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NANOTECHNOLOGY AND BAMBOO FIBRES AS AVENUES TO REJUVENATE THE GHANAIAN TEXTILE INDUSTRY

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Ghana could boast of 16 textile companies and about 138 garment manufacturing firms in the 1970s. However, over the years, a combination of poor reforms and government policies, competition from China, Europe and the US coupled with imbalances in trade policies have dwindled the fortunes of the textile industry and resulted in its sharp decline. Currently, only four (4) textile companies are still in existence but are however working below capacity. This deplorable situation calls for a paradigm shift from considering this industry in isolation to one which includes the government, the textile industry, the universities and research institutes, and the medical and pharmaceutical sectors. This paper conducts a review of nanotechnology and bamboo fibre and presents a proposal for incorporating them in revitalising the Ghanaian textile industry. The study suggests an evolution from producing basic fabrics to functional fabrics using the current advances in nanotechnology and alternative natural fibres like bamboo as raw materials for the production of superior green yarn and fabrics. The research also revealed that a favourable economic environment and policies, strategic placement within the within the global market supply chain, increased diversification and collaborations with ECOWAS and BRICS can ensure sustainability and growth in the textile industry.

Keywords: Antibacterial, Electrospinning, Nanofibres, Nanoparticles, UV-absorption.

1 INTRODUCTION

The Ghanaian textile industry, a once vibrant, economically viable and industrially relevant sector is gradually gravitating towards extinction. The 1970s saw the industry at its peak where as many as 16 textile companies and 138 garment-manufacturing firms shared a symbiotic relationship Quartey (2006). A plethora of inconsistent policies coupled with stiff competition from cheap imports specifically from China has become the bane of this industry Olarewaju (2001). The impact on employment, in particular, is quite significant. Reports from Ampofo (2002) and Ghana Employers Association (2005), show that from 1977 to 2005, employment levels in the textile industry dropped from 25000 people to 2961 persons. From 1977 to 2011, statistics reveals a sharp decline in industry output from 129 million yards to 42 million yards (Bruce-Amartey et al,2014, Quartey, 2010).
Till date, cotton remains the main raw material in the textile industry and the sector has not undergone any significant reforms. This lack of diversification is gradually stifling the industry in terms of innovation and, therefore, a critical assessment of this industry is required to explore viable alternatives that can resist the decline and

stimulate growth. This paper presents nanotechnology and the use of bamboo fibres as the catalyst for the transformation of the textile industry.

2 GLOBAL TREND IN THE TEXTILE INDUSTRY

The basic needs of man are food, clothing and shelter. With the world’s population reaching 7 billion, the need for a vibrant textile industry to meet the clothing requirements cannot be over-emphasised. It must be noted that in comparison to other sectors, the textile industry in terms of size and importance is second only to the information technology and the tourism industries. From the 1950s to the 1980s, the industry metamorphosed from relying solely on natural fibres to the introduction of man-made fibres. Also new weaving, warp knitting and non-woven fabric production technologies were developed. The early 2000s saw significant interest in developing functional textile which had, for example, anti-bacterial and flame retardant properties. Recent trends, however, show a growing interest in smart and interactive textiles, incorporation of nanotechnology, microencapsulation technology and UV-curing technology into textile production. Another area receiving huge patronage is the development of composite textiles for the automotive, aerospace, marine and wind energy sectors Shishoo (2012).
Another interesting phenomenon is the gradual focus on eco-friendly or green products. Bamboo textiles seem to be gaining grounds as an alternative to cotton while providing extra properties such as UV-blocking, antibacterial and biodegradability Afrin et al. (2009).
The textile market seems to be going through a transition from what Scheffer (2012) describes as an extensive accumulation regime (1989-2008) where growth was in terms of natural and human resource usage, to an intensive accumulation regime, where efficient resource utilisation is the main approach to growth. In 2010, the market grew by 70% and Asia was the main region that made strides into this capitalist economic system. Africa is the only region yet to make any significant claim. The 2014 Textile & Apparel Industry Report revealed that the apparel global market is currently estimated at US$1,100bn and with US$700bn as its trade value, of which china is the leading exporter with US$288bn per annum while the European Union leads with the largest consumer market of US$350bn per annum. There appears to be a tripartite divide in the global market where the U.S, EU and Japan focus mainly on the value addition stage within the supply chain of the textile industry while China, India and developing countries including Bangladesh, Vietnam, Indonesia etc, direct their attention to the manufacturing stage. The third group which includes Hong Kong, South Korea and Taiwan provides the connection between end-users and the manufacturers.

3 NANOTECHNOLOGY

Merging nanotechnology and textile manufacture is trying to bring together two (2) technologies that are over 200 years apart. Federal Ministries of Education and Research, Germany (BMBF) defines nanotechnology as “the testing, implementation and manufacturing of structures, molecular materials and systems with a dimension of production tolerance typically below 100 nm” Stegmaier (2012). There are many opportunities that are derived by incorporating nanotechnologies into textiles through the use of nanofibers and nanoparticles.
A few African countries are making strides policy wise to strategically be placed in order to benefit from nanotechnology. Cameroon, Ethiopia, Kenya, Namibia, Nigeria, the Republic of South Africa, Senegal, Sudan, Tanzania and Zimbabwe as

reported by The Fourth Annual Report on Nanoscience and Nanotechnology in Africa, have put in place national agendas and initiatives or established institutes and organisations that are specifically focused on nanotechnology research and development. (Masoka et al., 2012; Musee et al., 2012). Although Ghana is conspicuously missing from the list, efforts are being made to introduce nanotechnology through several collaborative initiatives including; United Nations Departmment of Economic and Social Affairs (UN DESA) projects and projects by foundations such as Gates and Siemens (Musee et al., 2012; Flament, 2013).

Ghana can easily adopt the South African model which has successfully combined efforts from lobby groups like the South African Nanotechnology Initiative (SANi), a national strategic policy (South African Nanotechnology Strategy), huge investment by government of about half a billion Rand from 2005 to 2012 and promotion of nanotechnology research activities in 10 universities and several research institutes. Masoka et al. (2012). Flament (2013), suggests that to strengthen the economic growth of developing countries in the nanotechnology market, four essential ingredients must be merged; namely, a favourable policy environment, scientific capacity, industrial capacity and a reliable market.

3.1 Electrospun Nanofibers

Cooley (1900) was first issued with the patent in the UK for electrospinning, but from 1934 to 1944, several patents were issued to Formhals. The very first recorded successful commercialization of electrospinning nanofibers, however, was attempted in 1938 by Rozenblum and I. V. Petryanov-Sokolov in the USSR at Ya Karpov Institute. They were able to develop a non-woven filter material from the electrospun fibres known as Petryanov filters. This groundbreaking work led to the development and production of over 21 million m^2 per annum of electrospun gas mask smoke filter elements (Filatov et al., 2007).

The difference between conventional fibre spinning and electrospinning is the type of force acting on the liquid. Mechanical force is made to act on the end of a jet during conventional fibre spinning while an electrical force is applied on an element of charged fluid when electrospinning Haghi, (2012). It is an efficient process of producing nanometer-scale diameter fibres called nanofibres. Surface tension at a syringe needle's tip holds a droplet of polymer solution while a strong electric field is made to act on it. This causes the surface of the droplet to become electrically charged. As the intensity of the electric field is steadily increased, the droplet distorts to a cone shape also known as the Taylor cone and after a certain threshold, the surface tension is overcome by the repulsive forces within the electric field which causes a stable jet to emerge from the tip of the cone. The jet elongates and thins rapidly as it approaches the target while experiencing drying due to solvent evaporation and then finally high repulsive forces cause smaller jets to emerge as a result of increased surface charge density and continuous thinning diameter. Solidified randomly-oriented non-woven fibres eventually get deposited on the collector as illustrated in figure 1, Haghi and Zaikov (2012).

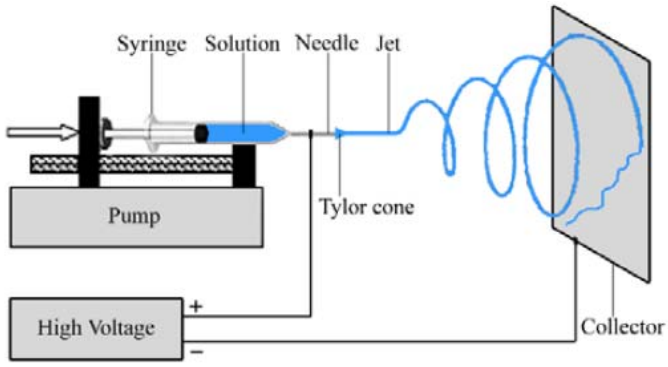

Figure (1) The Electrospinning process source: Haghi and Zaikov (2012).

The Ultrathin and extremely fine fibres are produced during the electrospinning which possess high porosity and pores of small size making them suitable for applications in protective clothing and use in filtration systems. In protective clothing, nanofibres are known to trap particles quite efficiently while ensuring air permeability. Nylon polybenzimidazole, polyacrylonitrile, and polyurethane are well known electrospun fibres capable of providing particle protection. One significant advantage that electrospun nanofibres have over other processes as carbon nanotubes is that the nano dimensions in terms of diameter are achieved while having lengths that reach over 1 kilometre. Therefore, the possible health risk associated with nanoscale particles or short fibre is avoided Haghi (2012).
In comparison with other processes, electrospinning is relatively simple, versatile and scalable. It is simple because, the whole setup consists of two (2) electrodes, DC power supply and a polymer delivery system. Electrospinning is very versatile because the production of ultrathin membranes from a combination of different categories of particles, fibres and polymers is possible Gibson et al. (2001). Successful electrospinning of nanofibers from over 50 different polymer solutions have been recorded Huang et al. (2003). Electrospinning is an easily scalable process whereby simply increasing resources or modifying techniques can result in considerable increase in the output. Therefore, it is much more versatile than drawing, template synthesis, phase separation and self-assembly. The perfect control of fibre dimensions and repeatability are added advantages of using the single-nozzle in electrospinning Ramakrishna et al. (2005).

3.1.1 *Justification for Protective Clothing*

Chemical Protective clothing must meet certain critical performance criteria provided by Graham et al. (2003) such as “excellent protection against liquid and vapour contaminants, resistance to rain intrusion, air permeability, tear strength, fabric weight requirements and durability”. The existing fabrics have the disadvantage of being bulky and heavy and retains water and heat as a result of several fabric layer system (Sundarrajan and Ramakrishna, 2007; Chen et al., 2009). However, electrospun nanofibers can be directly incorporated into protective fabrics as a solution to the above-stated disadvantages. Schreuder-Gibson et al. (2002) observed that electrospun nanofibres were capable of allowing evaporative cooling and effectively trapping particulates.
The advantages of using electrospun nanofibers in protective clothing include (1) High resistance to particulate penetration (Gibson et al., 2001; Lee and Obendorf, 2006), (2) Good ‘breathability’ (evaporative cooling) (Gibson et al., 2001; Gibson

et al .,1998; Lee and Obendorf, 2006). (3) Low basis weight and low-pressure drop and (4) Surface functionalization. One unique characteristic of electrospun nanofibres is the ability to incorporate catalysts which cause the fabric surface to detoxify agent while remaining unchanged by the reaction.

3.1.2 *Limitations of Electrospun Fibres*

The main disadvantages associated with electrospinning are issues with rather low productivity, and inferior mechanical properties of fibres. However, a lot of research is ongoing to make it more productive.

3.2 Nanoparticles

Some standard definitions for nanoparticles are: (1) The International Organization for Standardization (ISO) defines a nanoparticle as “a particle spanning 1–100 nm (diameter)”, (2) American Society of Testing and Materials (ASTM) defines nanoparticles as “an ultrafine particle whose length in 2 or 3 places is 1–100 nm” and (3) British Standards Institution (BSI): All the fields or the diameters are in the nanoscale range. Nanoparticles cannot be treated as normal objects that are governed by Newton’s laws because they are far smaller and also cannot be treated as atoms or simple molecules that are governed by quantum mechanics because they are bigger Horikoshi and Serpone (2013).
The history of the commercial and industrial production of nanoparticles can be traced to the twentieth century where nanoparticles of carbon black were used in rubber tire fabrication for automobiles. However, research-led innovation in the development of nanoparticles took off in the 1970s. There are two major approaches to producing nanoparticles. Firstly, the breakdown or top-down method which basically requires the application of external force to pulverise solids, and secondly, the Build-up or bottom-up method which entails producing nanoparticles from gas atoms, liquid atoms through atomic transformation or condensation of molecules as shown in figure 2, Horikoshi and Serpone (2013).

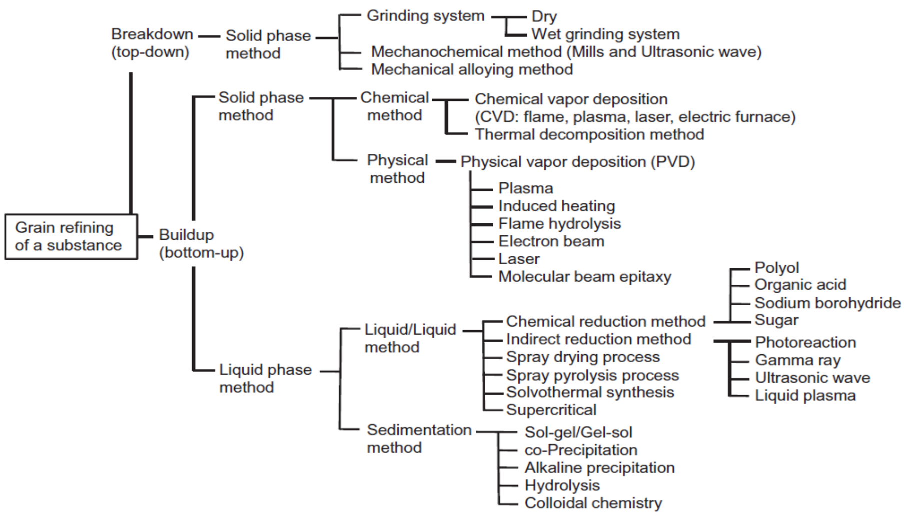

Figure (2) Methods of producing nanoparticles, Source: Horikoshi and Serpone (2013).

3.2.1 *Nanoparticles in textiles*

Functional nanoparticles are gradually being used in the textile sector to develop new textiles or alter and improve their properties. Examples of such nanoparticles steadily gaining industrial interest include silver (antimicrobial properties), TiO2 (photo-active properties), ZnO (UV-absorbing properties), conductive metals like copper and metals or their oxides possessing magnetic properties. The global textile market is steadily gravitating towards thinner fibres which make the need for nano-scaled or nanostructured finishings even more critical in ensuring that small fibre diameters are maintained Stegmaier et al. (2007).

3.2.2 *Self-Cleaning Superhydrophobic Surfaces*

The Lotus plant in nature has the unique characteristics of what is termed “Self-cleaning” properties. This phenomenon is as a result of the plant’s surface having low surface energy and nanostructured surfaces which make them super hydrophobic. Only rainfall is required to completely rid itself of all contaminants. This is often described as the Lutos-Effect. This ability is being mimicked in the textile industry by developing textiles which have surfaces that are capable of self-cleaning by means of only water without the need for cleaning agents. Hence in the fabrication of ultra-hydrophobic textiles two main properties are required; namely, the low surface energy of fibres and an extended degree of surface roughness. To achieve these requirements, the fabric surface is coated with a combination of low surface energy polymer layer for hydrophobicity and Nanoparticles for roughness Stegmaier et al. (2007).
There are several applications for such self-cleaning textiles, such as in outdoor clothing, sunscreen textiles and textile roofs for railways and airports.

4 BAMBOO FIBRE

4.1 Brief description of the plant bamboo

Bamboo is classified as a grass belonging to the family Gramineae, subfamily Bambusoideae and having over 1500 different species (Chaowana, 2013; Steinfeld, 2001). Within 3 months after germination, bamboo grows to its maximum height ranging from a few inches to over 100ft (30 m) and eventually approaches maturity within 3-4years. It is capable of growing up to 1 metre overnight and, therefore, categorised as one of the fastest-growing plants in the world. Bamboo is very resilient and can thrive in many habitats such as temperate, tropical, humid, arid, coastal and montane areas. (Bambrotex, 2015; Afrin et al., 2009; Fu, 2001).

4.2 Bamboo resources in Ghana

An estimated 300,000 hectares of wild bamboo can be found in five regions of Ghana, namely; Accra, Ashanti, Brong Ahafo, Central, Eastern, Northern and Volta regions. However, the region holding the largest stock is the western region with an estimate of 60%. There are seven (7) locally identified species found in Ghana and they include, Bambusa multiplex, Bambusa vulgaris (the green type), Bambusa arundinacea or Bambusa bambos, Bambusa pervariabilis, Bambusa vulgaris var vitata (the yellow type), Oxythenanthera abyssinica and Dendrocalamus strictus. Only two species, namely, Bambusa multiplex and Bambusa vulgaris can be classified as indigenous. 18 new species were introduced by the Bamboo, Rattan

Development Programme (BARADEP) Secretariat in 2003 and distributed throughout the country (Anokye and Adu, 2014; KCIPU, 2013).

4.3 Bamboo fibre market

A study carried out by Durst revealed that in 2006, bamboo textiles worth $10 million would be sold in the US alone and $50 million worldwide. The market for bamboo textiles is expected to continue growing (Dust, 2006). Bamboo textile and products are generally more expensive. In 2005, trade source revealed that the cost of bamboo fibre ($1 - $1.50) per pound is higher than that of cotton ($0.50) but it is expected that the rising demand would eventually even out the prices USITC, (2005). The main actors in the bamboo fabric market are the US, UK, China, India and Japan.

4.4 Benefits of using bamboo over cotton plant

A direct comparison of bamboo and cotton from the literature reveals that in terms of fibre per acre, bamboo yields 50 times more Durst (2006). As a raw material for textiles, it has the advantage of being renewable, biodegradable, and efficient in utilisation of space, frugal in water consumption and possesses carbon sequestering capabilities Steinfeld (2001). It can be regarded as a green plant. In relation to other trees, bamboo sequesters five times more carbon (five tonnes of carbon dioxide per acre) and releases to the atmosphere 35% more oxygen Knight (2007). Another unique characteristic of bamboo is that it is a grass and, therefore, replanting is unnecessary. It is capable of replacing within a year over 30% of its biomass, which is quite significant when compared to 3-5% for forest trees Steinfeld (2001). Pesticides, chemical weeding, insecticides, and fungicide are not required during cultivation of bamboo which makes it environmentally friendly and cheaper when compared with cotton (Afrin et al., 2009; Waite, 2009). Bamboo spreads rapidly and is capable of thriving in diverse climatic and soil conditions, and can therefore, be used to improve soil quality (Afrin et al, 2009; Bambrotex, 2015). Bambrotex also claims that clothes made from bamboo have 3 times service life than those of cotton. Bamboo qualifies to be termed green and eco-friendly because it is biodegradable and has an excellent growth recovery rate. On the average most forest trees take a minimum of 60 years to recover after logging but bamboo takes just 2-3 years.(Yu, et al. 2003; Afrin et al, 2009)

4.5 Properties of bamboo fibre and fabric

Literature from (Hoffmann et al., 2001; Afrin et al., 2009; Waite, 2009; Majumdar et al., 2011; Tyagi et al., 2011; Bambrotex, 2015), report that bamboo fabrics possess and exhibit certain unique properties such as superior UV-blocking efficiency, biodegradability, excellent mechanical properties such as superior tensile strength and flexibility, antibacterial and hypoallergenic characteristics, high moisture absorption capacity and ventilation due to fibre micro gaps and holes, softness, breathability, higher wrinkle resistance and colorfast property.

4.6 Manufacturing processes

Philipp Lichtenstadt is reported as recording the earliest U.S. Patent in relations to bamboo textiles in 1864 Lichtenstadt (1864). This patent describes a process for disintegrating bamboo fibres for use in manufacturing cloth, mats, cordage or pulp for paper.

(Wiate, 2009) describe the two main methods of processing bamboo to extract the fibre; namely, chemical and mechanical methods

4.6.1 *Chemical Method*

(1) Removal of leaves and inner fibre from bamboo, (2) Preparation of bamboo cellulose by crushing the leaves and inner fibres together, (3) Soaking of bamboo cellulose in 18% sodium hydroxide (NaOH) for 1-3 hours at a temperature of 20-25°C, (4) Pressing of Bamboo cellulose/NaOH mixture to expel excess NaOH then crushing and drying for 24 hours, (5) Addition of Carbon disulfide to mixture, (6) Formation of cellulose sodium xanthogenate by removing CS2 through decompressing the bamboo, NaOH and CS2 mixture. (7) At this stage, a viscose solution is formed by the addition of dilute NaOH to cellulose sodium xanthogenate. (8) A spinneret nozzle is used to force the viscose into a vessel containing dilute sulphuric acid. This causes the viscose to and reconverts to bamboo fibre (9) Spinning of bamboo fibres into yarns

4.6.2 *Mechanical Method*

(1) Cutting strips from bamboo culm, (2) Boiling to loosen and remove inner fibres from the strip, (3) Addition of natural enzymes to break the bamboo into soft mass or degumming, (4) Combing individual fibres out, (5) Spinning fibres into yarns.

4.7 Verification of Properties

Many research and studies have been conducted on the unique properties of bamboo fibres. A large percentage of these claims have come from manufacturers and commercial bodies that rarely disclose their research reports. Rigorous scientific examination is therefore required to confirm or reject these claims Afrin et al, (2009).

The green and eco-friendly attributes of bamboo textiles may be misleading as it is dependent on the manufacturing process. The chemical method or viscous bamboo cannot be eco-friendly because of the use of highly toxic and hazardous chemicals such as sodium hydroxide (NaOH) and Carbon disulphide (CS2). However, the mechanical method can be termed as green or eco-friendly because, natural enzymes are used in the degumming process (Vehvilainen et al., 2008; Candilo et al., 2010).

A study on the UV absorption properties of bamboo was conducted by Afrin et al. (2011), and revealed that the unique properties of bamboo textiles were dependent on the manufacturing method. Bamboo is a natural nanocomposite made up of lignocellulosic fibres, where celluloses is embedded within the lignin and hemicelluloses matrix (Rao and Rao, 2005; Afrin et al., 2010). Bamboo consists of about 30% lignin and is characteristically gummy. Afrin et al. (2011) conducted an experiment to compare untreated bamboo, cotton, 100% cellulose and commercial bamboo viscose fibres using FTIR and UV diffuse reflectance measurements. The results revealed that there was a direct correlation between increased UV absorption and increased lignin in bamboo, implying that the presence of lignin is responsible for UV absorption. This means that current ways of fibre manufacture, specifically chemical or viscous method which involves complete degumming (removal of lignin) destroys the UV absorption properties and is, therefore, unsuitable. Afrin et al. (2011) proposed an environmentally sound approach to bamboo fibre extraction which involves the use of microwave, ultra-sonication and enzymes without the

need for toxic and hazardous chemicals. This method retains lignin and hence ensuring UV absorption and antibacterial properties.
XI et al. (2012) reported that natural bamboo fibre did not possess antibacterial properties, however, regenerated or viscous bamboo fibre displayed antibacterial properties. It can, therefore, be inferred that the extraction method has an influence on this property. A study conducted by Afrin et al. (2012) observed that the lignin consisted of some antibacterial compounds and could be traced to the aromatic and phenolic functional group within it.

Bamboo fibre properties can be further enhanced through nanotechnology by mixing nanoparticles of bamboo charcoal into the solution of viscous before spinning commences (Lin, 2008; Waite, 2009).

5 PROPOSAL FOR TRANSFORMATION OF THE TEXTILE INDUSTRY FROM LESSONS LEARNT

To successfully adopt nanotechnology and alternative fibres like bamboo, lessons and from the above discussions as summarised from the Flamment (2013) model which requires merging a favourable Policy environment, scientific capacity, industrial capacity and reliable markets must be adopted.

5.1 A Favourable Policy Environment:

Quartey (2010) reports that uncustomed goods inflow; intellectual property rights infringement and imitation goods importations have contributed significantly to the demise of the local manufacturer. This calls for direct and decisive interventions as the Federal Government of Nigeria did in 2002 by enforcing a total ban on importation of all finished textiles, 10% duty incentive, 30% export expansion grant, 0% Valued Added Tax (VAT) and National Health Insurance Levy (NHIL) to help their textile industry. The Ghanaian textile manufacturers, however, pays 12.5% VAT and 2.5% NHIL on all finished goods, which in effect makes their products more expensive. Hence, many stakeholders have advocated for the reduction or total removal of duty on inputs for the production process while increasing duty on finished imported fabrics.
Although, Nigeria took these drastic measures their textile industry continues to struggle. This implies that another approach must be introduced whereby an amalgamation of tax incentives and introduction of new approaches and technologies such as nanotechnology and alternative fibres such as bamboo is introduced. The government of Ghana must, therefore, institute a national policy on nanotechnology as countries like South Africa and Nigeria has done. Agencies such as Bamboo and Rattan Development Program must be empowered and properly funded.
Scientific capacity: Universities and research institutes such as the Centre for Scientific and Industrial Research (CSIR) should have access to funding for Nanotechnology and bamboo projects, just as the South African government is doing. Ghana must start collaborating effectively with associations such as African Materials Research Society (AMRS), the Nanosciences African Network (NANOAFNET), the African Network for Solar Energy (ANSOLE), The African Network for Drugs and Diagnostics Innovation (ANDI), the African Materials Science and Engineering Network (AMSEN), the Network of African Science Academies (NASAC), the African Technology Development and Transfer Network

(TDTNet). All the above are directly involved in nanotechnology promotion Masoka et al. (2012).
Industrial capacity: To transform the sector, textile companies must undergo major infrastructural and equipment change and hence access to funding, and government incentives like tax reliefs are critical to attracting direct local and foreign investment. Workers in the industry must be given rigorous training on the current industrial practices.

5.2 Reliable Market:

5.2.1 *Internal Market*

The pharmaceutical and medical industries will greatly benefit from any research, in the area of functional fabrics and protective clothing. One of the approaches to the fight against malaria is the use of mosquito nets. However, studies have shown that after several washes the net's effectiveness reduces. Coating the fabric surface with mosquito-repelling nanoparticles is one way to go. Nanofibre can also be coated with these nanoparticles and incorporated into fabrics. Cornell University has already designed insecticide-treated garments with the use of nanotechnology. The Ghanaian pharmaceutical industries in collaboration with the textile companies can easily produce these types of nets and clothing. Nanofibres are known for their filtering capabilities and are perfect for manufacturing antibacterial textiles for hospitals. The UV-absorption and antibacterial properties of bamboo fibres make them suitable for use in hospitals as well. Ghanaians already patronise insecticide-treated nets, mosquito-repellent creams, mosquito coils and sprays and so there is a huge local market for both anti-mosquito and antibacterial garments and fabrics.

5.2.2 *External Market*

The Ghanaian textile market should form collaborations with their South African counterparts to have easier access to some markets outside Africa. In 2006, South Africa officially became a member of the BRICS which includes Brazil, Russia, India, China and South Africa. The aim of this association is to meet the economic needs of this century which include infrastructure, consumption and increased trade. The influence of this group is ever increasing in importance with respect to the global economy (Dube, 2013). Below are the four recommendations that were made during the BRICS Summit 2013 on Strategies for South Africa's engagement:

- South Africa should develop a proper, well-articulated strategy for BRICS engagement, framed firstly around South Africa's domestic economic interests and then around Africa's regional integration agenda that is mindful of BRICS' competition on the continent.

- African countries should undertake domestic reforms to improve their business and investment climate in order to facilitate the BRICS role in the continent's development.

- South Africa should work on developing bilateral relations with key African states, as these are crucial to South Africa's BRICS–Africa engagement; and any outreach to Africa should complement such relations.

- The BRICS Summit should be viewed as a potential opportunity to reframe the African development discourse with emerging economies.

6 CONCLUSION

The Ghanaian textile industry can regain its importance locally and internationally by placing itself with the supply chain of the global textile market. By adopting current technologies in nanotechnology and diversifying to alternative fibre raw materials such as bamboo which is easier and less expensive to cultivate, the industry may gain access to the global market and become a leading manufacturer in Africa. If the government can provide the conducive economic and legal environment, then, the industry would recover. It is also imperative that Ghana collaborates with countries such as South Africa and Nigeria in creating and accessing new markets. As things stand, the textile market is gradually losing to imports from China and until radical reforms are put into place, the sector may eventually collapse.

REFERENCES

Afrin, T., Kanwar, R. K., Wang, X., Tsuzuki, T., Properties of bamboo fibres produced using an environmentally benign method, Journal of the Textile Institute, 105 (12), 1293-1299, Feb, 2014.

Afrin, T., Tsuzuki, T. and Wang, X., Bamboo fibres and their unique properties, Natural fibres in Australasia: proceedings of the combined (NZ and AUS) Conference of The Textile Institute, Dunedin 15-17 April 2009, 77-82, Textile Institute (NZ), Dunedin, New Zealand, 2009.

Afrin, T., Tsuzuki, T., and Wang, X., Bamboo: A distinctive green fibre, ICTA 2010: Recent developments and challenges of textile and apparel industry: Proceedings of the 1st International Conference on Textile and Apparel, Amin, A. S. M. T. (Ed), 14–19, Jan, 2010.

Afrin, T., Tsuzuki, T., Kanwar, R. K. and Wang, X., The origin of the antibacterial property of bamboo, *The Journal of The Textile Institute*, 103 (8), 844- 849, Aug, 2012.

Ampofo, V. O., Ghana's Textile and Garment Industry, Ministry of Trade and Industry, Industrial Development and Investment Division, 2002.

Anokye, R. and Adu, G., The Status of Non-Timber Forest Products (NTFPs) Development in Ghana, *Journal of Environmental Science, Computer Science and Engineering & Technology*, 3(1), 144-155, Jan, 2014.

BambroTex, China Bamboo Fibre Manufacturer.Retrieved from www.bambrotex.com/second/anti_UV.htm , on November16, 2015.

Bruce-Amartey, E. J., Amissah, E. R. K., and Safo-Ankama, K., The Decline of Ghana's Textile Industry: Its effects on Textile Education in Ghana, *Arts and Design Studies*, 22, 36-44, 2014.

Candilo, M.D., Bonatti, P.M., Guidetti, C., Focher, B., Grippo, C., Tamburini, E., and Mastromei, G., Effects of selected pectinolytic bacterial strains on water-retting of hemp and fibre properties, *Journal of Applied Microbiology*, 108(1), 194–203, Jan, 2010.

Chaowana, P., Bamboo: An Alternative Raw Material for Wood and Wood-Based Composites, *Journal of Materials Science Research*, 2 (2), March, 2013.

Chen, L., Bromberg, L., Schreuder-Gibson, H., Walker, J., Hatton, T. A. and Rutledge, G. C., Chemical protection fabrics via surface oximation of electrospun polyacrylonitrile fiber mats, *Journal of Materials Chemistry* , 19 (16) , 2432–248, Mar, 2009.

Cooley, J. F., Improved methods of and apparatus for electrically separating the relatively volatile liquid component from the component of relatively fixed substances of composite fluids , *United Kingdom patent application 6385*, 1900.

Dube, M., BRICS Summit 2013: Strategies for South Africa's Engagement, *SAIIA POLICY BRIEFING 6 2 Economic Diplomacy Programme*, March, 2013

Durst, S., The Panda Food in Your Pants, *Business 2.0*, 7(9), 2006.

Filatov, Y., Budyka, A. and Kirichenko, V., Electrospinning of micro and nanofibers: Fundamentals and applications in separation and fi ltration processes, New York, Begell House Inc., 2007.

Flament, G., Closing the Gap: The Impact of Nanotechnologies on the global Divide, *Nanotechnology Industries Association*, Brussel, Belgium, Nov, 2013.

Fu, J., Chinese Moso Bamboo: Its Importance, *ABS Magazine*, 22(5), Oct, 2001.

Ghana Employers Association, Measures to Save the Textile Industry in Ghana, A Report Prepared by the Sub-Committee of the National Tripartite Committee on Measures to Save Ghana's Textile Industry, March, 2005.

Gibson, P., Schreuder-Gibson, H. and Rivin, D., Transport properties of porous membranes based on electrospun nanofibers, *Colloids and surfaces a-physicochemical and engineering aspects*, Elsevier , 187 , 469–481, Aug, 2001.

Graham, K., Gogins, M. and Schreuder-Gibson, H., Incorporation of Electrospun Nanofibers into Functional Structures, *International Nonwovens Technical Conference*, Baltimore, Maryland, Sep, 2003.

Haghi, A. K., *Electrospinning of Nanofibers in Textiles*, Apple Academic Press, Inc., Oakville, Canada, 2012.

Haghi, A. K., Zaikov, G. E., *Development of Nanotechnology in Textiles*, Nova Science Publishers, Inc.,New York, 2012.

Hoffmann, K., Laperre, J, Avermaete, A., Altmeyer, P., Gambichler, T., Defined UV Protection by Apparel Textiles, *Arch Dermatol.* 137(8), 1089-1094, Aug, 2001.

Horikoshi, S. and Serpone, N., Introduction to Nanoparticles, *Microwaves in Nanoparticle Synthesis*, Horikoshi, S. and Serpone, N. (Eds), Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2013.

Huang, Z. M., Zhang, Y. Z., Kotaki, M. and Ramakrishna, S., A review on polymer nanofi bers by electrospinning and their applications in nanocomposites, *Composites Science and Technology* , Elsevier, 63(15) , 2223–2253, Nov, 2003.

Knight, D., Going Green with Bamboo: Versatile Fiber Provides a Popular Alternative to Traditional Hardwood Floors, *Environmental Design and Construction*, 2007.

Lee, S. and Obendorf, S. K., Developing protective textile materials as barriers to liquid penetration using melt-electrospinning, *Journal of Applied Polymer Science* ,Wiley, 102 (4) , 3430–3437, Nov, 2006.

Lichtenstadt, P., *Verification of Bamboo Fibre*, US Patent & Trademark Office, 1864.

Lin, M., Bamboo Fibre Market Prices, *SuZhou ShengZhhu Household Co. Ltd*., 2008.

Majumdar, A., Mukhopadhayay, S., Yadav, R. and Mondal, A. K., Properties of Ring Spun Yarns Made from Cotton and Regenerated Bamboo Fibre, *Indian Journal of Fibre & Textile Research*, 36, 18-23, March, 2011.

Masoka, X., Utembe, W., Sekobe, G., Gulumian, M., Nanotechnology Research & Occupational Health and Safety in Africa, *African Newsletter on occupational Health and Safety*, Lehtinen, S. (Ed), 22 (3) 56-59, Finnish Institute of Occupational Health, Helsinki, Finland, Dec, 2012.

Musee, N., Foladori, G., and Azoulay, D., Social and Environmental Implicationa of Nanotechnology Development in Africa, CSIR (Nanotechnology Environmental Impacts Research Group, South Africa) / ReLANS (Latin American Nanotechnology and Society Network) / IPEN (International POPs Elimination Network), Aug 2012.

Nurfaizey, A. H., Tucker, N., Staiger, M. P., Functional nanofibers in clothing for protection against chemical and biological hazards, *Functional nanofibers and their applications*, Wei, Q. (Ed), Woodhead Publishing Limited, Cambridge, 2012.

Olaweraju, O., China Quietly Usurps African Textile Market, *The Stitch Times*, 12, Jan, 2010.

Quartey, P. and Abor, J., Do Ghanaians Prefer Imported Textiles to Locally Manufactured Ones?, *Morden Economy*, Scientific Research, 2, 54-61, Feb, 2011.

Quartey, P., The Textile and Clothing Industry in Ghana, *The Future of the Textile and Clothing Industry in Sub-Saharan Africa*, Jauch, H and Traub-Merz, R. (Eds), 135-146, Friedrich-Ebert-Stiftung , Bonn, Germany, 2006.

Ramakrishna, S., Fujihara, K., Teo, W. E., Lim, T. C. and Ma, Z., *An introduction to electrospinning and nanofi bers*, World Scientific Publishing Co. Pte. Ltd. , Hackensack, NJ, London, 2005.

Rao, K. M. M., and Rao, K. M., Extraction and tensile properties of natural fibers: Vakka, date and bamboo, *Composite Structures*, Elsevier, 77(3), 288–295, Feb, 2005.

Scheffer, M. R., Trends in textile markets and their implications for textile products and processes, *The Global Textile and Clothing Industry, Technological Advances and Future Challenges*, Shishoo, R. (Ed), Woodhead Publishing Limited, Oxford Cambridge Philadelphia New Delhi, 2012.

Schreuder-Gibson, H., Gibson, P., Senecal, K., Sennett, M., Walker, J., Yeomans, W., Ziegler, D. and Tsai, P. P., Protective textile materials based on electrospun nanofibers, *Journal of Advanced Materials* , 34 (3) , 44–55, July, 2002.

Shishoo, R., Introduction: trends in the global textile industry, *The Global Textile and Clothing Industry, Technological Advances and Future Challenges*, Shishoo, R. (Ed), Woodhead Publishing Limited, Oxford Cambridge Philadelphia New Delhi, 2012.

Stegmaier, T., Dauner, M., Vonarnim, V., Scherrieble, A., Dinkelmann, A., and Planck, H., Nanotechnologies For Coating And Structuring Of Textiles, *Nanofibers And Nanotechnology In Textiles*, Brown, P. J. and Stevens K. (Eds), Woodhead Publishing Limited, Cambridge, 2007.

Stegmaier, T., Recent advances in textile manufacturing technology, *The Global Textile and Clothing Industry, Technological Advances and Future Challenges*, Shishoo, R. (Ed), Woodhead Publishing Limited, Oxford Cambridge Philadelphia New Delhi, 2012.

Steinfeld, C., A Bamboo Future, *Environmental Design and Construction*, 1-5, 2001.

Sundarrajan, S. and Ramakrishna, S., Fabrication of nanocomposite membranes from nanofibers and nanoparticles for protection against chemical warfare stimulants, *Journal of Materials Science* , Springer, 42 (20), 8400–8407, April, 2007.

The Kumasi City Investment Promotion Unit, Investment Opportunity In Kumasi, Ghana Bamboo Cultivation and Processing, 2013.

Tot, B. V., Textile & Apparel Industry Report, Opportunities for Breakthrough, Ftp Securities, Hanoi,Viet Nam, 2014.

Tyagi, G.K., Bhattacharaya, S. and Kherdekar, G., Comfort Behavior of Woven Bamboo-Cotton Ring and MJS Yarn Fabrics, *Indian Journal of Fibre & Textile Research*, 36, 47-52, March, 2011.

United States International Trade Commission, Commercial Availability of Apparel Inputs (2005): Effect of Providing Preterential Treatment to Apparel From sub-Saharan African, Caribbean Basin, and Andean Countries, Office of Industries, Washington, Mar, 2006.

Vehvilainen, M., Kamppuri, T., Rom, M., Janicki, J., Ciechanska, D., Gronqvist, S., Siika-Aho, M., Christoffersson, K. E., and Nousiainen, P., Effect of wet spinning parameters on the properties of novel cellulosic fibres, *Cellulose*, Springer, 15(5), 671–680, Oct, 2008.

Waite, M., Sustainable Textiles: the Role of Bamboo and a Comparison of Bamboo Textile Properties, Journal of Textile and Apparel, *Technology and Management*, 6(2), 1-21, 2009.

Xi, L. X., and Qin, D. C., The Antibacterial Performance of Natural Bamboo Fiber and Its Influencing Factors, *Proceedings of the 55th International Convention of Society of Wood Science and Technology August 27-31, 2012 - Beijing, CHINA*, Paper BAF-1, 1-8, 2012.

Yu, W.K., Chung, K.F. and Chan, S.L., Column buckling of structural bamboo, *Engineering Structures*, Elsevier, 25(6), 755-768, May, 2003.