also France spends about 400million Euro per year and has created about 130 companies and over 700 nano-researchers as at the time of this review.

2.2 Nations at the Research and Development Level

The second group is the research and development nations. These include a few developing countries visibly lead by the BRIS (Brazil, Russia, India, and South Africa) - that have caught the vision of upcoming nanotechnology industrial revolution and have started their own nanotechnology initiatives through proper policy frame work, robust budgetary plan, collaboration/network linkages and human capital development for successful national development in line with United Nation APCTT-ESCAP mandate. [12]. Other countries include at this stage, Malaysia, Iran, Singapore, Sri Lanka, Taiwan, and Thailand among others.

Brazil in 2005 did setup 10 research networks involving about 300 PhD researchers [13] and launched her first nanotechnology programme with a budget of about US$31million. Brazil had a strong collaboration link in her plan 2007-2013 with European Union, South Africa and India and this has strengthened their nanotechnology capabilities. Their major product targets include nanoparticles, nanophotonics, nanobiotechnology, CNTs, nanocosmetics, simulation and modeling of nanostructures.

Russia since 2006 launched their nanotechnology activities with block funding from various government agencies with Federal Agency for Science and Innovation (ROSNAUKA) as the implementing body [8] targeted to create many nanotechnology industries by 2015 [14].

India launched her five year plan 2007-2012 with a budget estimate of US$254 Million [15]. India developed many centers of excellence (COEs) targeted at laboratories, infrastructure and human resource development. India Department of Science and Technology (DST) is the agency responsible for both basic and applied research in nanotechnology, their areas of focus include nanotubes, nanowire, and nano structured alloys/systems among others.

South Africa is at the fore front among African nations [16] and had strategically started her nanotechnology activities with a budget of US$2.7m in 2005 and has spent a total sum of about US$77.5m (2005-2012). South Africa nanotechnology is powered by Department of Science and Technology (DST) focusing on Human Capital Development through students on researcher support program, establishment of Nanoscience Centers, Equipment Acquisition Program, and establishment of nanotechnology platform and two nanotechnology innovation centers that will encourage patent and prototype products [17]. South Africa has a strong collaboration with foreign partners especially Brazil and India. Today South Africa has gone into applied research stage focusing on nanocatalysts, nanofilters, nanowires, nanotubes and quantum dots [15].

Other countries with evident nanotechnology development include Iran [12, 18], Iran had its National Nanotechnology Initiative launched in 2005 for a 10 year period up to 2015. Thailand [19] launched her national nanotechnology center NANOTECH in 2003 with an annual budget of approximately $2 million per year [20]. Malaysia started her nanotechnology campaign in 2001 with a more robust plan made for 15 year period 2005-2020 with more than150 local researchers focusing on nanotechnology for advance materials, biotechnology to encourage the development of new companies and new products [21].

The greatest challenge to African nations is that of Sri Lanka, a country of about 20 million people and primarily of an agricultural based developing economy but with visional leaders who through its Ministry of Science and Technology and National Science Foundation (NSF) recognizes the importance of nanotechnology in the oncoming industrial revolution. Nanoglobe [12] reported that "Sri Lanka, though with limited infrastructure built for R&D and limited funding from the government has so far shown high commitment in development of nanotechnology with unique private public partnership and passionate scientists. Sri Lanka NSF launched its Nanotechnology Initiative in 2007 and did set up the Sri Lanka Institute of Nanotechnology (SLINTEC) as a private company with LKR 420 million (about USD3.7M) in 2008 with a unique public private-partnership (PPP) structure.

In the PPP arrangement, 50% of institute funding comes from 5 private companies including Hayleys, MAS Holdings, Brandix, Loadstar and Dialog". This Sri Lanka approach is a typical lesson for Africa and LDC governments to learn from.

2.3 Nations at the Demonstration of Interest stage - African Nations

Recently, on August, 7, 2012 in Abuja, Nigeria, Federal Ministry of Environment signed a joint agreement to promote training and capacity building for development of a nano-safety pilot project in Nigeria with financial support from government of Switzerland – the overall aim was to create awareness [22]. Zainab [23] reported that "nanotechnology is a new field in Nigeria, and systematic efforts are being made by the academia, research institutes and government to create awareness and interest in nanotechnology development. Nigeria has so many agencies claiming to be developing nanotechnology but without any clear budget or coordinating ministry. Nanotechnology in Nigeria is at its best at the level of conference/workshops and individual research. Apart from South Africa, most other countries in Africa are like Nigeria at the demonstration of interest stage in their nanotechnology development effort. Many have not even indicated interest while those that indicated are not having enough drive to push for success [24]. The big question is, when will African nations launch their National Nanotechnology Initiatives or for how long must they continue to be passive actors?

3.1 Challenges, Opportunities and Prospects of Nanotechnology for Africa Nations

It is very true that the challenges of a country's engagement in nanotechnology are enormous and some of them seem insurmountable simply because of the political issues dominant in most developing countries, but the truth is that nanotechnology is here with us and will soon form part of our everyday product usage, therefore our nations must use adaptive capacity approach in order to conquer. Some of the challenges of nanotechnology development in Africa nations as reported by Babajide [25] include but not limited to; Lower government spending on research and development (R& D), Lack of infrastructure and human capacity, Lack of private enterprise participation in research and development, Lack of proper education relating to curriculum development matters, Lack of proper legislation/ regulatory framework and the relevant political drive, Lack of proper collaboration and network programs among agencies, research institutes and industries that will translate basic research into applied research and end products. Others include;

- Poor industrialization status of third world countries
- Inadequate foreign linkage particularly with donor agencies in nanotechnology.
- Fear of Health, environmental and safety risks associated with Nanotechnology

To be part of these technological revolution Africa nations can adopt the following practical action plans/steps needful to establish a robust nanotechnology program in their country. These include but not limited to;

1 A ministry of nanotechnology or a department of nanotechnology should be created under the ministry of Science and Technology with budgetary allocations to coordinate and oversee the general activities of nanotechnology in other ministries/agencies in the nation. The nation's policy formulations and definite goals should favor multidisciplinary nanoscience and nanotechnology such that inclusion of nanotechnology budget in relevant ministry of government is guaranteed.

2 Each country in Africa should work out strong collaboration link with successful nations like USA, South Africa, India and European Union which has strong nanotechnology capabilities. The benefit is enormous including funding and training of human resources

3 African nations should formally launch their National Nanotechnology Initiative (NNI) with a specific date and target outcomes/focus for economic development. Their first focus should be on human capital development through students on researcher support program with priorities on Energy, Health, Water & Environment, Nanomaterials and Construction and other priority areas.

4 Centers of excellence (COEs) in nanotechnology research and development should be established with state-of-art facilities for nanotechnology in African universities and research institutes. In these centers, specialized trainings can be organized for personnel as to fast tract on human resource requirements mentioned above.

4.0 Conclusion

Many nations of the world including some developing countries have since launched their nanotechnology programs and are at various levels of success. African nations and indeed other developing nations at the expression of interest stage can also embrace the challenges with vigor and determination to make it, by establishing a fortified nanoscience/nanotechnology program in their country through proper curriculum development, timely legislation and budgetary funding /investment. Collaborations in partnership with the private sector and donor nations/ agencies should be adopted. The long term economic benefits will surely increase the country's sustainability and global competitiveness.

These nations at the demonstration of interest stage should endeavor to utilize the window of cooperation and collaboration now available with developed countries such as USA, European Commission, China and Japan to enable them access assistance. This assistance may be sort through proper training of her human capacity and funding/ donation of equipment from these national activity nations. This very window is wide open now but will not remain so for a long time. African nations and other Least Developed Countries (LDC) should not allow such opportunity to waste away. The earlier they make advances to the realities of nanotechnology the better their nations will be.

References

1 http://www.kymanox.com/JSNN;_31AUG12.pptx;

2 http://www.nano.gov;

3 http://www.ncp.edu.pk/docs/nsc.pdf;

4 http://www.docstoc.com/docs/116170/folic-1;

5 *http://www.ec.europa.eu/health;*

6 http://*www.nni.org;*

7 http://www.cienstifica.com/html;

8 http://www.observatorynano.eu/.publicfundingofnanotechnologies;

9 Bai C.: Progress of Nanoscience and Nanotechnology in China: Journal of Nanoparticle Research,_3 (4) pp251-256, 2001.

10 http://www.ice.it/paesi/asia/china/20nanotechnology%industry;

11 http://www.crs.org.pdf;

12 http://www.nanotech-now.com>nanotechnology.colums>nanoGlobe;

13 http://www.nanformeula.eu.pdf

14 http://www.rusano.comm;

15 http://www.teriin.org;

16 http://www.nano.gov/sites/defaults/files/Molapisi.pdf;

17 UITAR/OECD/IOMC**:** Awareness–Raising Workshop for Developing and Transition Countries on Nanotechnology/Manufactured Nanomaterials Africa Region, Abidjan, Co'te d' Yreire, January 25-26, 2010 pp 76-84.

18 Sarkar S and Beitollahi A: An Overview of Nanotechnology Activities in Iran; Iranian J Publ Health, Vol. 38, Suppl. 1, 2009, pp.65-68,2009.

19 Wiwut Tanthapanichakoon: An Overview of Nanotechnology in Thailand; KONA No. 23 pp 64-68, 2005.

20 http://www.azonazo.com/article.aspex;

21 Uda Hashin, Elly Nadia, Shahrir **(2009)**: Nanotechnology Development Status in Malaysia Industrialization Strategy and Practice; *Int J. Nanoelectronics and Materials* 2 No1 pp 119-134, 2009.

22 http://www.unitar.org/nigeria~holds~nanotechnology~workshop~part;

23 Zainab Hammanga: **Nanotechnology: Present Status and Future Prospects in Nigeria.** Conference proceedings on Nanotechnology - Present Status and Future Prospects in Developing Countries Kashan, Iran by the NAM S&T Centre. 18-20 May 2009, ch 20

24 http://www.nanowerk.com/news/nevid~2364ph;

25 http://www.who.int/entity/ifes/documents/forums..ppt~nano~alo~pdf;