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Michael H. Lee: Seongsik Chang; Quang Lam; Omer Gila

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In this work we describe an impedance technique to map the developer roller resistance across its surface. The roller only needs to be a single conductive dielectric layer. Hence its relevant impedance spectrum can be simple and uniquely determined by the corresponding capacitance and resistance obtained at a single well-chosen frequency. Although the actual material can be more complex, we show that scanning the roller surface at one frequency can provide very useful information. The process is reasonably rapid, allowing multiple rollers to be readily compared to see if process/materials variations produce changes.

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Michael H. Lee, Seongsik Chang, Quang Lam and Omer Gila, Hewlett-Packard Laboratories, Palo Alto, CA 94304

Abstract

The binary ink developer in the HP-Indigo press selectively applies condensed ElectroInk® onto the photoreceptor to form the image. The ink is transported by the elastomeric developer roller, which needs to be sufficiently conductive to allow its surface voltage remains essentially constant as it moves through the various interfaces encountered along its periphery. But it cannot be so conductive as to discharge the ink before it is developed. So it would be useful to know the roller resistance and its uniformity.

In this work we describe an impedance technique to map the developer roller resistance across its surface. The roller only needs to be a single conductive dielectric layer. Hence its relevant impedance spectrum can be simple and uniquely determined by the corresponding capacitance and resistance obtained at a single well-chosen frequency. Although the actual material can be more complex, we show that scanning the roller surface at one frequency can provide very useful information. The process is reasonably rapid, allowing multiple rollers to be readily compared to see if process/materials variations produce changes.

Introduction

HP Indigo presses use a liquid electrophotographic (LEP) process to produce excellent print quality (PQ) [1,2]. One key element is the binary ink developer (BID) unit [3,4] which converts the low viscosity ElectroInk® [5,6] entering the BID to a much more usable paste-like layer on the developer roller (DR). This densified ink is pressed against the photoreceptor (PR) and sticks instantaneously to the latent image, allowing the process speed to reach 2.15 m/s in the new HP Indigo 7500 and W7200 Series III presses. The DR in the BID and the PR ground serve as the two electrodes between which the ink paste chooses allegiance depending on the local E-field [7]. The resultant density on the PR depends on factors such as the ink characteristics in the contact zone [8].

The DR is the hub of the BID as shown in Fig. 1. The process starts in the electrode region where it accumulates ink solids. The resultant layer is compacted by the squeegee and presented to the PR. Any remaining material is removed by the cleaning roller for a clean start of the next cycle. Each step uses an electric field to retain or move the ink particles. Hence the DR resistivity must be reasonably low and consistent enough to avoid introducing a significant, variable voltage drop. On the other hand, it cannot be so low as to discharge the adjacent ink layer on its way to the PR. For the 40 mm Indigo DR this dual requirement can be met by properly adjusting the conductivity of the 4 mm outer elastomeric layer, which also helps ensure mechanical compliance. Since polymers are inherently insulative or modestly conducting, the task is to add the right type and amount of conductive agents uniformly.

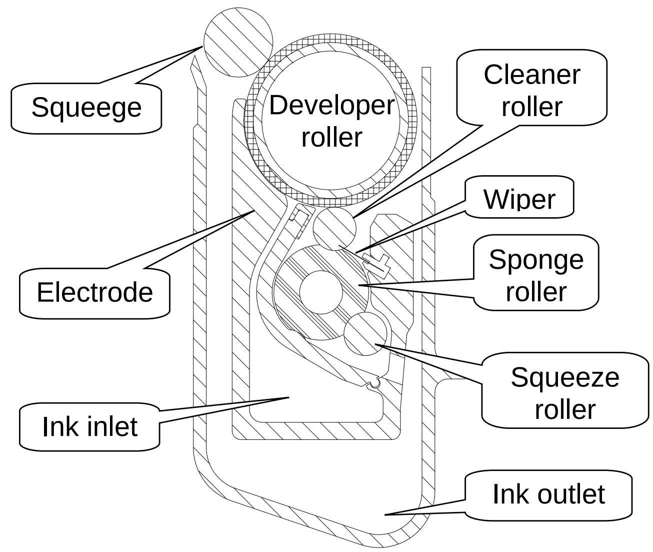

***Figure 1**. HP Indigo BID unit.*

Conductivity is typically introduced using carbon black or ion-based agents. Although zeroing in on the right concentration seems straightforward, getting good uniformity is not because it depends on the exact processing technique and conditions. For example, mixing may be incomplete and additives may move during material curing. So having a way to assess the roller resistivity magnitude and uniformity is desirable. In this work we show that these characteristics can be determined using an impedance technique similar to that used previously for studying Indigo-style blankets [9] and inks [8]. We find that the resistance profile across the roller surface differs significantly among rollers depending on the process conditions and materials used. Hence the technique can be used to provide a quick assessment of any contemplated process/material change.

Experimental

The impedance measurements were done using two different tools. One is the Solartron 1280B Electrochemical Test Unit [8,9]. This instrument returns Z as ($|Z|$, θ) or (Z', Z'') and can operate from 1 mHz to 20 kHz. For the DR the results were obtained between 1 Hz and 10 kHz, which covers the critical frequencies for the DR and more. In one earlier work [9] we used a pair of 25.4 mm by 40.6 mm electrodes inside a housing placed against the blanket to apply the signal. Here we use a similar arrangement with one same sized electrode that has been reshaped to conform to the roller surface (Fig. 2, bottom). This has 11.2 cm^2 area, about

8% over the flat electrode. The other electrode was replaced with a recessed block connected a wire and clip that is attached to the DR shaft to supply the return current path.

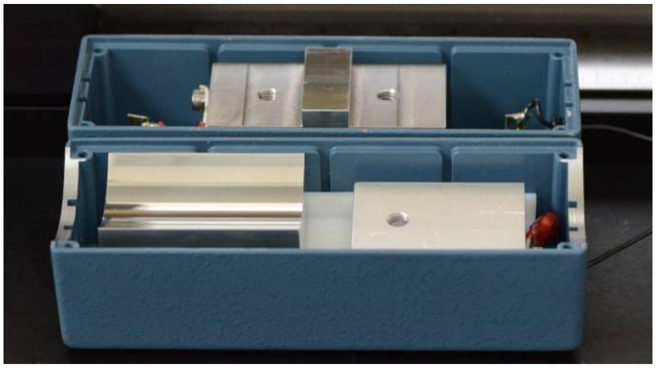

***Figure 2**. Electrode housing for mapping using 10 mm wide electrode (top) and DR-conforming electrode for impedance spectra (bottom).*

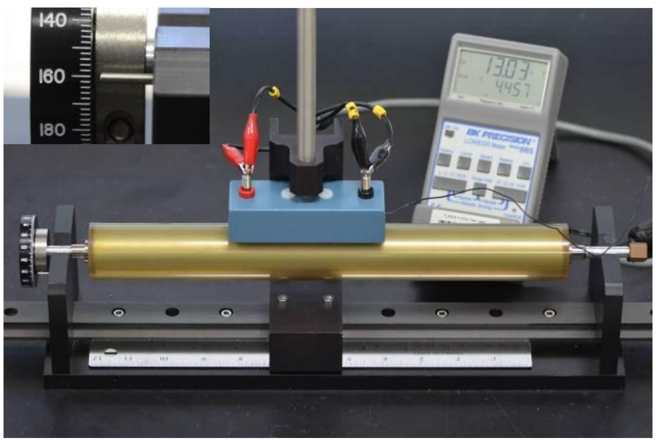

***Figure 3**. Apparatus for holding DR during impedance mapping. The electrode housing sits on top of the DR and against the structure that keeps it aligned. The vertical rod supplies repeatable pressure to the housing.*

For surface mapping a BK Precision Model 885 LCR/ESR meter was used. It provides Z in the same two forms at four frequency choices, 100 Hz, 120 Hz, 1 kHz and 10 kHz. In principle a single-layer leaky dielectric can be characterized by (|Z|, θ) at any frequency. But the roller material deviates a bit from ideal, and hence mapping results are not identical for results obtained at f a decade apart. Nevertheless, choosing just one is generally close enough if the task is to see whether the roller is uniform or not.

A photo of the mapping apparatus is shown in Fig. 3. The DR is place on a stand with V notches to align the shaft. A wheel with engraved angle markings is attached to one end of the shaft. The roller can be turned on the stand and its orientation determined relative to a stationary pin. A stage is used to align the electrode housing and to hold it down using a vertical rod. A scale pasted on the stand gives the horizontal position of the stage, which can be slid parallel to the DR shaft. The electrode arrangement is the same as that used for the Solartron but the electrode replaced with a flat one 10 mm wide (Fig. 2, top) with a 2.5 mm contact width. Since the polymer is 4 mm thick, there is some current spread to the DR shaft. Simulation was done to determine the correction factor to obtain the right resistivity. Note that the area needed to obtain stable measurements is much smaller for the BK instrument.

Results and Discussion

Within the 30 mm electrode region the DR picks up ink solids, which need countercharges to hold them in place. The DR interactions at the other interfaces occur much faster, in the ms range. These set the required frequency response for the DR, ~0.1 to 1 kHz. A single-layer dielectric with the right conductivity should be sufficient, at least with respect to electrical characteristics. For our tests we look at the impedance spectrum over an expanded range, 1 Hz to 10 kHz, to see a bigger picture.

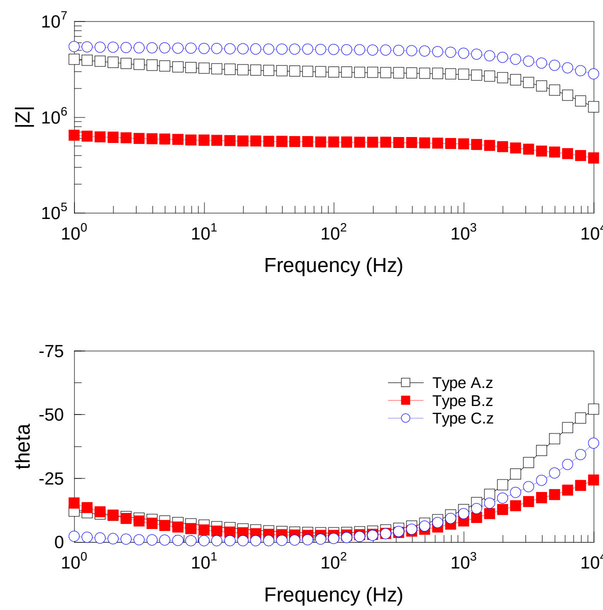

***Figure 4**. Impedance spectra of three rollers, which all appear to be essentially resistive in the relevant frequency range.*

Consider the spectra of three DR-sized rollers (Fig. 4), which use different polymers, conductive agents, and/or processing conditions. Each has a nearly constant |Z| with a resistivity in the range useful for a DR. From this measurement alone, all three should operate adequately although their behaviors are not all entirely ideal (cf., Fig.4 in [9]). That would require θ to approach 0 below some f. Types A and B are at least some distance from 0 and turns up below 10 Hz. The increase is similar to that seen with Indigo-style blankets [9], characteristic of a surface layer. But here the corresponding f is significantly lower, indicative of a much thinner and likely irrelevant layer.

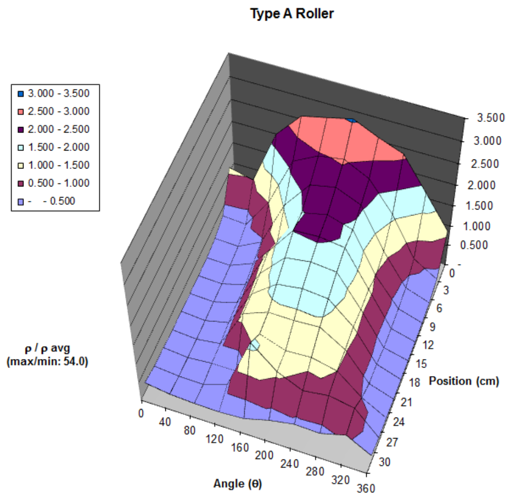

Figure 5*. Impedance profile of Type A roller. The local resistivity is clearly not uniform with maximum/ minimum over 50.*

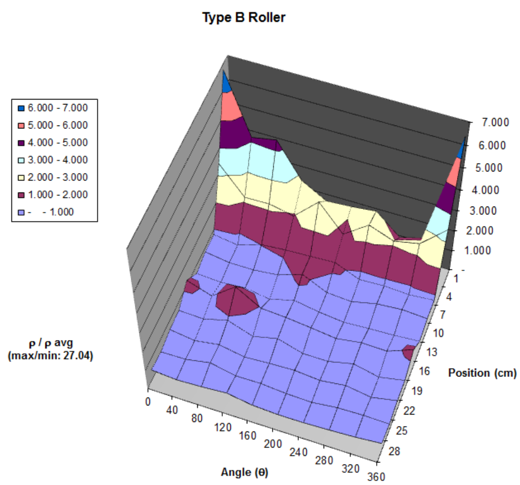

Figure 6*. Impedance profile of Type B roller. The local resistivity is not uniform but the nature is clearly different than that of Type A.*

While the impedance spectra suggest that each roller may work in the BID, more data would be helpful. Figure 5 shows the impedance mapping of a Type A roller at 1 kHz. The average resistivity was found to be 9.2 MΩ-cm, in the same ballpark as that measured with the Solartron shown in Fig. 4. But the variation is extremely large, over a factor of 50. One side of the roller is much more resistive than the other, and that side is graded from one end to the other. Contrast this with the mapping obtained on a Type B roller shown in Fig. 6. The ratio of highest and lowest values is almost as large, around 27. But most of the high resistivity region is confined to one end of the roller. The average resistivity from the mapping is 0.59 MΩ-cm, very close to that in Fig. 4.

Making rollers non-uniform is probably quite easy if the formulation process is not well thought out and care not taken to make sure it is done correctly. But it is also possible to produce ones that have little variations under the right circumstances with the right materials. Figure 7 shows the impedance mapping of a Type C roller. At first glance there appears to be some sizable difference between two sides half a circumference apart. But in fact the vertical scale here is quite small, ranging from 0.9 to 1.1. The ratio between the extremes is just 1.13 compared to at least 27 for the previous two rollers, over 20 times smaller.

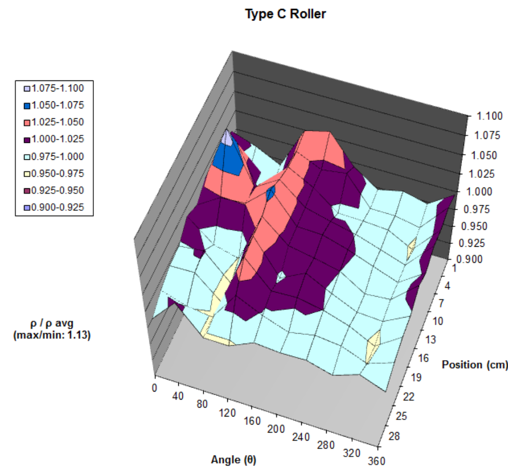

Figure 7*. Impedance profile of Type C roller. The vertical scale here goes from 0.9 to 1.1 compared to 0 to 3.5 and 0 to 7 for Figs. 4 and 5, respectively. The resistivity variation is just a small fraction of that in Types A and B.*

Process changes can alter the resistivity profile of a particular formulation. Figure 8 shows the mapping for a Type D roller made with a certain process. Here the roller is non-uniform along its circumference. On the resistive side, it is more so one end compared to the other. Its general profile bear some resemblance to that of the Type A roller (Fig. 5), suggesting that perhaps a similar technique or process was used. Figure 9 shows the Type D roller made using a different method than that for the roller in Fig. 8. This impedance profile looks nothing like the other, remaining relatively flat over most of the surface. The resistivity only increases on the ends and is highest on the opposite end compared to the ones in Figs. 5, 6 and 8. Along the circumference the roller is relatively uniform except at the far end where there was an increase to a spike. This result suggests that tracking the impedance profile with the process can provide clues as to how better uniformity can be achieved.

Our mapping process is relatively quick and painless. At each designated position along its length, the roller can be turned step-by-step until the required angles have all been checked. The housing is lifted and put back at each step. After placing the rod on the housing, the reading can be recorded within a few seconds. For a laboratory environment, this process is perfectly adequate. If automation is desired, the stand design would be more complex. Some means of indexing the radial position would be needed along with a screw drive or equivalent to move the stage. Some way to move the housing up and down would also be required. None of these is difficult. It is a question of whether enough measurements would be done to justify the time needed for the design.

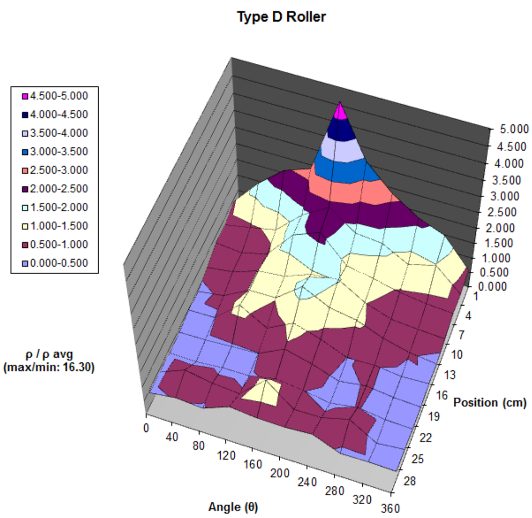

Figure 8*. Impedance profile of Type D roller. The roller was fabricated using one process.*

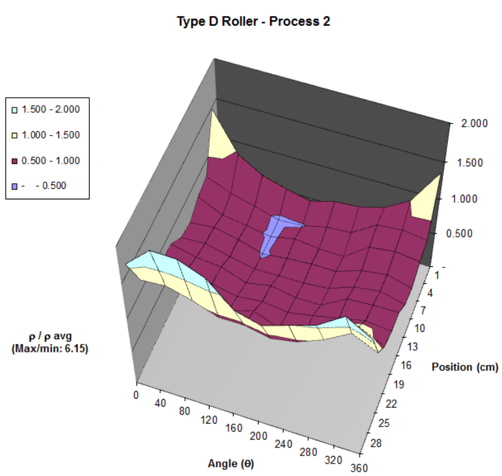

Figure 9*. Impedance profile of Type D roller. The roller was fabricated using an alternative process aimed on improving the resistivity uniformity compared to the other version.*

Conclusions

In this work we discussed the role of the BID DR in the Indigo LEP process and its electrical response requirements. For this a single-layer conducting polymer is sufficient so long its resistivity is in the proper range and relatively uniform. Some rollers fabricated in the form of a DR were examined with respect to these two parameters using an impedance mapping technique introduced here. Although the values obtained may not uniquely determine the roller electrical characteristics, they are close enough to give the big picture. Indeed, vast differences in the impedance profile can be seen among rollers made with different material sets and in different ways. This mapping need not be confined to the DR. It is a tool that any roller formulator can use to improve the electrical uniformity of that product.

Acknowledgments

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Author Biography

Michael H. Lee is a Principal Scientist at HP Labs in Palo Alto. He received his B.S. from the University of California at Berkeley in 1971 and his M.S. and Ph.D. from the University of Illinois at Urbana-Champaign in 1972 and 1974, respectively. He has worked in electrophotography since 1983, focusing more recently on the HP Indigo LEP process. He served as General Chair of NIP15 and is currently an Associate Editor of JIST. He is a Fellow of the IS&T.