Properties of Paper Substrates Made with Nanotechnology

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Abstract*: Traditionally, in term nanotechnology nano refers to the small sizes below one milliardth of metre while technology refers to the change of the properties of materials and manufacture of products with special properties. In photolithographic procedures used in the production of integrated circuits, e.g. when they reach the limits of their applicability, procedures different from traditional ones must be used where parts of atomic sizes are made with atomic accuracy. The use of nanotechnology is spreading also in paper, packaging material and printing industries. Development of various surface layers with special properties, use of paint particles of nano size in inks of inkjet printers, development of special printing inks for the creation of prints with electricity conductivity properties or the improvement of paper strength by regulating bonds between the paper fibres are examples of their application.*

The research work focuses on the use of nanotechnology in printing. Identification of the physical and mechanical properties of paper substrates made with nanotechnology and their use in practice are covered by the investigations.

Keywords*: nanotechnology; nano-paper; ash content; printability*

1 Introduction

Nanotechnology is a collective term for technologies the characteristic sizes of the end products of which range between one and one hundred nanometre. It covers a wide range of the applied sciences and techniques, cooperating with sciences such as colloid chemistry, semiconductor physics or supramolecular chemistry [1]. The results of nanotechnology researches are used in chemistry, pharmaceutical production, building industry and various fields of economy, and provide completely new possibilities for the industry. Bill Clinton, President of the USA launched the "National Nanotechnology Initiative" in 2000, and this was the first time the world took a significant notice of nanotechnology. The fact is that by that time politicians became aware that nanotechnology was likely to become a key economic branch. Basic researches have accumulated key information on the basis of which we can confidently state that nanostructures will reform our everyday life to the same great extent than mobile phones and computer technique.

Investors in Hungary are less responsive to nanotechnology as this field is still undeveloped and our research centres do not have a reference period of a decade either. Capital companies in the countries of the European Union almost fear from investments, therefore the Union supports nanotechnology developments with separate framework programmes. Highlighted support and attention are paid to technology in Japan, and the companies spend much more on research & development, and due to this half of nanotechnology patents is owned by the country. However, only fifth is owned by the United States, while less than ten percent by Europe. Though the new technology is welcome with a great enthusiasm everywhere, there are also some concerns. These include a report of the Canadian ETC civil organisation which gives warning of dangers in the biological use of nanotechnology.

2 Nanotechnology in Graphic Artz Industry

2.1 Nanotechnology

The basis of nanotechnology is made by nanostructures the physical, chemical and electronic properties of which significantly affect the possibilities of the technologies. Nanostructures are made of materials the mechanical, optical, electronic etc. properties of which are specified by their structures of atomic size. Such structures may be e.g. nanotubes. Carbon nanotubes are of material structures with important mechanical and electric properties.

They may play an important role in microelectronic devices and fibre reinforcement of polymer materials. An optimal nanotube is a helical configuration of carbon atoms winding into a seamless tube. While its diameter is only a few nanometres, its length may be up to several tens of micrometers. Their special electric properties are attributable to the fact that electrons are able to flow only in the direction of the tube axle and within the tube due to quantum physics aspects. It is confirmed with measurements that it is able to behave as a metal or a semiconductor. If a proper technology can be developed then it is quite possible to make microelectronic devices purely from carbon without even the need for polluting atoms in the devices. For example tennis-rackets reinforced with the use of carbon nanotubes have been made in Japan (Figure 1) [2].

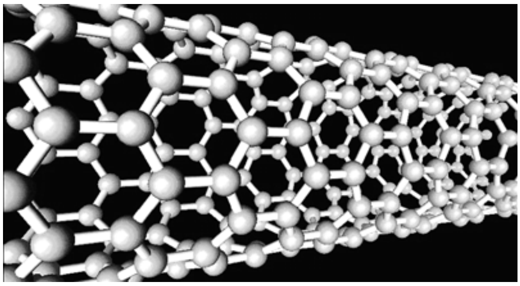

Figure 1
Model of carbon nanotube

2.2 Application Nanotechnology in Printing

The use of nanotechnology is spreading also in paper, packaging material and printing industries. Development of various surface layers with special properties, use of paint particles of nano size in inks of inkjet printers, development of special printing inks for the creation of prints with electricity conductivity properties or the improvement of paper strength by regulating bonds between the paper fibres are examples of their application.

Paper with breaking and tear strengths similar to cast iron and with hardness similar to bone may be made from nano-fibrils made of fibres. A paper product with such properties may offer new possibilities on the market for the printing industry [3] [4].

Nano-fibrils are thin cellulose fibres the thickness of which is between 5 and 10 nanometre depending on the type, and the length is several micrometres (Fig. 2).

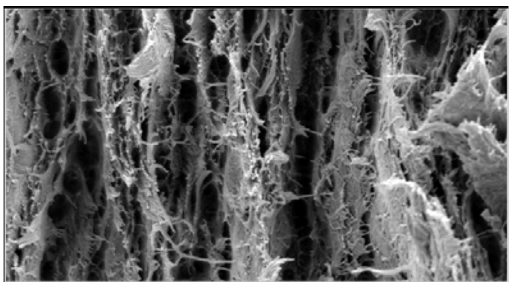

Figure 2
Nano-fibrils made from cellulose

A new paper type has been developed in the paper mill of Mondi Business Paper, which was presented at the international event of Paper-world 2007, in Frankfurt. A specificity of the new paper type with fantasy name *"Neox"* is that it was the first time nano-hybrid technology was used for paper making. Neox is a standard A4 paper with twenty five trillion nano particles on its both sides. A smooth paper surface of nano structures is achieved with the new technology, which combines the smooth and bright of coated paper with great whiteness and stiffness of quality uncoated paper.

The range of pigments and printing inks made with the use of them has become more extensive with the development of pigment manufacturing technology. With the appearance of nano-technology a number of various printing inks with new properties have appeared on the market. These include for example colour nano paints without dyes and pigments, nano lacquers and electronic paints suitable also for optical communications purposes. A wide range of medias may be printed with paints manufactured with nanotechnology. The pearly effect is more intensive on dull and smooth surfaces, and high opacity of the media is also a benefit. Its application has been started in the printing not only of traditional products but also of top quality products. An additional benefit is that further processing procedures are not troublesome either.

One of the licences of company DuPont is *"ecology coating"*, a viscous solid matter, each molecule of which is part of the paint coat, contrary to traditional paints where the paint coat is hardly 20-30%, the remaining part is solvents which evaporate. This so called nano paint is able to bind under ultraviolet radiation within three seconds, saving time and space. It does not contain volatile organic matters so it does not pollute the air. It may cause minor problems such as irritation.

Electronic paint, more commonly known as *"e-ink"* is a paint showing the necessary information on a digital display i.e. on e-paper surface. It is constituted by electrically charged pigment particles floating in the oil in the form of microcapsules. By now an acceptable quality of display face based on this principle has been achieved (Figure 3).

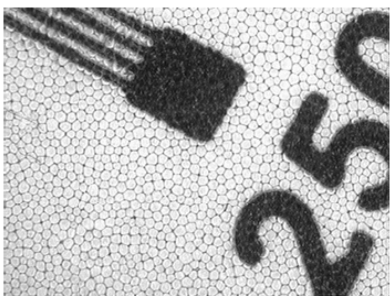

Figure 3
Microscopic image of microcapsules of e-ink

3 Methology of Investigation

Properties of paper substrates made with nanotechnology was compared to those of traditional coated paper medias during the examining [4]. Characteristics of papers are summarised in Table 1.

Table 1

Used paper substrates

Name of papers	Type	Distributor	Mass per sq. m, g/m^2
Neox 110	Coated, nano-hybrid	Budapest Papír Kft.	110
UPM DIGI 115	Coated, semi-bright	Papyrus Hungária Zrt.	115
Neox 250	Coated, nano-hybrid	Budapest Papír Kft.	250
UPM DIGI 300	Coated, semi-bright	Papyrus Hungária Zrt.	300

The features of printing substrates prepared by nanotechnology during research were compared with traditional coated paper printing substrates. The mechanical features and the printability features of Mondi Neox (nano) and UPM Digi Finesse gloss papers recommended for digital printing were tested.

4 Results and Discussion

4.1 Investigation of Paper Substrates

Breaking strength is a tensile force necessary to break a paper strip of specific size. One end of the trial piece is caught, while the other end is subject to an increasing tensile strength until it is broken. FRANK breaking tester was used for the test. Neox papers with mass per square metre values showed higher elongation both in production and crosswise directions than UPM DIGI papers compared to them. In case of Neox and UPM DIGI papers with high mass per square metre the crosswise elongation of UPM DIGI papers was higher, while a similar result was obtained in the production direction (UPM DIGI: 2.65%, Neox: 2,66%) [5]. (Figure 4).

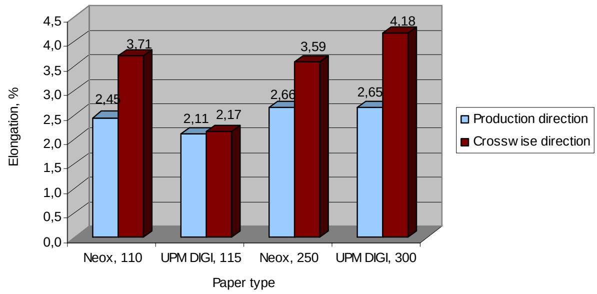

Figure 4
Elongation of papers

Strength necessary to break a paper is breaking strength while that necessary to further break it is tearing strength. The breaking strength is always higher than tearing strength. Eldendorf tear tester was used for measuring the tearing strength. On the basis of values calculated during the tests we found that a tearing strength by 16% higher is required to tear Neox papers on an average than in case of UPM DIGI papers, both in production and crosswise directions (Figure 5).

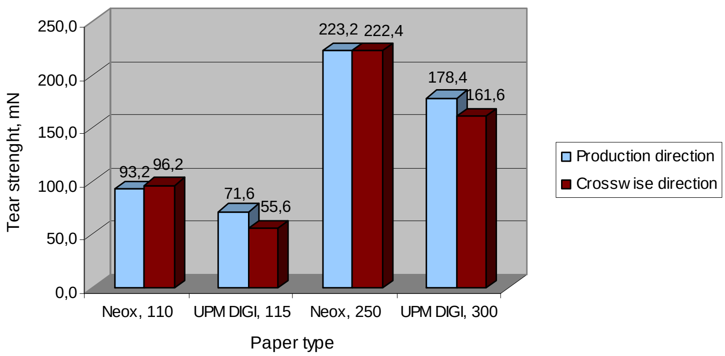

Figure 5
Tearing strength of papers

Part remaining after combustion and annealing of paper of a specific mass at a temperature of 573˚K is called ash content. Papers contain also fillers of mineral origin. In addition to ash contained in the fibres, the ash content indicates the filler volume of the paper. Pots, digital analytic scales, annealing furnace and exsiccator were used for the test. Ash is contained in the fillers of papers and in the surface coat, and is an inorganic matter remaining after charring [6]. On the basis of the ash content values we can state that the ash contents of UPM DIGI papers are by 54% higher on an average than those of Neox papers. Based on the obtained results we can assume that the coats of Neox papers, manufactured with nanotechnology do not or hardly contain fillers of mineral or vegetable origin (Figure 6).

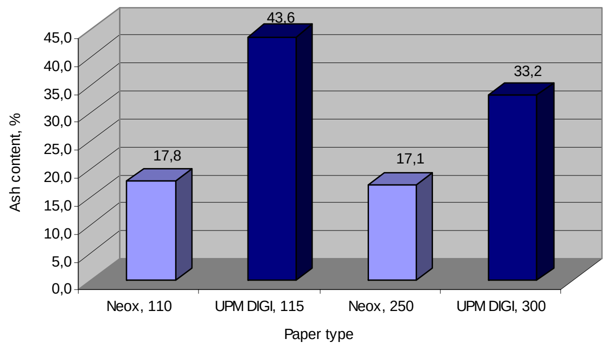

Figure 6
Ash content of papers

4.2 Microscopic Tests

Stereo microscope type BIM-312T was used for the tests. The forms, morphological characters of fibres of the paper media, the rate of fibrillation as well as the surface of prints were tested with the instrument. The instrument is constituted by CMOS digital camera with a resolution capacity of 1.3 MP and a set of lenses with different zooms, and is provided also with image processing software. The sample may be illuminated via a lens or by means an external auxiliary light. The zoom figures of the obtained colour digital records are specified by the resolution capacities of the lens and of the monitor.

First the surfaces of the papers and differences between the coat layers not visible to the naked eyes were tested. Papers made with the different technological procedures were shot with 4x zoom via the stereo microscope.

A very thin coat layer was observed on Neox papers, cellulose fibres of the paper showed through, and small air bubbles were detected. The coat layer of UPM DIGI papers is thicker and more even than that of Neox papers. In the next phase of the tests sectional views of Neox with low mass per square metre and UPM papers were shot. The trial pieces were soaked in iodine solution with a concentration of 2% for ca. 10 minutes before the trial. Then the soaked and ready sample pieces were removed from the solution, and the surplus water was absorbed with the use of a filter paper. The trial pieces were observed with 4x magnification through the microscope. Comparing shots made on Neox and UPM DIGI papers a higher discoloration was observed on the section of Neox papers. The darker discoloration may be explained by the fact that the starch content of papers under examination was higher. The glue content of the paper may be concluded from the starch content. We can state on the basis of the experiment that in case of a low mass per square metre Neox papers contain more glue than UPM DIGI papers (Figure 7).

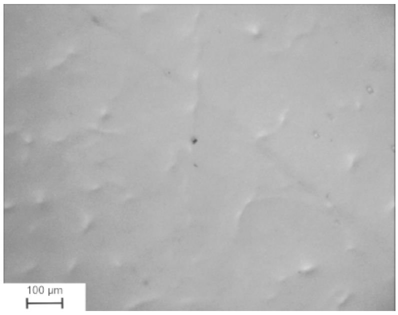

Figure 7
Surface of Neox paper

Conclusions

During the investigations of the paper medias we found that the thickness of Neox papers was more even than the thickness of traditional wood-free UPM DIGI media coated on both sides, optically bleached and compared to it However, the mechanical tests showed that Neox papers had higher breaking strengths and tore under higher tearing strengths than UPM DIGI papers. Based on the tests of the ash content we can assume that the coat layer of Neox papers contain minimum quantities of fillers of mineral and vegetable origin, contrary to traditional UPM DIGI papers. During the visual controls of the test prints no differences visible to the naked eyes were found. During observation of the paper medias and prints with the stereo microscope a significant deviation was observed on the coated surfaces of the papers and in the breaking of the printed samples when they were bent.

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