A Novel Approach to IJ Film (or Paper) Media Granting Highest Resolution, Fast Drying and High Durability

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Introduction

Ink Jet—The Most Versatile Color NIP Technology

Within the last 10 years the ink jet printing technology was emerging.

We have all seen that booming technology; in most offices today you find a personal IJ printer as computer output device. Ink Jet printers have basically replaced the matrix printers. They are printing quietly with an ever increasing resolution at lower and lower cost/printer. Most of these office IJ printers work on the DOD (drop on demand) principle, using either mechanical or thermal pulses to eject liquid ink from a nozzle in the printhead onto a substrate.

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Ink jet printing technology has also strong inroads in the technical bureau: IJ plotters b/w as well as color capable are available from various suppliers up to a format of DIN A0.

In the graphic arts field high performance IJ printers of Iris Grafics and Du Pont (Stork) are installed more and more as digital printers for layout, color and even contract proofing applications as component in electronic image processing systems. These printers are based on a continous ink jet principle invented by Prof. Hertz from Lund, Sweden.

The choice of the IJ print medium influences and limits the resulting print quality basically independent of the IJ printer characteristics (within a certain printer performance group). There are still significant differences in performance between the IJ medias available in the market place.

An optimum ink jet film or paper (coating) should satisfy the following requirements:

- **fast ink drying,** absorption of even high ink volumes
- **high color density and brilliance**

- **high sharpness of the printed dot:** round and regular
- **mechanically resistant** (coating), even directly after printing
- **durability of the printed image:** resistance against spray water, light, uv radiation etc.
- **good ageing performance.**

Fundamentals

The Ink Jet Model: **Mechanisms to be considered: "The realities of slow drying and dye diffusion within the tradtional IJ film coatings."**

Transparent ink jet films (representing the majority of these films) carry a **continuous coating** responsible to accomodate the liquid projected ink.

After impact, the ink droplet equilibrates itself on the coating surface according to its contact angle (wetting). This surface wetting area on the coating and the subsequent dissolution and diffusion of the liquid ink into the coating control the drying speed **(solution/diffusion mechanism** according to the laws of Fick). Such processes are slow even when the coating components are easily swollen by the IJ ink solvents. **An excellent match of coating polymer and ink constituents is indispensable to a working IJ system.**

The possibility to increase the ink drying speed by increasing the contact angle is only very limited: to safeguard a reasonable dot resolution the contact angle built by ink, coating surface and air should be as low (critical) as possible to still allow sufficient drying.

In the next graph I put together representative data on the ink drying performance on different IJ films (transparent OHP films, IJ plotter films, white opaque display films) printed on two different well known IJ printers.

Beside the ink drying problematics with continuous IJ film coatings deterioration of printed dot resolution may happen with time.

As long as enough (ink) solvent is dissolved in the polymer coating the diffusion of the dye within the coating will continue, leading to completely blurred pictures eventually. Such problems can be experienced with any IJ film media storing freshly printed films in water vapor impermeable jackets (see samples).

On the Way to an Alternative

The New Coating Concept

Facing the above mentioned drawbacks of the existing coninuous IJ film coatings, we theoretically investigated possible alternative coating concepts.

Normal PPC or offset **paper** show fast ink drying due to the pronouced **capillarity** alongside the paper fibers. However who is not aware of the **feathering** problem with such paper. The **anisotropy** of these paper substrates and the mostly parallel orientation of the cellulose fibers and capillaries with respect to the paper surface causes uneven and rugged shaped ink dots and loss of resolution in the fine print structures.

Today speciality ink jet papers carrying highly clay resp. carbonate filled starch resp. polymer coatings are available resolving the feathering problematics.

Such highly filled coatings however do not represent any viable concept for a new IJ <u>film</u> coating.

But the paper model still triggered our concept for a NEW Ll FILM COATING.

A microporous coating with well defined capillaries oriented perpendicular to the coating surface, allowing capillar suction would represent a viable alternative to the traditional, continuous IJ film coatings, functioning on the basis of a solution / diffusion mechanism.

Capillar suction as alternative to the solution / diffusion based transport of the ink into the coating is advantageous due to the following reasons:

- the ink "transport" through capillary is **much faster** than solution / diffusion transport
- in microporous coatings the **matching of the surface tension of the coating and the ink is significantly less critical,** rendering such **coatings more universally suitable** for different IJ printers and inks. The capillar suction is dominating even in cases of poor surface wetting, when the contact angle between coating surface, ink and air is high (up to a threshold value).
- the **ink is transported exclusively within the capillaries** and only as far as the capillaries reach: **any undesired diffusion of the dye into and within the polymer matrix, causing a loss of dot resolution, is excluded.**
- the ink solvents do hardly swell the polymer matrix, rendering the freshly printed **media surface more resistant against mechanical damage** (scratching, smearing etc.)
- due to the open structure of the microporous coating the ink solvents evaporate faster; the dye is adsorbed and immobilised at the capillary walls.

In the ideal microporous IJ film coating the capillaries ought to be extremely fine, regularly distributed over the whole surface and preferably oriented perpendicular to the surface. Due to the vast amount of phase boundaries such coatings would most probably be of high opacity.

The "only" questions were, how to generate such a coating with well defined porosity and the necessary transparency.

Options and Realization

After definition of the target we were studying a variety of different routes to achieve our goals.

Most of our work can be summarised under the following three methods to generate capillarity:

- capillarity through **air entrainment**
- capillarity through **incorporation of fillers and fibers**
- capillarity through **membrane technology**

Air entrainment leads mainly to closed cell structures in a polymer matrix. Such closed cells unconnected with the surface do not deploy any capillary sorption activity; they rather cause turbidity and haze depending on the amount of air entrained.

Air bubbles interrupting capillaries even "desactivate" the capillary suction.

Incorporating inorganic or organic fillers into a coating formulation below the critical pigment volume concentration (CPVC), leads to very hazy but nevertheless dense coating structures with almost unchanged sorption characteristics. By further increasing the pigment volume over the critical threshold, the binder resin(s) can no more wet the entire surface of the filler(s) and thus (depending on the ratio of filler surface area and amount of binder used) a porous matrix results. Such coatings are to be found in speciality paper coatings. Due to the high level of fillers these coatings are opaque and fully unsuitable for products used for overhead presentation resp. display purposes.

In l990 new IJ paper and film were presented carrying a speciality coating based on spherical silica gels of very narrow particle size distribution. In those coatings the uniform particle size of this filler material, even when tightly packed, causes large intergranular cavities, which allow to accomodate large amounts of ink; the spherical shape of the particles causes relatively little light scattering. To my knowledge this concept is no more persued due to high raw material cost and manufacturing problems.

There is however a third option to achieve coating layers of defined porosity: by a **phase inversion process** well known in the preparation of permselective membranes.

Phase inversion membranes are solvent cast structures, which owe their porosity to immobilisation of the gel prior to complete solvent depletion. The conditions for the formation of such membranes are, that the selected polymer is dissolved in a mixture of one or more solvents together with other components with lesser affinity for the polymer. It is beneficial for the ease of the generation of a phase inversion membrane, when the polymer solvating species evaporates easier and faster than the nonsolvent.

The following five stages of a porous phase inversion membrane layer generation can be differentiated:

- loss of volatile polymer solvating solvents
- gelation of the polymer (sol / gel transition)
- contraction of the gel
- capillary formation and immobilisation
- loss of residual solvents

Upon evaporation of the solvent from the polymer solution the ratio of solvent/nonsolvent shifts: the concentration of the non solvating species remaining within the polymer solution gradually increases. Reaching a critical solvent / nonsolvent concentration ratio representing the threshold solubility of the polymer, the polymer gels. Upon further evaporation of the solvent(s) the gel contracts, the capillaries are formed and fixed.

Example 1

A casting solution consisting of 5 % cellulose nitrate, 54,2% methylacetate, 23,7% ethylalcohol, 12,3% butylacohol, 3,3% water and 1,5% glyerol is applied in a wet thickness of 650 microns on a flat and very smooth substrate. The following graph shows the weight and thickness loss as a function of evaporation time at 21°C/62% rH. Gelation of the polymer occurs between about 3 and 10 minutes after casting, during which time most of the volatile true solvent, methylacetate has evaporated.

The resulting membrane thickness is only a fraction of the as-cast thickness owing to solvent loss and the resultant increase in the concentration of polymer per unit volume. However because of the inclusion of voids it is substantially greater than the thickness of a dense membrane containing an equivalent amount of polymer.

Our development work on such a phase inversion system suitable for the continuous generation of a microporous coating was very demanding. As many of you can imagine the step from a casting solution suitable for a discontinuous and room temperature generation of a microporous coating (membrane) to a continuous coating process was very tricky. But finally we were very lucky and found a fully workable system based on selected polymers.

I would like to use the remainder of my time to give you some ideas about the properties of these new microporous coatings.

The Novel Family of Microporous IJ Film Products

Product Characterisation

The microporous IJ product range consists of a variety of different products all based on the concept outlined above:

- clear transparent
- translucent for back side printing (display)
- white opaque

With all these products the microporous coating is applied on a polyester carrier film.

In the following graph the physical properties of our new product family are summarised.

It is basically possible to apply these microporous coatings on any desirable substrate without impairing any of the properties discussed in detail below.

Color Density

The next graph shows a comparison of color density readings on a variety of different transparent and translucent ink jet films.

Ink Drying

Printing tests performed with our new microporous products in comparison with existing ink jet films of ours as well as competitors' demonstrate the extremely high efficiency in accomodating even high amounts of ink projected onto the coating surface. The resulting drying times, quantified as the time elapsed until full smear restistance in high density color areas was reached (internal Celfa method) obtained with our new microporous film products, confirm our model concept and demonstrate the high impact, this new technology has on ink drying.

These drying tests have been performed on most recognized ink jet printers without major differences in the drying times reported in this chart.

Resolution

The analysis of micrographs of specific test prints on different IJ substrates including offset and speciality IJ paper, traditional IJ transparency and plotter films clearly shows the scope of resolution possible with our new microporous products.

From the following laser photo micrographs of our different microporous coating products you can easily assess the order of magnitude of pore diameter and distribution as compared to the printed dot size.

Mechanical Resistance

Durability of Print

Due to the unique composition of these microporous coatings free of any inorganic fillers it is possible to transform the imprinted microporous coating on an inert carrier material into a dense, continuous coating. There are several ways to do that, even without using any solvents or other liquids. After transformation the image is fully encapsulated and protected against humidity, spray water, mechanical damage. The effect of this encapsulation process against color fading due to uv resp. light radiation is presently under investigation. This transformation process does not alter or change any of the printed information.

Final Remarks

We have proven the viability of our theoretical concept of a novel microporous IJ coating satisfying all relevant requirements for an optimum IJ product:

- very fast ink drying
- high color density
- highest resolution
- mechanically resistant coatings
- improved durability
- good ageing performance and
- universality

The development of microporous coatings for a variety of other applications continues. Presently we are finalising a special film for color laser copiers, granting improved toner adhesion, color gain and mechanical (scratch) resistance. The inherent microporosity of these coatings not only contribute to an outstanding toner adhesion, but prevents the unesthetic and uncomfortable feel of the silicon oil contamination on top of traditional copier films.

Before closing I want to thank all my coworkers for their concentrated and dedicated work on this fascinating and demanding project.

Reference

1. Robert E. Kesting, Ph. D.: *Synthetic Polymeric Membranes* McGraw-Hill Book Company, 1971.