

Alternative and special applications of printing -Innovative printing and finishing technologies

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Chapter 1 An Introduction to Innovative, Alternative and Special Applications of Printing

Historically, Graphic Arts seem to be one of the most interdisciplinary fields. The most significant inventors, printers and artists were mainly very good scientists. Graphic Arts growth involved disparate cognitive fields such as Aesthetics, Chemistry, Calligraphy, Physics, Mechanics, Literature, Paleography, Mathematics etc. As a result, papermaking, typography and other printing techniques, photography and photoreproduction, typesetting, desktop publishing and multimedia publishing, have constituted a scientific and social fact during the centuries.

As minimal return to the sciences, Graphic Arts attended the guarantee and the distribution of cognitive wealth of scientific fields beyond time and territorial restrictions. Cause of the distribution of typography in Europe, was the refoundation of the modern sciences bases and the end of the Middle Ages.

Nowadays, Graphic Arts seem to adapt rapidly all the scientific and technological realizations marking an appreciable growth. Informatics and Communication Sciences are widely used in the Graphic Arts' world. Automatism and robotics are applied in the most graphic arts productive processes. Laser technologies, piezoelectric, electrostatic and electromagnetic phenomena are used in the digital printing techniques as well as to the common Computer to plate/press techniques. In Conclusion, it seems that the future of the Graphic Arts includes and involves all the newest scientific and technological achievements.

On the other hand Graphic Arts may provide the necessary technological solution to many applications. Printed electronics and energy systems (photovoltaic devices), smart materials, printed sensors and indicators, micro- and nano-lithography techniques and many medical applications could be considered either the new Graphic Arts field or a new field that could not have been developed without the technological assistance of the Graphic Arts.

Perhaps Gutenberg could not imagine the contribution of the Graphic Arts in the modern way of living but his field seems to be a silent and calm giant forced to service Sciences, Arts and Humanity neither time restrictions nor huge voices.

Chapter 2 Printing Hot Melts for the production of a high gas barrier properties activated carbon multilayer fabric

2.1 Activated Carbon

Activated carbon (AC) is a term that refers to carbon-based materials that exhibit a well integrated porous network and a high specific surface area (Jankowska et al., 1991). According to Bansal (Bansal et al., 1988), these attributes ensure that ACs exhibit excellent adsorption properties and make the AC material family extremely useful for many applications such as distillation, liquid and gas purification processes, decolourization, as well as biomedical, packaging and other applications in various technological areas.

Spherical Activated Carbon Adsorbents (SACAs) are primarily consisted from carbon (in the order of 90–97%) (Yenisoy-Karakas et al., 2004). However, many other elements are also present in their structure, either as trace elements or primary structural components such as H, O, N, and S. Functional groups (such as -OH, -C=O, -C-O-C-) are also present. These are usually introduced with the prospect of replacing the carbon atoms and as a means of tailoring or optimizing the SACA (or AC) material properties with respect to specific application. Functional groups are either present in the raw material (subsequently enriched during the synthesis process) or are developed and/or side-produced during the synthesis and thermal elaboration of the SACA material (Pilatos, 1997; Jacek Przepiórski et al., 2002).

In general, there exist two general types of SACAs: a) grainy activated carbon materials (GAC) with particles bigger than 0.8 mm and b) powder activated carbon (PAC) with smaller carbon particles. Usually GAC has smaller pores and a higher specific surface than PAC.

2.2 Synthesis and modification of SACA

Four series of spherical activated carbon samples, which have been impregnated with various metals (Fe^{3+} , Co^{2+} , Ni^{2+} , Sn^{4+}), were prepared using cross-linked polystyrene (commercial polymeric catalyst PuroLite CT-275) as the precursor. The purpose of this process was the study and optimization of the effect of the carbonization temperature and the metal salt impregnation on the physicochemical properties of the SACA samples [5]. For this reason three different carbonization processes were used changing temperature (400 °C, 600 °C and 800 °C) and a fourth in which chemical activation with KOH was carried-out. The primary objective was the preparation of SACA material with optimal adsorption properties and bactericidal and bacteriostatic attributes. This was accomplished as there was a significant increase in the specific surface area of the precursor material from 1282 m^2/gr to 2400 m^2/gr in the thermally elaborated SACA spherules and prior to impregnation

by metal salts. The N₂ isotherms of the SACA samples developed were measured by means of an Autosorb-1 Quantachrome nitrogen porosimeter with krypton upgrade. The overall sensitivity of the instrument did not allow for a more precise measurement of the specific surface area of the SACA material as the 2400 m²/gr represented its outmost measurement capability. The overall process and detailed results obtained are presented elsewhere and are out-of-the-scope of the current lecture (Kakizis et al, 2009; Andrianopoulos, 2005).

2.3 Development of the multilayer fabric

The primary objective of this study was the development of a an adsorptive multilayer fabric/filter assembly in which a monolayer of packed, 3-D constrained, printed SACA spherules provided the active adsorbing and filtering component of the assembly. The assembly is graphically depicted in Fig. 1. Similar multilayer material systems are used in biomedical, environmental and packaging applications and the overall approach is also followed for the development of suits and garments for biological, chemical and other hazardous environments. Polymer textiles (100% polyester) of different textures were used as the printing substrate for the SACA spherules (Fig. 2).

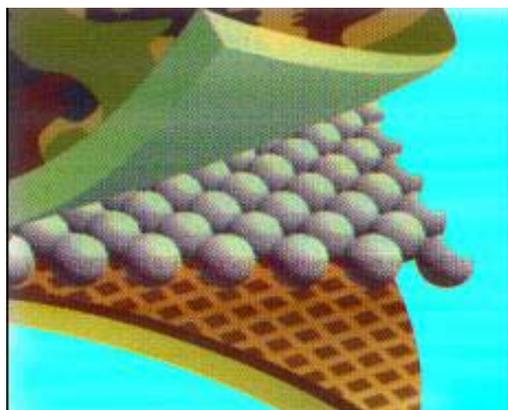


Fig. 1 A schematic representation of the multilayer assembly with the printed SACA active monolayer

In this manner, two different plain weaves (one dense and one sparse) of the same textile were used as a means to determine the effect of the textile material to the overall adsorptive attributed of the active monolayer. The pilot unit and the various stages of the process that was developed for the production of the samples may be depicted graphically in Fig. 4. Overall, the pilot unit allows for 2 or 4 different textiles (points 1, 13 in Fig. 4) to be used for the development of the multilayer filter assembly, two of which functioning as the substrate and constraining layers of the active SACA monolayer. The other two may provide additional attributes to the multilayer assembly (i.e. perspiration removal characteristics through the use of NOMEX or Gore-Tex).

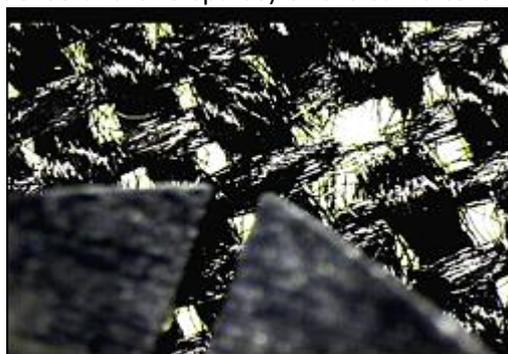


Fig. 2 100% Polyester textile was the printing substrate of the SACA monolayer

The hot melt adhesives were applied on both the substrate and constraining layer during a two-stage process by means of an engraved, heated anilox cylinder (5-8 lpi anilox degree, and 25% tint). The diameter of the SACA spherules determines the cell and wall geometry of the engraved anilox (see Fig. 3). For a typical SACA spherule diameter of 400 μm a cell diameter of 160 μm and a cell wall thickness of 400 μm was engraved on the anilox surface while the anilox degree was 5 lpi. Some more anilox cylinders were engraved for smaller SACA spherules (7 and 8 lpi degree). A dot matrix pattern of 25-64 dots of adhesive per square inch occurred (points 2 and 12).

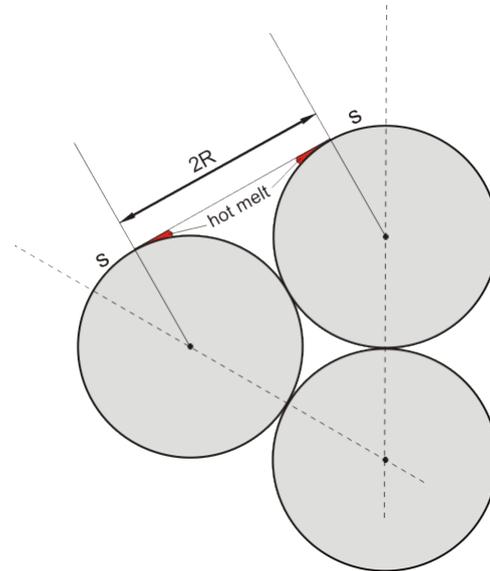


Fig. 3 Geometry sizes that were considered in order to manufacture the engraved anilox cylinder

Inside the anilox cylinder hot current oil flows through while temperature sensors indicate and control the temperature between input and output edges of the cylinder. Cylinder temperature was adjusted around 125 $^{\circ}\text{C}$ with a small fluctuation of 3-4 $^{\circ}\text{C}$ was observed between the cylinder edges (cylinder length: 1.2 m). During hot melt printing excessive amounts of adhesive were removed by a Dr Blade system (point 4, Fig. 4).

A Kufner non-woven, thermo-adhesive Tech-Tex textile was used as the constraining layer (point 13). This was of sparse overall weave and exhibited a weight in the order of 40-50 g/m^2 . The SACA spherules were introduced to the substrate by means of a series of scales of various sizes (points 6, 8, 9, Fig. 4) in a manner that ensured, uniform overall distribution of both particles as well as particles sizes. No sieves or similar methods for the distribution of spherules on the substrate fabric are used. As the use of sieves usually leads to blockage of the sieve holes and uneven distribution of the spherules, a different approach was applied. This involved the use of subsequent spherule drops from containers (points 6, 8, 9) containing spherules of the same diameter. In this manner, the first stage of the spherule deposition is subsequently followed by additional drops. Every subsequent drop involves spherules of diameter approximately 1/3 of the diameter of the spherules deposited in the previous process step. As a measure towards the optimum allocations of spherules to all existing adhesive dots the spherules were forced into a rolling effect by means of a suitable angle that existed between the substrate textile and the horizontal and which was imposed by suitable positioning of the supportive textile rollers (points 10, 11, 15, Fig 4). In this manner, spherules introduced at different points during the deposition stage were allowed to roll and thus optimally occupy the available surface. However, the fact that the adhesive dot printing process created a two-dimensional uniformly spaced matrix of dots in

conjunction to the fact that not all spherules were able to bond ideally (with respect to both the angle of the bond the percentage of the spherule surface attached to the adhesive dot lead to the formation of voids on the monolayer surface (Figure 5).

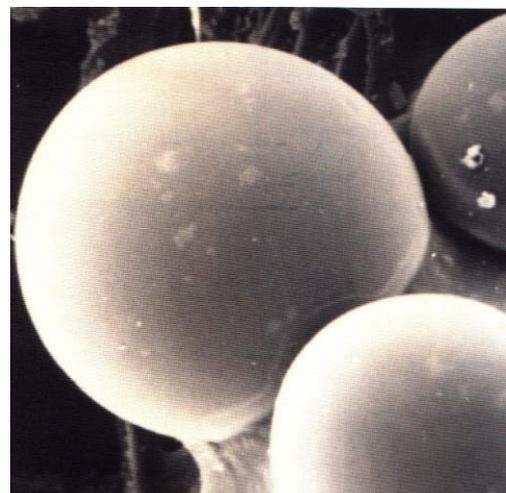
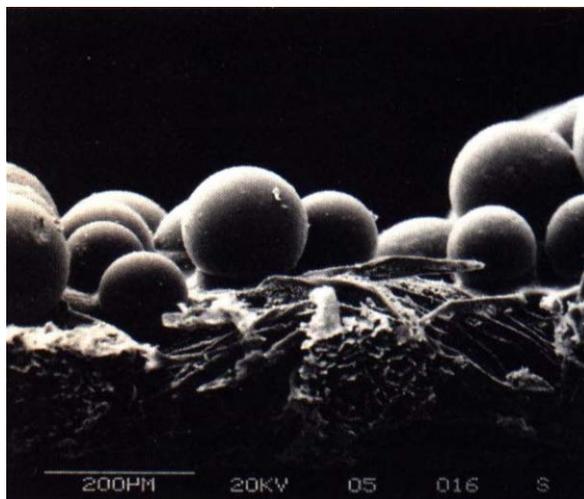
A number of suction hoses were used for the removal of excessive spheroid particles from the assembly (point 5) and a heated calender was used for the development of the monolayer. As an additional measure for the increase of the overall mechanical stability of the monolayer, the substrate and constraining layers were woven together.



Fig. 5 The pilot unit that was used in order to print the hot melt on the fabric substrate and laminate the SACA spherules

For the adhesion of the SACA spherules to the carbon fabric a number of hot melt adhesives were utilized. Specifically, these included the National Starch PUR-FECT 310 or Henkel urethane hot melt. The hot melt adhesives were used, instead of "solid isocyanate" adhesives (such as the "high solids" Impranol-Imprafix of the Bayer company), which have been utilized and mentioned in a number of existing patents and licenses [8], due to a number of disadvantages they pose. The basic disadvantage that has

been explicitly presented both in previous relevant licenses and studies [9] is that the hardening of "solid isocyanates" requires heating at 170 °C for 5 minutes. This renders necessary the addition of an extra step in the printing process and the integration of a heating oven. In a possible scale-up process of the currently presented pilot production unit



this may imply significant costs in the production line development and subsequent operational costs. The pilot-unit assembly developed and presented in the current study is considerably simpler and involves lower development and operational costs. This may be attributed to the fact that the curing and hardening of the hot melt adhesives used takes place by means of adsorption of atmospheric humidity. The second important advantage of the utilization of humidity hardening hot melt adhesives is the increased resistance of the multilayer filter assembly in washing and similar cleaning processes.

As the system, due to its increased mechanical attributes, is susceptible to further treatment for the improvement of both its physicochemical (i.e. adsorptive) as well as mechanical properties the treatment of the spherules with oxygen plasma will lead to the development of OH groups on the spherule surface, which will subsequently lead to the improvement of the morphology of the surface of spherules and the achievement of a significantly improved bond between the spherules and the adhesive as well as to the development of a hydrophobic effect on the spherule surface.

2.4 Conclusions

The results show that the SACA spherules prepared satisfactory physicochemical attributes that are suitable for their integration as an active monolayer into a multilayer assembly and the subsequent development of a filtering material system. The characterization of the SACA samples was carried-out by means of nitrogen porosimetry. The high surface area values which the prepared activated carbons present favour their utilization as adsorbents, while their impregnation with metals aims at attributing catalytic properties and selective adsorptive capability to these materials. After the verification of the necessary physicochemical and surface properties of the SACA materials the development of a pilot-unit and the optimization of a spherule printing process suitable for application in a pilot-scale production. Test runs that were carried-out indicated the soundness of the concept developed as well as its potential towards both optimized operation as well as scaling-up. The produced multilayer samples of were primarily designed for use in bio-medical applications and for the development of suitable garments for hazardous environments. The increased levels of catalytic adsorption properties that were observed with respect to both gaseous and aqueous compounds and the bactericidal and bacteriostatic effects that were observed after application in biomedical applications (presented elsewhere) signify the potential of multilayer textile assemblies integrating a SACA active monolayer. Scale-up and process optimization studies are currently carried-out as well- as extensive characterization and process intensification efforts.

Chapter 3 Innovative printing and finishing technologies - Using microwave drying systems in the Graphic Arts

3.1 Drying systems in printing – the existing situation

Drying of the printed substrates is an important issue for the printing industry. Many alternative drying systems are currently in operation both off and online with the printing machines and processes, such as thermal devices that rely on gas combustion or infrared radiation. These systems speed up the drying procedure by assisting the solvents' evaporation. Penetration of a printing ink is faster if the viscosity is low. Viscosity decreases when the temperature is raised so, the transferred ink film can be heated up together with the substrate by using a thermal gas combustion or IR radiation source.

Chemical drying processes (e.g. oxidation) following the physical drying process is also accelerated by a heating. Such processes are found in almost any kind of solvent-based oleophilic ink (Kipphan et al., 2001).

In newspaper offset printing, the printing ink dries on the paper substrate by partial adsorption or penetration onto the paper fiber body (coldset method). In commercial printing, the printing ink on coated papers, that is, less absorbent papers, also needs to be dried by thermally evaporating the solvent (heatset method). Long extended hot air drying is used to blow hot air over both sides of the fresh print via nozzles. Combinations of hot-air dryers and infrared dryers are also in use. Infrared dryers are used in newspaper printing only to stimulate ink adsorption, thereby facilitating printing with higher ink density, that is, with higher ink application. Nowadays UV radiation dryers are hardly ever used, due to their limited quality (they don't give the "ink melting effect" which offers brilliance) and to the high printing ink costs they incur in web offset. For the same reason, electrobeam dryers or ink curing systems have not come to be generally accepted in practical operation, although they have efficient drying properties (Kipphan et al., 2001; Todd, 1997 & Stanganellis, 1995).

The ink used for rotogravure and flexographic printing has a low viscosity so that the ink in the cells can run out properly and be transferred onto the paper. This low viscosity is principally achieved by using a high proportion of low boiling point solvent with the ink. To dry the printed ink, the solvent must evaporate in a high velocity air dryer after leaving the printing nip. Counter flow/parallel flow drying systems and heating drums are no longer used. Instead, high-velocity nozzle dryers are used. Radial fans route the air in pipes fitted closely above the web and equipped with circular or slot nozzles. The air hits the web vertically, and thus the fresh print. The effect of the impact is to turn the air around by 180°

which returns between the pipes, back to the radial fans, to be fed back into the nozzle pipes. In front of the radial fans, part of the circulated air is branched off and routed into a solvent recovery unit in order to prevent uncontrolled increase in the solvent concentration in the ambient air. The solvent (usually Toluene) must be recovered for environmental and financial reasons. The proportion of air removed thereby is automatically replaced by fresh air or ventilation air. Since not only the speed at which the air emerges from the nozzles, but also the length of the dryer plays a decisive role in determining the effectiveness of drying and therefore the maximum production speed (typically 5-15 m/s) of the gravure or flexographic printing press, the dryers are placed on both sides and surround the entire printing unit. Depending on the type of solvent used, shorter drying units, which do not surround the entire printing unit, are sometimes sufficient. (Tsimi, 2010; Kipphan et al., 2001; Thompson, 1995; Nomikos, 1995).

3.2 Microwaves in various drying applications

Microwaves have been used in the past for many industrial applications. In the food industry, besides the well known heating, microwaves can be used for the desiccation of foods like carrots, fish, peach, biscuit and many other foodstuffs (Zheng-Wei Cui et al., 2004; Tao Wu et al., 2008; Jun Wang & Kuichuan Sheng, 2006).

Microwave processing of ceramic materials is another novel industrial application with Microwaves offering superior drying efficiencies and increases in production of existing or new factories. Even high tech materials have been successfully treated with microwave processing (Sutton, 1989).

Many interesting environmental applications are also reported. Biological waste treatment and thermal inertification of asbestos with microwave irradiation constitute just two of the environmental MW applications (Martin et al., 2005; Leonelli et al., 2006). Hundreds of other industrial MW applications are mentioned in the international bibliography.

3.3 The use of MICROWAVES for Ink drying

In this study, Microwave drying of ink has been evaluated for potential use in printing drying systems. For this purpose the drying effectiveness of a group of inks used in the printing industry (offset, rotogravure, flexography and screen printing) was studied with the use of drying systems based on microwaves in comparison with ambient drying, drying in hot air environment and infrared radiation drying (Ploumi, 2009).

Energy consumption estimations of the most popular drying techniques in comparison with an assisted MW drying system energy consumption were also carried out with the aim of evaluating their comparative cost. Water-based inks were examined in greater depth regarding their printing quality and drying effectiveness with the MW drying systems.

The results indicate that the assisted MW drying method offers definite advantages for drying all inks based on polar solvents, especially water-based ones, both in terms of effectiveness and speed of drying and lower production costs.

Furthermore, the higher speed of drying offered by the assisted microwave systems studied in this work shows that substantial environmental benefits are possible for most of the inks used.

3.4 Conclusions

This study clearly shows the potential of microwave systems to dry effectively the ink on the substrates examined, rapidly and efficiently. It also demonstrates the environmental benefits of the use of MW drying systems compared to conventional ones since it offers the possibility for use of water-based inks instead of solvent-based ones. The use of microwaves for drying may offer significant energy and cost efficiencies but quality of rapid offset printing may improve as well. The financial profits that may occur as a result of the proposed replacement of drying mechanisms in the productive process of graphic arts are clear but further works is needed to elucidate the details of an application.

3.5 Future R&D Plans

To incorporate a microwave drying system in Graphic Arts production we have already started a collaboration with a Greek SME with extensive expertise in industrial microwave drying systems. The first design for a prototype MW-assisted dryer for an offset printing press incorporates special field traps for safety, special field distributors (ensuring good field distribution) and measurement of surface humidity at the entrance and exit of the paper. We expect to have the pilot prototype ready for testing in the next few months to carry out tests under real production conditions. Our aim is to determine all major industrial parameters such as printing quality, cost benefit, maximum possible printing speed improvements, energy consumption and environmental sustainability benefits.

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Authors' Biography



Marios Tsigonias was born in 1978 in Athens, Greece where he lives and works.

He got his Diploma in Graphic Arts Technology from the T.E.I. of Athens, his MSc in Chemistry (Polymer Science and Applications) from the National and Kapodistrian University of Athens and his MEd in Pedagogical studies from the School of Pedagogical and Technological Education of Athens. As a student he was distinct and founded three times by the Greek State Scholarships Foundation. He is a PhD candidate of the Greek Open University working on green packaging materials and sustainable printing.

He worked as a Laboratory Assistant (Typesetting laboratory) for the Faculty of Graphic Arts Technology – T.E.I. of Athens, during his practice and for the J.C.S.C. - NATO as a Graphic Arts Specialist during his tenure. He had also some collaboration with E.E.A. (the Greek Writers Association) as a bookbinder and book conservator and with the I.E.K. of Sivitanidios and the I.E.K. of Helioupolis as an instructor, teaching Graphic Arts, Desktop Publishing and Paper and Book Conservation.

He currently teaches, since 2006, Offset Printing Techniques, New Printing Technologies, Graphic Arts Materials, Color and Packaging Design in the TEI of Athens. Since 2003, he works, as a researcher, for the "Membranes and Materials for Environmental Separations Laboratory (M.E.S.L.)" - N.C.S.R. Demokritos, on complex, environmental friendly, polymer packaging materials. He also collaborates with the I.I.E.K. INTERDIGITAL (since 2004) as an instructor of the Faculties of Printing Technicians, Graphic Designers and 3D Animators where he gives Graphic Arts, Printing and Desktop Publishing lessons.

He has attended a lot of seminars on new educational methods, marketing, packaging, hygiene and safety, environmental solutions and the last technological and scientific progresses in material science and physics. He has written some technical articles for the GA - Graphic Arts and Allpack journals. He has also written some tens of announcements for National and International Conferences and has participated in two National, one International and two European Scientific Research programs.

He speaks and writes English and Italian and in his spare time he likes to be occupied with Art Bookbinding, photography, fishing and free diving.