

Microporous Paper for Use in Digital Printing

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Abstract

We have developed paper sheets having microporous layers that meet the demands for print quality in digital printing. In 1999 we reported on the preparation and print quality of this microporous paper, which is used in thermal wax transfer printing.

In this paper, the application of this microporous paper for toner-based marking is described. The application of the microporous technology to toner-based marking ensures that the paper has little gloss even after printing. Other print qualities such as mottle, the reproduction of the gray scale level, TEP and NEP are better than other types of paper as well.

Introduction

In the digital printing field, demands for more precise printing increase second by second. To fulfill these needs, it is necessary to make increasingly excellent printing media that can reproduce the original image with ever greater accuracy, and not just to develop more advanced printing systems.

The microporous layer can be easily made by coating a sheet substrate with a coating mixture containing fine bubbles. As the porous sheets have several advantages, such as high ink/toner absorbency, low thermal conductivity and high compressibility, in producing accurate images, they are used in a wide range of digital printing applications.

A porous intermediate layer was used in making dye diffusion thermal transfer paper because of its elastic and heat insulating properties[1]. The high affinity to ink, the low thermal conductivity, and the high compressibility of the fine porous layer gives rise to continuous tone graduation of high accuracy[2].

In our previous work, we focused on the use of microporous paper for thermal wax transfer printing[3, 4]. In this area, it is used because it has high heat insulating and cushioning properties.

Other applications that will benefit from the improved print quality of this microporous paper include solid inkjet printing, toner-based marking, and direct thermal printing. In the first and second applications, the microporous layer acts as an ink/toner-receiving layer. This layer improves the image uniformity of the receiving sheet in terms of mottle and graininess, for example. This is because the molten ink/toner permeates into the pores of the microporous surface layer due to the capacity of the pores and capillary action, and then fixes on the surface due to mechanical interlocking.

On the other hand, in the last application, the microporous layer acts as an intermediate layer. It enhances the sensitivity of the receiving sheet, due to its heat-insulating nature and cushioning properties.

On electrophotographic prints, a certain amount of gloss is desired by the end users, regardless of the types of paper used[5, 6]. However, a low gloss difference between imaged and non-imaged areas is required. The porous surface of our paper makes sheet gloss low, and when the size of the surface pores is appropriate, the gloss of the printed sheet is low as well.

In this paper, we describe the characteristics and the print qualities of our microporous sheets for use in different types of digital printing, with particular emphasis on toner-based marking.

Experimental Methods

Preparation of Microporous Sheets

The composition of the coating liquid (solid contents 31%) is shown in Table 1. The viscosity of the liquid is around 3000 *cps*.

In the continuous foaming machine, air was mixed in the liquid and stirred in a closed system at a mixing volume ratio of air/liquid=0.6/1.0 with constant stirring of 600 rpm. The schematic diagram of a typical foaming apparatus is shown in Figure 1.

Immediately after the foaming treatment was completed, one side of a sheet of paper of weight 127.9g/m^2 was coated with a mixture of 10 g/m^2 dry weight, using an applicator bar. Then the coated paper was dried.

Table 1. Composition of the coating liquid

Component	Part by solid weight
Aqueous resin: Polyurethane	100
Foam stabilizer: Salt of long-chain fatty acid	4.0
Viscosity control agent: Cellulose derivative	2.0

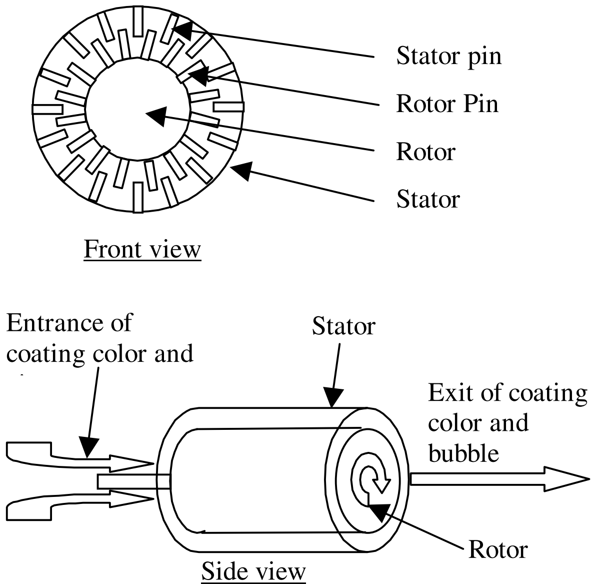

Figure 1. Schematic diagram of a typical foaming appratus[4]

Samples

To evaluate the microporous paper (Mp) for toner-based marking, three other sheets were used: plain paper 1 (Pp1), plain paper 2 (Pp2) and coated paper (Cp).

Print Quality of the Microporous Sheets

The images to measure gloss were printed using a PC FMV6450 CL3 manufactured by Fujitsu Co., Ltd., an LP-8000C laser color printer manufactured by EPSON Co., Ltd., and Adope Photoshop 4.01j software manufactured by Adope Systems Inc.

Other factors such as mottle, the reproduction of the gray level, TEP (Tangential Edge Profile), and NEP (Normal Edge Profile), were evaluated using the following instruments: a Power Book G3 (Operating System: Mac OS 9.00) manufactured by Apple Computer Co., Ltd., a Magicolor 2 manufactured by QMS Co., Ltd. and FreeHand 8J software manufactured by Macromedia Co., Ltd.

The specular gloss meter manufactured by Murakami Shikisai Co., Ltd. was used to measure gloss at 75º.

The APQS (Automated Print Quality evaluation System) manufactured by Oji Scientific Instruments Inc. was used to quantify the print qualities other than gloss. The methods used to evaluate mottle, the reproduction of the gray level, TEP, and NEP are described in detail in Shinozaki's report[7].

Results and Discussion

Gloss

Figure 2 shows the measurements of maximum gloss (Max), minimum gloss (Min) and differential gloss (Dif), which is the gloss difference between the maximum and minimum gloss.

In most cases, the non-imaged areas exhibit the minimum gloss for all the papers. At the minimum gloss, the coated paper has much higher gloss than both the plain paper 1 and the plain paper 2; this is due to the smoothness of the surface of its coated layer. The microporous paper has higher minimum gloss than the plain paper 1 and the plain paper 2, as it also has a coated layer. However, the microporous paper has a much lower minimum gloss than the coated paper, because it has a porous surface that reduces the gloss.

The maximum gloss of printed sheets is usually given to the black color solid fill area 100 %. When the surfaces of the plain paper 1, the plain paper 2, and the coated paper are covered with toner, these surfaces become smooth and, as a result, they have high gloss. In the case of the microporous paper, even when its surface is covered with toner, it has a lower maximum gloss than the other papers. This is because the pore structure of its surface remains intact.

For the above reasons, the differential gloss of the microporous paper is much lower than for the other sheets, as shown in Figure 2. This makes images printed on the microporous paper easier for observers to look at.

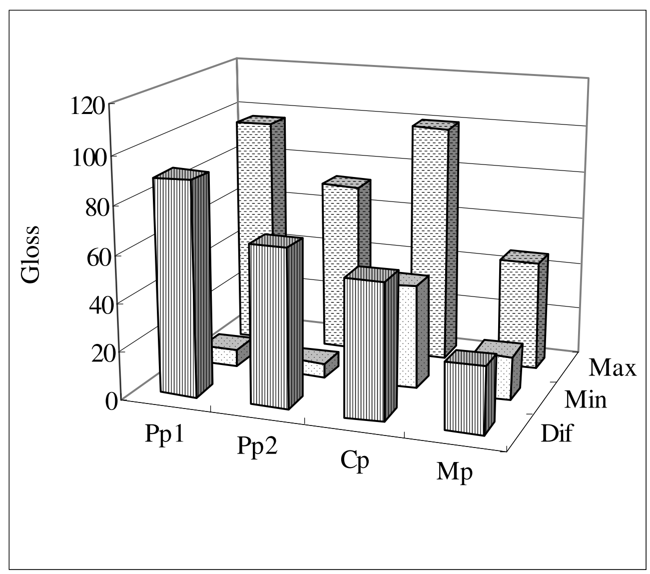

Figure 2. Comparison of gloss

Max means the maximum gloss
Min means the minimum gloss
Dif means the differential gloss

Mottle

Figure 3 shows mottle measurements as a function of tile size. The smaller values of the standard deviation of the gray scale indicate more uniformity. With the increase in tile size, the standard deviation of the gray scale decreases. It is clear that the standard deviation of the microporous paper is smaller than those of the other sheets, especially at lower tile size. Furthermore, the relative change in standard deviation with respect to tile size is much less in the case of the microporous paper than for the other papers.

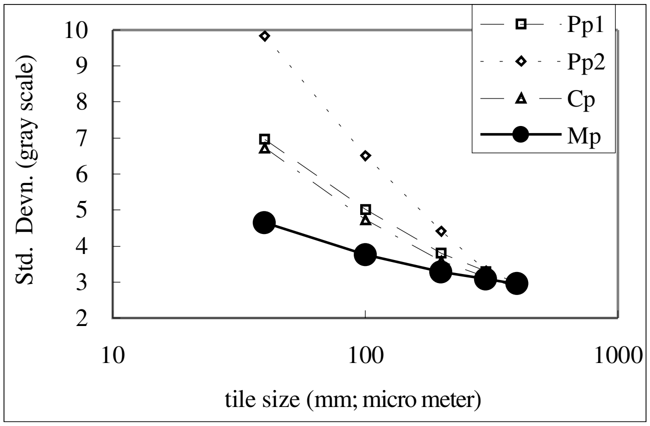

Figure 3. Mottle: The standard deviation of the gray scale as a function of tile size

TEP

Figure 4 shows the measurements of TEP. Each measurement is the mean value of the measurements of the top, bottom, and right and left sides. TEP measures the geometric distortion of an edge from its ideal position, and it is characterized as the standard deviation of the residuals, which are calculated perpendicular to the fitted edge. The greater the TEP, the more rough and wavy the line. Therefore, the lower the TEP, the better the line quality.

The microporous paper has the smallest TEP of all the paper.

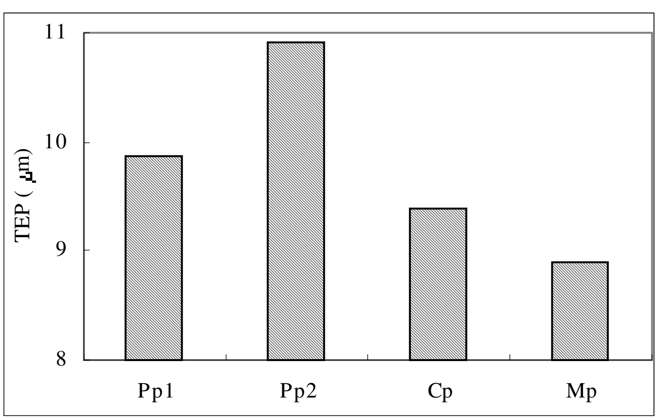

Figure 4. Comparison of TEP

NEP

Figure 5 shows the measurements of NEP. Each measurement is the mean value of the measurements of the top, bottom, and right and left sides. NEP measures the distinctness of the outline. The more blurred a line, the greater its NEP.

The NEP of the microporous paper is about the same as that of the coated paper, and is significantly less than that of the other papers.

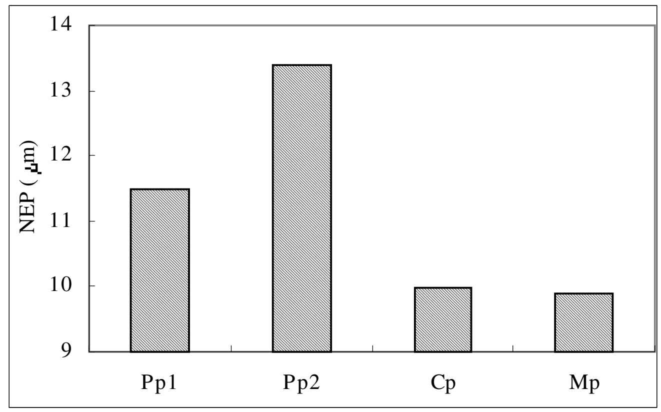

Figure 5. Comparison of NEP

Reproduction of the Gray Scale

Figure 6 illustrates the measured solid fill areas as a function of the designated gray scale for the four different papers. The fine dashed line represents the ideal solid fill area expected from each gray scale level.

Obviously, the experimental data points of the coated paper are further from the ideal line than those of the microporous paper.

The mean difference D is calculated from the Equation (1) and the results are shown in Table 2. The smaller the mean difference, the better the reproduction of the gray scale. The mean difference for the microporous paper is a little smaller than those for the plain papers 1 and 2, and much less than that for the coated paper.

$$D = \left(\frac{\sum^{n} (x_{mi} - x_{di})^2}{n} \right)^{0.5} \qquad (1)$$

x_{mi}: the measured solid fill area
x_{di}: the designated gray scale
n: the number of the data

These results show that the microporous paper can better reproduce the gray scale than the other papers.

Table 2. The mean difference

	Pp1	Pp2	Cp	Mp
Mean difference	4.64	4.89	7.63	4.51

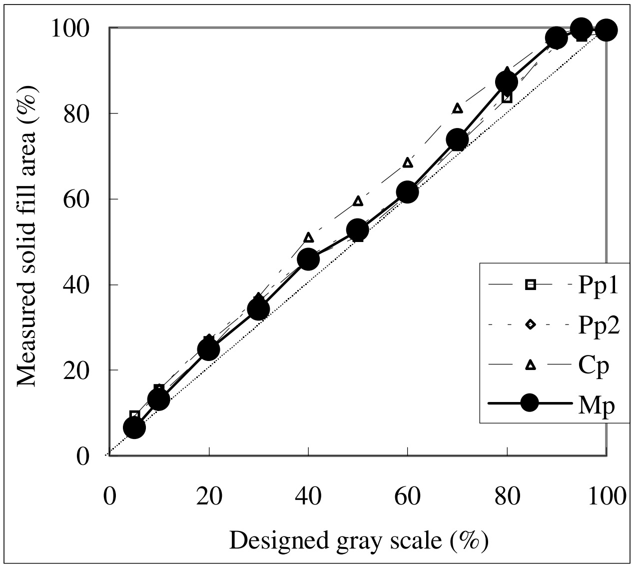

Figure 6. Reproduction of the gray scale. Measured solid fill area as a function of the designated gray scale

Conclusion

The microporous paper exhibits the characteristics of excellent quality matte paper in toner-based marking. It has the lowest differential gloss and the lowest maximum gloss of all the papers tested. Its other print qualities, such as mottle, reproduction of the gray scale level, TEP and NEP are better than the other papers as well. For these reasons, images printed on the Microporous paper have much greater clarity than images printed on the other papers.

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Biography

Yasuhiro Oba received his M.Sc. and B.Sc. in Chemical Engineering from Tokyo Institute of Technology in 1988 and 1990 respectively. Then he joined Oji Paper Company and worked as a research scientist at the Pulp and Paper Research Laboratory. With funding from Oji, he studied paper physics at UMIST (the University of Manchester Institute of Science and Technology) between 1997 and 1999. After receiving his Ph.D., he has been working at the Imaging Media Development Laboratory at Oji.

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