Nano-Hybrid Technology – A New Tool for Improving Print Quality

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Abstract

Nano-scaled synthetic pigments, which are attached to the surface of an inorganic carrier pigment, are used for the production of a paper with excellent electrophotographic print quality, silk gloss, high brightness and bulk, as well as good toner adhesion. This nano-hybrid technology has the great potential to improve the quality of printing and copy papers by combining the advantageous properties of both nano-scaled and macroscopic materials. In order to address possible health concerns, a new high precision measuring device (Nano Dust Tester – NDT) was developed allowing the precise detection of possible micro- and nanoparticle emissions from paper surfaces. All papers tested with this device showed no emission of nanoparticles, whether nano-hybrid technology was employed or not.

Nano-hybrid technology

Nanotechnology as a science has experienced a large boom in the past few years. The properties of nanomaterials are expected to provide new solutions for a wide range of problems. Foremost amongst these properties is the high surface-to-volume ratio, which leads to e.g. enhanced chemical reactivity. On the nanometer scale, quantum effects become noticeable, e.g. color as a function of size and shape of nanoparticles. The possible applications in the paper industry are the control of hydrophobicity (lotos leaf), coloration, retention aids, fiber modification, and the control of specific paper properties such as gloss and print quality.

The development presented here was aimed at the production of a fine paper with excellent print quality in electrophotographic printers, silk gloss, high brightness and bulk, as well as good toner adhesion. A possible means for achieving this goal was seen in a surface treatment using nano-scaled synthetic pigments. However, these pigments tend to penetrate into the paper, where they are not effective. The problem, therefore, lies in keeping the nanoparticles on the paper surface.

One possible solution to this problem is called nano-hybrid technology. Here, polymeric nanoparticles are attached to the surface of a carrier pigment, which in the simplest of cases is a standard pigment such as clay, ground calcium carbonate (GCC), aluminum oxide or mica. In the presence of this carrier pigment, the chemical precursors of the polymer undergo a chemical reaction and the product is deposited on the carrier pigment as nanoparticles. The properties of the resulting pigment are substantially determined by the properties of the polymer nanoparticles, opening the possibility to optimize the pigment to the intended application. At the same time, the pigment particles are large enough to be retained at the surface of the paper. This nano-hybrid technology has the great potential to improve the quality of printing and copy papers by combining the advantageous properties of both nano-scaled and macroscopic materials in a unique way.

Some combinations of the components of the nano-hybrid pigment led to properties that were more in line with those required of the finished paper. For example, it was observed that a high film-forming temperature of the polymer component prevented a complete film from forming. However, it was important to keep the film forming temperature low enough to still allow plasticizing in the calender. This in turn led to a smoother surface and therefore a higher gloss. In addition, it was found that using a platy carrier pigment such as clay or mica also enhanced the gloss of the calendered coating. This effect, caused by the orientation of platy particles during the coating process, is commonly observed also in standard coatings.

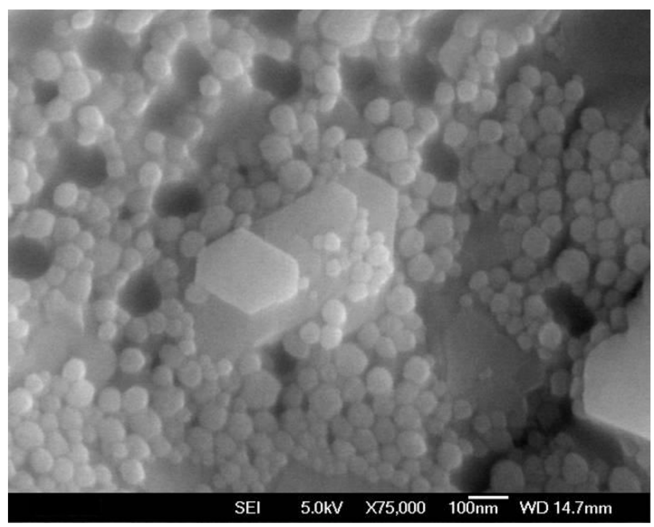

***Figure 1**. Scanning electron micrograph of a nano-hybrid pigment, consisting of 50 nm styrene copolymer nanoparticles deposited on hexagonal clay carrier particles.*

Figure 1 shows a high resolution scanning electron micrograph of a nano-hybrid pigment, consisting of a styrene copolymer on clay carrier particles. As can be seen from this image, the polymer particles cover a large portion of the surface of the carrier pigment. By carefully selecting the type and ratio of monomers for the polymer component, it is possible to adapt the surface tension of the nano-hybrid pigment. The surface tension is a crucial factor for improving the toner adhesion on the surface of the paper.

Print quality

Figures 2 and 3 show the results obtained with an 8 g/m² nano-hybrid coating. The print quality in terms of mottle surpasses that of both coated and uncoated papers. The print gloss is lower than for the silk coated papers. However, these papers are coated with 16-20 g/m². The high density of the coating leads to lower bulk of the paper and therefore to lower stiffness. Due to the low coating weight, the nano-hybrid coating allows a substantial print gloss improvement over uncoated paper with a minimum loss of stiffness.

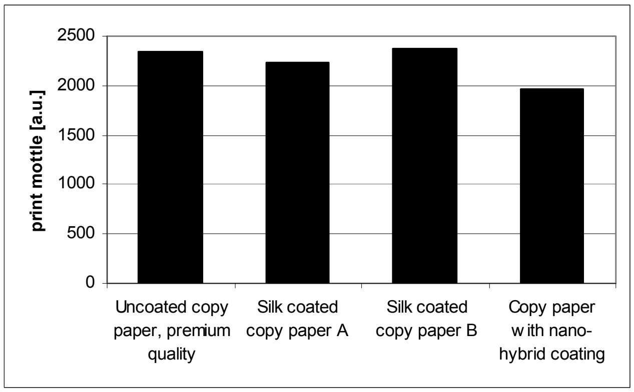

Figure 2. *The average print mottle on six different laser printers, analyzed using the ImageXpert print analyzer. Lower values correspond to a more even print.*

A common problem experienced with coated papers is the cracking of the coating in paper creases. When the crease is covered with dark print, the cracks are easily visible. Due to the low coating weight, the nano-hybrid coating is comparable to uncoated papers in this respect and shows no cracking.

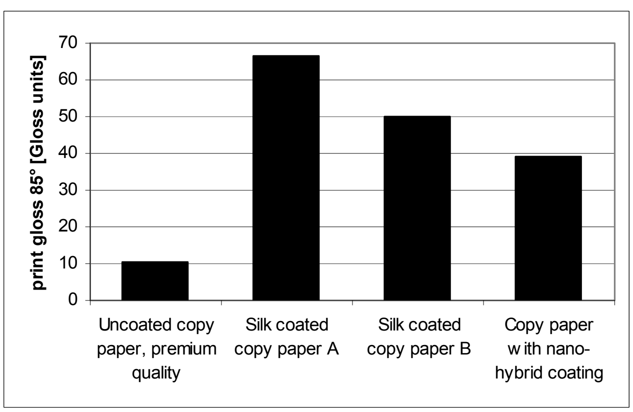

Figure 3*. Print gloss of 4 different papers.*

Indigo liquid toners require a special pre-treatment of uncoated papers in order to reach acceptable toner adhesion. By adjusting the surface tension of the nano-hybrid polymer component, it was possible to create a surface with excellent indigo toner adhesion, as can be seen in Figure 4.

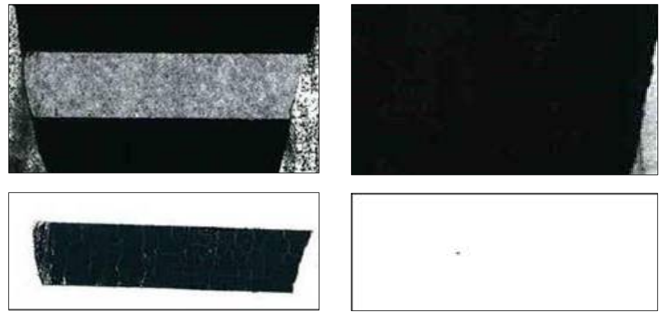

Figure 4*. Indigo liquid toner adhesion test using adhesive strips. The upper images show the printed surface after the removal of the adhesive strip, the lower images the removed adhesive strip. Left: Uncoated copy paper, premium quality. Right: Copy paper with nano-hybrid coating.*

Measurement of paper dust

In order to address possible health concerns due to the implementation of nanotechnology for paper production, a high precision measuring device [1] (Nano Dust Tester – NDT) was developed allowing the detection of paper dust (both micro- and nanoparticle emissions) from paper surfaces. In general one distinguishes between paper dust arising during paper production and paper dust at the end customer, i.e. during printing or further handling of paper sheets. Especially the avoidance of dust emissions/dust abrasions during the printing process, in order to avoid deposition of dust particles on the various flexible and fixed parts of a printing device, is a tremendously important quality characteristic of high grade office and communication papers. In addition, it has to be ensured that all health risks arising from an increased concentration of respirable dust particles (especially nanoparticles) due to the handling of paper can be completely excluded.

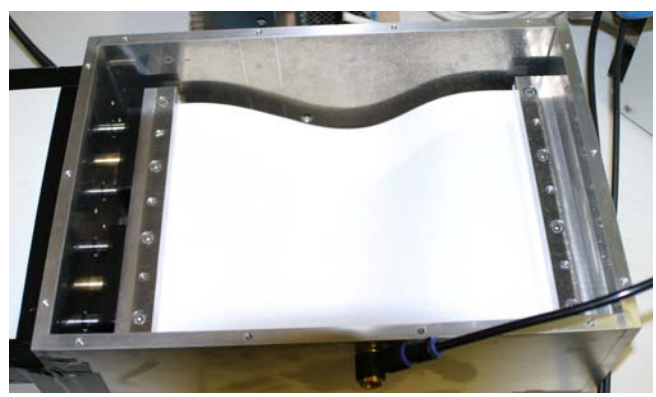

Figure 5*. Opened NDT chamber with clamped A4 paper sample.*

The new NDT measurement method determines the dust emission of single paper sheets in a both quantitative as well as qualitative manner. For the first time it is now possible to expose paper surfaces to mechanical stress under clean room conditions and to precisely measure emitted dust particles. A single paper sheet is clamped in a specially constructed chamber (cf. Figure 5) and periodically moved forward and back via linear motors (with typical values for amplitude and frequency reading 2 cm and 2-6 Hz).

All particles emitted from the paper surface due to this mechanical stress are electrically neutralized and transported via a high purity airflow directly from the measuring chamber into the detection system. Therefore, it can be guaranteed that no particles remain in the measuring chamber or are deposited on any surfaces within the measuring device. The detection system comprises a condensation nucleus counter that measures the number concentration (see Figure 6) and an electric mobility spectrometer that analyzes the particle size distribution of the dust particles. Due to the sensitivity of this device even particles with a size of only a few nanometers can be reliably detected. Accordingly, the new NDT method enables the precise measurement and sophisticated analysis of the whole spectrum of possible dust emissions of paper surfaces.

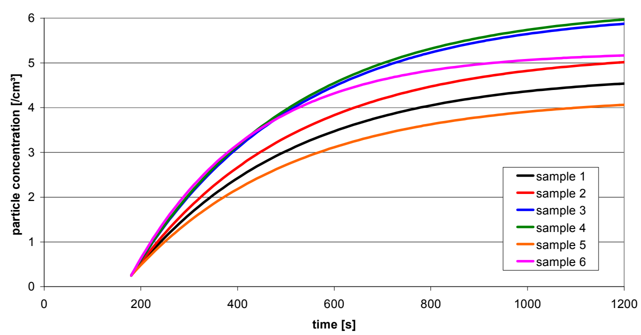

***Figure 6**. Time dependent course of the particle concentration released from a typical paper brand in a NDT measurement, different colors reflect different A4 sample sheets of the same brand.*

A high precision detection of all particles that are released from the paper surface is absolutely necessary as the concentration of these particles being emitted during the measuring procedure is very low. Typical values of such particle concentrations of high grade paper sheets read only a few particles per cubic centimeter – a value that is considerably below the average dust exposure in interior rooms (10.000 to 100.000 particles/cm^3).

The new method can also be used for the dust measurement of lab handsheets as only a few sheets have to be examined in a typical NDT experiment. This is in contrast to most other measurement methods where some hundred up to hundred thousand sheets are required for long-time tests. A series of studies comparing NDT measurements with conventional dust measurements showed an excellent correlation regarding the dusting propensity of various paper samples during the printing or copying process. In addition, simultaneous measurements of the concentration as well as the particle size distribution of the emitted particles allow for a detailed analysis of the nature and origin of paper dust emissions. Accordingly, the NDT method is not only an indispensable tool for precise prognoses about the possible dusting propensity of new paper products during printing on the basis of a few paper sheets only but also for the health risk analysis of the emitted particles.

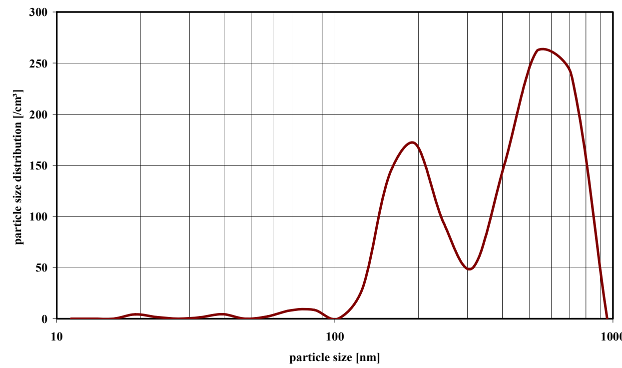

***Figure 7.** Averaged particle size distribution of the paper dust released from a typical paper brand.*

In a first survey, a number of different paper brands were tested via the NDT method and the concentration and particle size distribution of the possible emitted (ultra)fine dust particles were analyzed: all paper brands tested so far show no emission of nanoparticles – the typical size of particles being emitted is in the range of about 200 nanometers and above (cf. Figure 7). Especially paper surfaces employing the new nano-hybrid technology exhibited extremely low particle concentrations. Accordingly, it is ensured that this new technology leads to no additional exposure of human beings to nanoparticles.

Conclusion

Using nano-hybrid technology, it is possible to engineer paper coating pigments for a specific application. Here, the technology was used to develop a paper with excellent print quality and toner adhesion for both dry and liquid toners. A silky gloss coating was achieved using a coating weight of only 8 g/m².

In addition, the new NDT measurement method has already paved the way to gain totally new insights into the principle dusting propensity of paper surfaces. This method enables the precise measurement and sophisticated analysis of the whole spectrum of possible dust emissions of paper surfaces. So far, however, all papers tested with this device showed no emission of nanoparticles – whether nano-hybrid technology was employed or not.

References

[1] Andreas Kornherr, Papier aus Österreich, 06, 32 (2008).

Author Biography

Andreas Kornherr received his BS in mathematics (1996) and his PhD in chemistry (2000) at the University of Vienna, Austria, where he also worked as university assistant until 2006. During several stays at Davy-Faraday Research Laboratory, London, and Department of Chemistry, Cambridge, he was engaged as senior researcher in international projects in the fields of polymer chemistry, materials science and nanotechnology. In 2006 he joined the Research & Development team at Mondi Uncoated Fine Paper.