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Nanopaper Innovation in Paper and Packaging Industry

Hajar Mohammadpour Kachlami , Ghasem Javadzadeh Moghtader , Habib Mohammadpour Kachlami

Abstract**—**Nowadays due to globalization of economy and competition environment, innovation and technology plays key role at creation of wealth and economic growth of countries. In fact prompt growth of practical and technologic knowledge may results in social benefits for countries when changes into effective innovation. Considering the importance of innovation for the development of countries, this study addresses the radical technological innovation introduced by nanopapers at different stages of producing paper including stock preparation, using authorized additives, fillers and pigments, using retention, calender, stages of producing conductive paper, porous nanopaper and Layer by layer self-assembly. Research results show that in coming years the jungle related products will lose considerable portion of their market share, unless embracing radical innovation. Although incremental innovations can make this industry still competitive in mid-term, but to have economic growth and competitive advantage in long term, radical innovations are necessary. Radical innovations can lead to new products and materials which their applications in packaging industry can produce value added. However application of nanotechnology in this industry can be costly, it can be done in cooperation with other industries to make the maximum use of nanotechnology possible. Therefore this technology can be used in all the production process resulting in the mass production of simple and flexible papers with low cost and special properties such as facility at shape, form, easy transportation, light weight, recovery and recycle marketing abilities, and sealing. Improving the resistance of the packaging materials without reducing the performance of packaging materials enhances the quality and the value added of packaging. Improving the cellulose at nano scale can have considerable electron optical and magnetic effects leading to improvement in packaging and value added. Comparing to the specifications of thermoplastic products and ordinary papers, nanopapers show much better performance in terms of effective mechanical indexes such as the modulus of elasticity, tensile strength, and strain-stress. In densities lower than 640 kgm -3, due to the network structure of nanofibers and the balanced and randomized distribution of NFC in flat space, these specifications will even improve more. For nanopapers, strains are 1,4Gpa, 84Mpa and 17%, 13,3 Gpa, 214Mpa and 10% respectively. In layer by layer self assembly method (LbL) the tensile strength of nanopaper with Tio3 particles and Sio2 and halloysite clay nanotube are 30,4 ±**7.6**Nm/g and 13,6 ±**0.8**Nm/g and 14±**0.3**,3Nm/g respectively that fall within acceptable range of similar samples with virgin fiber. The usage of improved brightness and porosity index in nanopapers can create more competitive advantages at packaging industry.

Keywords**—**Innovation; NanoPaper; Nanofiber; Packaging

Hajar Mohammadpour Kachlami Master's Degree in Entrepreneurship; Iran(e-mail: mariamohammadpur@ gamil.com)
Ghasem Javadzadeh Moghtader Master's Degree in Engineering of Wood and Paper Industry, Iran(e-mail:javadzadeh.m.1382@gmail.com)
Habib Mohammadpour Kachlami PhD Entrepreneurship Student at Mid Sweden University; Sweden(e-mail: habib.m.kachlami@miun.se)

I. Introduction

TOWADAYS new technologies are changing the global economy so that technological innovations determine the face of economy and markets and they have to led to formation of new business model. Therefore nanotechnology will cause much marvelous turnover in future and include wealth and stability of nations, organizations and all economies. Thus we must plan from now and with technological innovation associated with nanotechnology we can achieve the goals and the usage of this technology in paper and packaging industry can cause more substantial and smart packaging.

One division of innovation is being recently and being new [28]. Being recently can be variable from incremental changes to radical innovation. Incremental innovation refers to changes which create in existing products while radical innovation point to products or services which are new fundamentally.

As the firms are dependent to incremental innovation for survival, they must develop and manage radical innovation to maintain their competitive advantage in future. In other words, radical innovation is vital for economic growth and competitive advantage of firms and business. In this type of innovation markets merge together and form new markets. Radical innovations lead firms to achieve bigger markets and to compete at international level. Thus radical innovation causes the growth markets, success of firms and economic growth of nations simultaneously [23].

Incremental innovation usually has lower associated risk and costs in comparison with radical innovation because it requires minor changes in technologies used. Very high incremental innovation in cases where assign resources and time to improve products and low-value services can be fatal. Full investment on incremental innovation can be vulnerable to competition in the organization.

Radical innovation usually has a significant risk and cost and requires substantial time because its emergence requires new knowledge, and extensive research and development activities, but due to creative destruction (breaking markets and creating a completely innovative products and services) more value added is supplied as well.

There is a need for reviewing the old mechanical, chemical and semi-chemical methods in paper and packaging industry and nanotechnology and the production of nanopapers, as a radical innovation, can improve applied properties and cause an increase in value added of paper products while also affecting the market growth of papers.

Between four types of packaging materials, Plastic, paper, metal and glass, paper packaging is cheaper, more recoverable and also more environmental friendly. Therefore their growth and development rate also has been higher.

Europe produces 40% of paper and paperboard used in packaging (2010, Datamonitor). Essentially paper materials are strengthening the packaging while providing better appearances as well, but in recent years paper and paperboard packaging has been threatened with the high functionality and low cost of plastic material. Incremental innovations such as small changes in existing technologies still makes the investment in this industry vulnerable particularly comparing to other industries such as plastic. Therefore nanotechnology can provide appropriate tools for paper-based packaging manufacturers to identify the new opportunities and with radical innovations to gain competitive advantages.

Packaging is considered as a silent salesman because the goods do not present themselves directly to the customers and their coverage with various forms and short sentences represent what is inside them and provide necessary information to the buyer. Thus innovation in packaging can differentiate the products from competing products and play an important role in marketing products which is one of the success factors of firms.

II. Materials and Methods

Today genetic engineering is being used in wood production industry through improving and modifications at nanoscale in production method and quality of wood fiber in paper industry [3]. Stock Preparation with the mechanical and chemical operations and other allowed additives will increase aboat 5-10% of surface layer resistance using nanopaper. The use of colloidal micro-particles and cationic alumina A_2O_3 with polymer in nanopaper improves retention particles [10].The use of nanomaterials in surface coatings and calendaring with a continuous cylindrical passage, increases the abrasion resistance, stiffness and impact strength of nanopaper about 20%. Fillers and pigments and kaolin particles with two-layer crystalline silica and alumina in nanopaper space provides a high value-added [7]. Layer by layer self-assembly (LbL) and a multilayer structure of nanoparticles/poly electrolyte, can form a thin layer of nanoparticles, TiO_2 (Titanium dioxide) or SiO_2 (Silicon dioxide) with a diameter of 30-80 nm, and halloysite clay nanotubes with a diameter of 50 nm on nanofiber thickness in kraft nanopaper of softwoods up to 46 or 58 and 115 nm respectively [8].

Using TiO_2 nanoparticles, paper brightness of 84% is achieved with a certain wavelength of 457 nm, 4% more than the virgin fibers [9]. Using TiO_2 and SiO_2 nanoparticles permeability, halloysite, and clay nanotubes increases 14%, 25-28% and 30-50% respectively. Increased multi-layered structures of nanoparticles/poly electrolyte improves the tensile strength of nano-particles about 30.4 ± 7.6 Nm/g, 13.6 ± 0.8 Nm/g and 14 ± 0.3 Nm/g compared with samples [12]. Conductive paper with tin-indium oxide and polystyrene sulfonate (PEDOT-PSS) nanoparticles increases conductivity index linearly with multiple layers. Wrapping nanopaper made of NFC (Nanofibers celloluse) can be used in the packaging industry [11]. The Porous nanopaper of cellulose nanofibers NFC and distingrating of natural fiber plants without dissolution and homogenization chemical mechanical pulp, reduces production costs.

Direct mechanical process on nanofibers with a width of 25-100 nm and enzymatic hydrolysis and oxidation with TEMPO on a width of 10-40 and 3-5 nm Nanofibers (TO-NFC) is produced respectively. NFC nanofibers of wood have 3-5 nm in diameter and 600 m^2g^{-1} specific area [12]. Preparation of porous nanopaper consists of three stage distingrate NFC from pulpwood as suspensions dispersed in water to form pulp Sulfites in softwoods, hemicellulose and lignin, 0.7% and 13.8% respectively, forming hydrogels with filtration and drying the hydrogel to produce porous nanopaper. Initial treatments of enzymatic and mechanical beating with homogenization continue forming with 2% concentration pulp. For preparation the TO-NFC suspension, distingrating softwoods in water containing sodium bromide and TEMPO ($mmol.gr^{-1}$ 1 and 0.1, respectively) to provide the 2% pulp concentration continuously [12].

Nanopaper cellulose with high porosity can be dried in three ways. Liquid evaporation (L-CO_2) that NFC hydrogels is displaced with ethanol solvent. Then NFC alcogel is replaced ethanol in drying chamber by the liquid carbon dioxide under controlled pressure 50 bar. In supercritical-CO_2 method (SC-CO_2) NFC alcogel dries in chamber from 50-100 bar and 36°C. In freezing tert-FD (Tert-butyl alcohol freeze drying) NFC alcogel for 24 hours is placed in the tank containing tert butanol for drying without direct contact with liquid nitrogen frozen and vacuum 0.05 mbar in a hot chamber [11].

Critical drying method is simpler and provides access to high specific surface. Tert-B-FD freezing due to condensation NFC, provides lower specific area. In porosity 56 and 28%, Young's modulus, tensile strength and strain are obtained, respectively 1.4 Gpa, 84 Mpa and 17% and 13.2 Gpa, 214 Mpa and 10% [11]. The desirable features of the network structure and distribution of balanced and random NFC in flat space with low-density less than 640 kgm^{-3} is like thermoplastic [12].

III. Conclusion

Nanotechnology will affect all economic aspects including payroll, employment, purchasing, pricing, investment, exchange rates and today it is an important factor in productivity and global competitiveness, so that the development of nano-scale products is a economic requirements in highly developed countries to improve the quality of life. Nanotechnology has entered into all section of industries and all advanced technologies are converging slowly nowadays. Without nanotechnology no development can happen in paper and paperboard industry and consequently packaging industry too. Incremental innovation in pulp and paper industry, can provide just a short term competition , But for economic growth and to maintain the competitive advantage in the long term, radical technological innovation is essential and if it doesn't happen, the packaging will lose its opportunity in future.

In the future, market for forest products without radical changes will lose a significant percentage of their sales. Radical changes in this industry can bring new products and materials that will create value added.

Packaging industry would be at risk for retardation of nanotechnology if does not recognize opportunities. Using nano-papers as a radical technological innovation in packaging industry can provide a great competitive advantage for it.

Convergence of pulp and paper industry with nanotechnology cause radical changes and its cheap and high quality products provide much value-added at this industry.

Effective performance of nanotechnology sections at board and paper industry may be much expensive but the convergence of it with other industries reduces the cost and increases the probability of reaching the peak of nanotechnology in all phases of manufacturing process.

With production of nanopapers the resistance will increase resulting in more competitiveness and return. Improving the resistance of the packaging materials, considerable weight reduction without reducing the performance of packaging materials, enhances the quality and the value added of packaging. Nanopapers have highly effects in improvement of product properties and possible reaction products especially food or wet and frozen products due to reactions control between water and cellulose. On the other hand, deformation of the product packages can be controlled by nanoclay or other impregnation of cellulose and flameproof or thermal degradation treatments. Production and application of inorganic and organic nanopapers and new nanocomposites with surface modification of fibers especially in the final stages of printing and packaging can be upgraded in nanopapers.

Nano-scale modification of cellulose creates electron optical and magnetic effects due to the improved properties, particularly in advertising and packaging materials, and added value. Reduced production cost is possible by using less energy consumption during processing and other main equipment. Nanopapers with permeability and brightness can be created by LbL assembly method in packaging. Modulus of elasticity, tensile strength and strain in porous nanopaper are appropriate compared with other paper products and thermoplastic.

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