A New Quick-Drying, High-Water-Resistant Glossy Ink Jet Paper

Kenzo Kasahara
Central Research Laboratory, Konica Corporation
Tokyo, Japan

Abstract

Konica Photo IJ Paper QP is an example of how microporous glossy paper allows today's ink jet printing to challenge the image quality of silver halide prints. QP paper incorporates ICOS particles in tandem with a polyvinyl alcohol binder and boric acid hardener, resulting in high ink-absorption capacity for exceptionally quick drying and fine resolution. These technologies further ensure the fixing of ink dyes, maintain the high gloss of the paper, and provide image-receiving layers that are physically strong and highly water resistant.

Background

Thanks to such advances as smaller ink drops and the use of up to seven ink colors, the image quality of ink jet printing has begun to approach that of silver halide photography. In fact, these advances have carried ink jet printing to the point that further advance now depends on the quality of ink jet papers. While an ink-jet-printed image on plain paper is far inferior to a silver halide image on photographic paper, it becomes difficult to distinguish between the two when the ink jet printing is done on a high-grade glossy paper.

Currently, three types of glossy inkjet paper are used: cast-coated, swelling, and microporous. Cast-coated glossy paper is of limited image quality due to its comparatively low optical density and gloss, but also because its paper base absorbs ink, which causes cockling after printing.

Swelling and microporous glossy papers avoid cockling because, unlike cast-coated paper, they use a paper base coated with a PE (polyethylene) layer that renders the base impermeable to ink. Since this PE-coated base is identical to that used in silver halide paper, these papers also offer the same thickness, stiffness, and flatness as silver halide paper.

Because their PE-coated bases does not absorb ink, the image quality of swelling and microporous papers depends chiefly on the mechanisms of their image-receiving layers, and these mechanisms differ fundamentally. In swelling paper, the image-receiving layers consist mostly of water-soluble polymers. When an ink drop alights on the surface of the paper, the polymer must swell in order to absorb the ink. This presents an intrinsic conflict between ink absorption speed and water resistance, since a quick-swelling polymer essentially means a high water-soluble polymer. So, while swelling paper does offer high optical density, it also carries such disadvantages as slow ink drying, loss of gloss after printing, curling both before and after printing, and, of course, low water fastness.

In contrast, the image-receiving layers in microporous paper do not need to swell in order to absorb ink. Instead, the microporous structure of these layers presents a honeycomb of pores which receive the ink. Since high water-soluble polymers are unnecessary, there is no trade-off between ink absorption speed and water resistance, so that microporous paper avoids all of the disadvantages of swelling paper, yet achieves far superior ink absorbing speed. In fact, surface ink absorbs so quickly that bleeding and beading are eliminated, and the surface ink on one sheet of paper is completely dry before the next sheet is finished printing.

Because microporous paper clearly offers ink jet printing's strongest challenge to the handling and image performance of silver halide photographic paper, there has been great interest in its development, despite the many difficulties involved. One successful development has been Konica Photo IJ Paper QP—or, simply, "QP" paper—and the technologies that make QP paper possible are reported here.

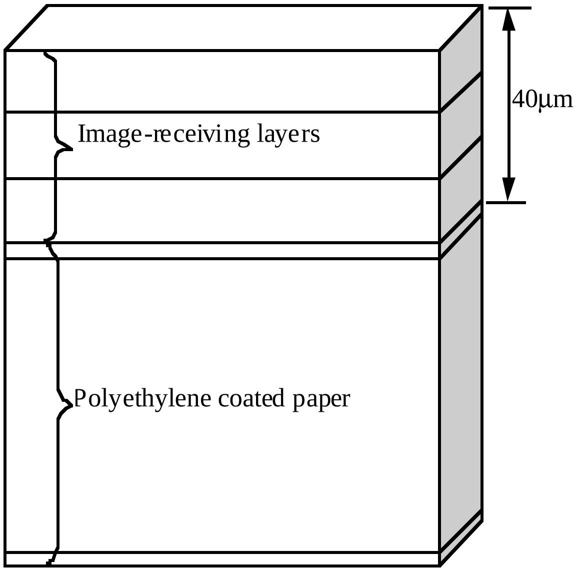

Figure 1. QP paper layer structure

QP Paper

The layer structure of QP paper is shown in Figure 1. On a PE-coated base, three image-receiving layers are coated using the same simultaneous multi-layer coating technology that is used in the production of silver halide paper and film. The total thickness of these three layers is 40 micrometers, and the total volume of their pores is about 25ml/m^2.

Although these layers each have secondary functions, their primary function is to receive images by absorbing ink within their microporous structure. To achieve the highest performance, that microporous structure must not only provide high ink-absorption capacity, but also aid in the fixing of ink dyes, contribute to the gloss of the paper, and be physically strong and resistant to water. To accomplish this, QP paper incorporates ICOS particles in tandem with a polyvinyl alcohol binder and boric acid hardener.

ICOS Particles

The heart of QP paper's image-receiving layers are the ICOS (inorganic core/organic shell) particles of which they are composed. The essential characteristic of the layers' microporous structure is, of course, its porosity, and to maximize that porosity, the aggregations of particles composing the structure must be of optimum size. To achieve optimum aggregate size, particle dispersion during mixing must be optimized. In turn, the optimal dispersion of these particles requires precise control of their electrical charges in order to balance the repulsive power of their electrical charges against the attractive power of van der Waals force. Gaining that precise control of electrical charge is the purpose of ICOS particles.

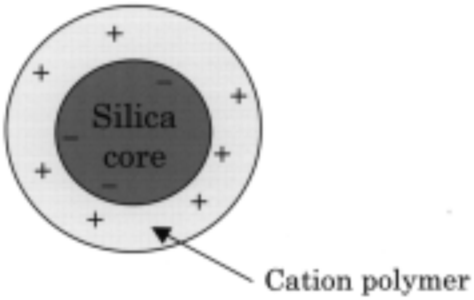

Figure 2. ICOS particle structure

The structure of an ICOS particle is shown in Figure 2. Surrounding the fine-grained, anionic silica core is a cationic polymer shell. By precisely controlling the particle's ratio of silica to polymer, the particle's charge is likewise precisely controlled, with the overall charge being slightly cationic.

Precision in the strength of the charge is critical. If the charge is too strong, it will overpower the attractive effect of van der Waals force, and little particle aggregation will occur. The resultant aggregates will be too small, so that they pack too closely when the image-receiving layers coated on the base paper dry. In this case, a pore ratio no better than 26% can be expected, a ratio that further falls with the addition of binders and other additives.

Conversely, if the electrical charge is too weak, van der Waals force dominates, and particle aggregates are too large. Because the aggregates are larger but fewer, fewer pores are produced in the structure, and the result, again, is a low pore ratio.

Precise control of ICOS particle charge thus results in maximized porosity. An example of such maximized porosity in a microporous structure is shown in Figure 3. The micropore ratio here is calculated at over 60%, providing an ink-absorption capacity that easily exceeds the demands of today's popular ink jet printers. To illustrate what can be achieved with such microporous structure technology, Figure 4 compares the ink absorption performance of microporous paper and swelling paper.

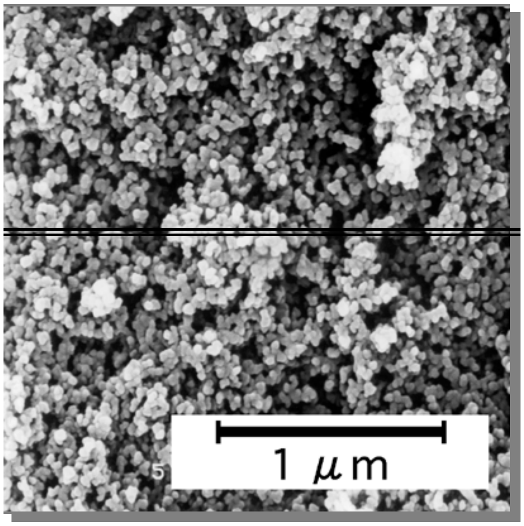

Figure 3. Microporous structure of image-receiving layers

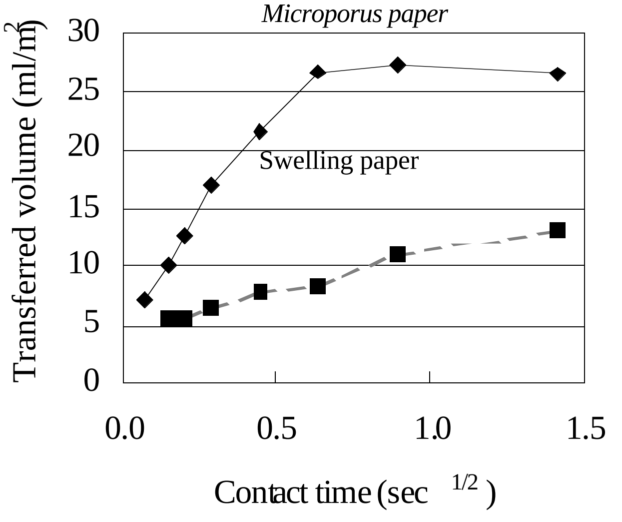

Figure 4. Ink absorption, measured by Bristow method (according to J. TAPPI No.51)

Naturally, this ink-absorption capacity is the key to QP paper's extremely fast ink drying and, thus, its easy handling. But high-speed drying also figures strongly in providing finer resolution. In the microphotograph of an actual print, shown in Figure 5, the black dots on QP paper form precise circles, whether printed alone or against a field of yellow dots. In contrast, the black dots printed on swelling paper become clearly distorted when printed against the same field of yellow dots because the black and yellow dots mix before either are absorbed.

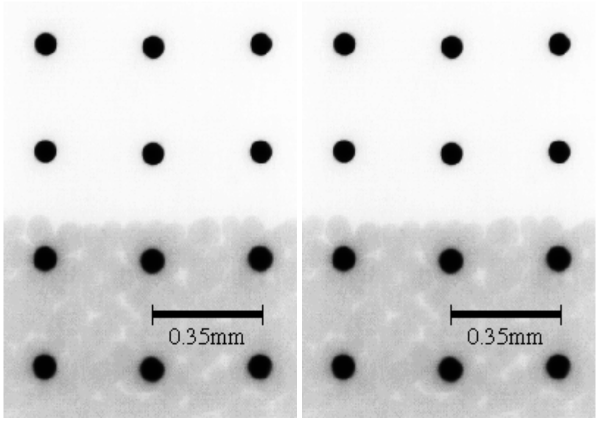

Figure 5. Dot shapes on a microporous paper print (left) and a swelling paper print (right). In the top half, only black dots are printed, in the bottom half, black dots are printed against a field of yellow dots.

In addition to providing high ink absorption, ICOS particles help to fix ink dyes. Since ICOS particles carry a cationic charge, they attract the anionic dyes in ink and thus function to fix the dyes. To produce ICOS particles that perform these functions efficiently, the polymer composing the cationic shell must be carefully selected, and an example of such a polymer is shown in Figure 6.

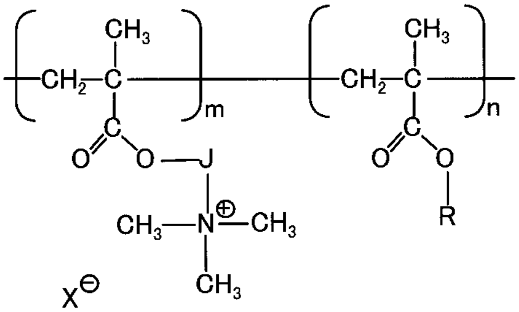

Figure 6.Cationic polymer suitable for ICOS particles

Finally, ICOS particles contribute directly to the high gloss of QP paper. The diameter of the ICOS particles is about 0.05 micrometers, so that the surface of the paper remains glossy without calendering. This small particle size is important, too, because pigments over 0.1 micrometers in diameter would result in a completely matt paper surface, regardless of how glossy the paper base might be.

Polyvinyl Alcohol Binder and Boric Acid Hardener

Since a microporous image-receiving layer is frail, a polymer binder is needed to keep the layer away from cracking. However, as little binder as possible must be used, since the binder takes up space and lowers the micropore ratio. A suitable binder must bind about three to eight times its weight in ICOS particle aggregates. In addition, to avoid hindering ink absorption, a non-swelling polymer must be used, for if the binder swells, it will block the penetration of ink. Polyvinyl alcohol was found to satisfy these requirements and to effectively strengthen the microporous image-receiving layers in QP paper.

But polyvinyl alcohol was also chosen because it increases the water resistance of the microporous image-receiving layers, since polyvinyl alcohol is hard to dissolve in water. To enhance this water resistance, boric acid was added as a hardener because the bonds between boric acid and polyvinyl alcohol increase the effective molecular weight of polyvinyl alcohol and make it even harder to dissolve.

Figure 7 shows the results of a water resistance test comparing QP paper and a swelling paper. After printing, water droplets were applied to the surfaces of the papers, after which the papers were rubbed several times. While the swelling paper clearly lacks resistance to water, no washing out of dye nor dissolving of the image-receiving layer is observed in the QP paper.

Figure 7.Water resistance testing of QP paper (left) and a swelling paper (right)

Summary

Microporous glossy papers present ink jet printing's strongest challenge to silver halide image quality. QP paper is a microporous paper that incorporates ICOS particles in tandem with a polyvinyl alcohol binder and boric acid hardener. Together, these technologies give QP paper its high ink-absorption capacity, for exceptionally quick drying and fine resolution. Further, they ensure the fixing of ink dyes, maintain the high gloss of the paper, and provide image-receiving layers that are physically strong and highly water resistant.

Biography

Kenzo Kasahara received his MS in chemistry from the University of Tokyo in1994. He joined Konica Corporation in the same year, where he has specialized in the development of ink jet papers.

Contact: kenzo@konica.co.