Customizing Paper-Based Substrates for Digital Fabrication Printing

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Abstract

Paper is generally not considered as a suitable printing medium for digital fabrication processes. However, several techniques and measures are available to overcome the intrinsic disadvantages of plain paper. The most important is extrusion coating with a thermoplastic resin, giving, beside other advantages, a mechanical smooth and chemical inert surface.

Introduction

Paper has been the preferred medium for printing since Gutenberg's times. It consists mainly of natural cellulose fibers, is porous, opaque and matte. Due to this, it is well suited for printing man readable text and graphics. Furthermore, its mechanical properties like stiffness and elasticity / lack of plastic deformation make it easy to handle a paper web on roll-to-roll printing equipment.

However, for printing of functional structures, there are severe drawbacks with the use of plain paper. One major issue is ink penetration, porosity and surface roughness, making it impossible to produce homogeneous thin layer structures.

Coating of Paper

Aqueous coating

"Wet" paper coating is a commonly applied technique to control ink penetration and reduce the surface roughness of high quality printing papers. Water based coating mixtures for paper generally consist of mineral pigments and binders, usually natural or synthetic film forming polymers. Especially when an additional calendering process step is applied after coating, a rather smooth and glossy surface can be obtained.

However, ink penetration and porosity cannot be completely suppressed with this technique, and the surface remains chemically active and hydrophilic. Furthermore, the release of fibers and particles from coated paper is an issue for all printing processes where a clean room environment is employed.

Extrusion coating

Extrusion coating with thermoplastic polymers, mostly polyolefines, is a technique applied to photographic paper base since more than 40 years [1], [2]. Hot liquid polymer material, e.g. polyethylene, is formed to a film through a slot dye, and pressed to the paper web by a chill roll. The surface of the chill roll determines the surface of the resulting web, very even and glossy surface can be achieved as well as defined structures by chill roll polishing or embossing.

The resulting synthetic polymer surface is chemically "clean", inert, and water and solvent resistant. The coated layer provides an efficient barrier for almost all liquids, suppressing ink penetration completely.

If extrusion coating is applied to both sides of the paper web, accidental release of dust and fiber particles from the paper base is efficiently avoided, making the resulting web well suited for a clean room environment.

Application Example

To test the printability of paper based substrates, a set of four different media was used as substrate for gravure printing with conductive polymer (PEDOT/PSS) [3], using a water based printing ink containing

- 0.5 wt.% Poly(3,4-ethylenedioxythiophene) (PEDOT),
- 0,8 wt.% Poly(styrenesulfonate), (PSS), and
- 0.5 wt% surfactant TRITON® X45 (polyethylene glycol 4-tert-octylphenyl ether) .

After drying the samples at 80°C for 5 minutes, the electrical conductivity of an homogenous printed rectangular pattern was measured, results are given in the table.

Conductivity of a gravure printing of conductive polymer on different substrates

Substrate	Electrical Conductivity (arbitrary units)
Plain paper	0.08
Coated paper (calcium carbonate + clay based coating)	0.40
Extrusion coated paper (polyethylene)	1.03
Polyester foil	1.00

The resulting conductivity using an polyethylene extrusion coated paper as printing substrate is the same as with polyester foil, whereas the uncoated and the aqueous coated paper substrate show significant lower performance. The loss in conductivity is assumed to be a result of ink penetration into the paper surface, which is completely suppressed by the polyethylene coating.

Discussion

Paper coated with thermoplastic resins by an extrusion coating process can combine the mechanical advantages of paper with the cleanliness and chemical inertness of a synthetic polymer foil. The extrusion coating process is well established in the industry for production of photographic base paper. A wide choice of additional technologies like corona treatment and coating of primer and / or back coat layers is available for further fine tuning substrate properties as needed.

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