

Making negatives and plates for printing by electroerosion: Introduction and overview

by K. S. Pennington

The most familiar electroerosion printers operate by removing the whitish or silvery aluminum overlayer from discrete areas of a special paper so as to reveal a black underlayer. The direct negative/direct plate (DNP) material described here is a new dual-function printing material which, when employed together with an electroerosion printer, allows direct generation of negatives or (short-run) offset printing plates suitable for use in printing and publishing applications. The DNP material has been specifically developed for use with the IBM 4250 electroerosion printer family, allowing these printers to generate negatives, plates, and camera-ready copy directly from the computer with no chemical processing.

Introduction

The field of printing and publishing is undergoing rapid change. With the advent of all-points-addressable page

printers combined with appropriate document composition software, many people who had previously been constrained to printing documents in one of a few limited font styles were able to generate composite documents containing multifont text and, in some cases, halftone images. The ability to create such documents with a small workstation and an associated laser printer has prompted the rapid growth and acceptance of "desktop" publishing. At the same time, a rapid increase in the capability of workstations is leading to a situation where many of the high-quality or high-demand publishing applications currently residing on mainframes or minicomputers can be supported on workstations of modest size. This trend, of course, will allow the mainframe either to be offloaded to work on other applications or to provide increased support for the entire publishing application, e.g., database support, remote access, networking, and/or remote publishing. Concurrent with this evolution of the basic application software and computer hardware, we are witnessing a rapid improvement in basic printer, scanner, and display devices. In particular, computer-output page printers are driving toward the increased resolution and

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addressability (600–1000 pels per inch) required for many moderate-quality graphic arts applications, and in some cases these printers are incorporating the ability to print color. Laser electrophotographic printing is the major nonimpact printing technology in use for desktop publishing applications and is finding rapid acceptance in support of many major publishing applications. Ink-jet printing and thermal transfer printing technologies, on the other hand, have been demonstrated to have significant potential as proof printers, in particular providing high-quality color proof documents.

Electroerosion printing [1] has been available for many years and was widely used in various strip-chart and low-quality printing applications prior to the introduction of the IBM 4250 printer. The 4250 combined that basic technology with high-resolution print heads [2] to produce printed copies suitable for use as relatively high-quality camera-ready copy.

This overview is intended to introduce a series of in-depth technical papers that deal with the processes involved in producing a new electroerosion printing medium known as direct negative/direct plate (DNP), which extends the use of the 4250 into other major areas of printing and publishing. With DNP, the 4250 is able to support three types of media commonly found in printing/publishing applications: camera-ready copy created through the use of a special aluminized paper, and negatives and offset printing plates generated directly on the printer through the use of the new DNP material. Thus, the DNP material has allowed the IBM 4250 to reduce the number of procedures and improve the workflow in several publishing applications.

Combined with the trends in the other all-points-addressable (APA) printers noted above, the DNP material further increases the range of publishing applications that can be met through the use of one or more of the available computer-output printer technologies. The advantages that can result from the use of the DNP technology (together with computerized document preparation) fall into several areas: 1) No chemical processing for the plates or negatives; 2) reduced time in document preparation; and 3) greater control over the document, procedures, materials, and processing costs throughout the entire publishing process.

Basic principles and early developments

The IBM 4250/II ElectroCompositor is a relatively high-resolution (600 dots per inch addressable, 300 dots per inch printable) electroerosion printer that can use two types of printing media and provide three types of printed output. If a special aluminized paper is used, the printer is capable of producing relatively high-quality camera-ready copy or page proofs that are suitable for use in several in-house publishing applications. In this application, the print head

of the 4250/II (which consists of an array of 32 electrodes of 80- μ m diameter) selectively removes aluminum from the surface of a special paper by injecting current into the aluminum film. The high current density beneath an addressed electrode erodes the aluminum from the paper surface, revealing a black varnish underlayer.

Alternatively, if the DNP material is used, the printer will directly generate negatives or offset printing plates with no need for chemical processing.

During the initial stages of development of the IBM 4250 printer family, the electroerosion printer was supported with just the special aluminized paper. It was, therefore, only possible to use the printer in publishing applications where the generation of camera-ready copy was a necessary and/or appropriate procedure. This severely limited the number of publishing applications that could be addressed with the 4250 and associated application software. These limitations could be virtually removed by providing the capability to generate negatives and offset printing plates directly on the electroerosion printer. To realize this enhancement, IBM Research started a project in this area in 1977.

The original concept and early investigations focused on the use of an aluminized polyester substrate as the electroerosion printing material [3, 4]. An electroerosion printer that employed a single 80- μ m electrode print head was used in the early stages of these investigations. With this approach, it was rapidly shown that aluminized polyesters with aluminum film thickness greater than 50–55 nm could be printed if used on a printer with the relatively low current/voltage drivers of the 4250. The offset printing plates that resulted from this process, however, were only capable of printing approximately 500 copies before the print quality deteriorated significantly. This plate life was totally inadequate for supporting the broad set of applications we hoped to address with the IBM 4250 printer.

To overcome these limitations and provide more suitable offset plate performance, we immediately investigated alternative material structures.

During the early and rudimentary stages of this research, we were able to achieve significant improvements in plate life by modifying the electroerosion film so that capacitive storage of electrical energy occurs prior to the arc breakdown that normally results in printing [4]. This capacitive approach resulted in the ability to erode through thicker aluminum films.

For this operation we fabricated the electroerosion material as follows: A relatively thick aluminum film (120–180 nm) was evaporated onto a polyester substrate, and then a 40–50-nm film of aluminum oxide was sputtered onto the surface of the aluminum. The primary advantage of this procedure (Figure 1) is that during the electroerosion printing process the aluminum oxide film

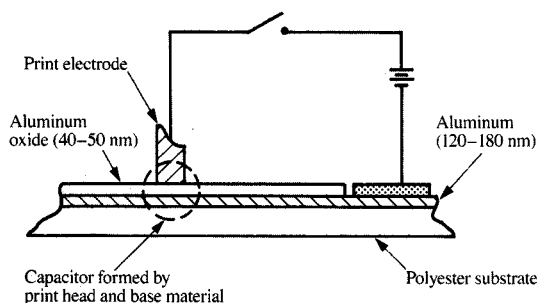


Figure 1

Diagram of the capacitive structure that allows electroerosion printing through relatively thick aluminum films with relatively low electrical drive requirements of the IBM 4250 printer. Although long run plates were produced, the material was unsuitable for use with a multielectrode print head because of mechanical stresses.

initially serves as the dielectric in a capacitor. This capacitor, formed by the print electrode, aluminum oxide, and aluminum film, initially charges up during an applied electrical pulse. The high field intensity across the aluminum-oxide dielectric during the applied pulse (10^7 V/m) ultimately results in electrical breakdown of the oxide and removal of both the oxide and the aluminum film. The rapid charging/discharging of the capacitive circuit yields a practical method for supplying greater peak electrical power to the aluminum film. This results in the ability to electrically erode through relatively thick (180-nm) aluminum films. Conversely, in the absence of the 40-nm aluminum-oxide film on the surface of the aluminum film, it was not possible to print reliably on aluminum films thicker than 50 nm with the electrical drive electronics available on the 4250. Attempts to print on such thick aluminum films without a suitable oxide coating were unsuccessful because thermal/electrical energy was generated and conducted away from the print electrode too rapidly to permit total removal of the aluminum film. The ensuing rapid melting and cooling of the aluminum beneath the print electrode often caused spot-welding of the electrode to the aluminized substrate, resulting in an inability to print reliably and excessive "scratching" and degradation of the print quality. The use of an aluminum-oxide film substantially thicker than the 2-4-nm natural oxide that forms on aluminum provided the capacitive energy storage and high peak-power electrical discharge characteristics described earlier, while avoiding spot-

welding and associated printing problems. Also, the hard aluminum-oxide film was believed to reduce the rate of plate wear in the background areas and increase plate life.

Electroerosion printing on these thick aluminum-oxide/aluminum films was shown to produce offset printing plates with significantly improved press life (approximately 10 000 impressions). However, it was found that these materials would not print with high reliability and quality when used on the IBM 4250 printer. Significant scratching of the material was caused by the severe mechanical stresses generated in the thin-film structures by the print head. Such scratching had not been observed when the material was printed on a single-stylus electroerosion printing robot, because it had been possible to adjust the pressure on the single printing electrode to avoid scratching. However, to achieve reliable printing at all electrodes of the high-resolution multielectrode print head on the 4250, it was necessary to apply sufficient pressure to the head to ensure very good electrical contact at all electrodes. Under these circumstances, the pressure under any single 80- μ m electrode often exceeded that required to remove the aluminum from the substrate.

These results indicated that more complicated multilayer structures were needed to satisfy the conflicting mechanical and electrical demands for fabricating a DNP material that would print reliably on the 4250, satisfy the requirements of use as a negative and printing plate, and also be relatively cost-effective. It was with this realization that the author reinitiated the research and development efforts to achieve a suitable material in 1979. Brief descriptions of the development and use of DNP material resulting from this latter work have been given elsewhere [5, 6]. The actual technical details which were associated with the development of the DNP and which culminated in the manufacturing of the IBM electroNEG material are given for the first time in the following papers [7-9]. The extensive nature of this type of materials and applications development made it necessary to divide the work into several sections.

Part I, *Physical principles*, describes many of the phenomena that combine to produce the printing technology called electroerosion printing. The electroerosion process is exceedingly complex, though our understanding of it grows as we continue to develop and study the overall print-head/material interface. Part I includes most of the understanding that led to the first practical and manufacturable materials. Further development of the overall factors that contribute to the process will be described in future papers.

Part II, *Larger-scale fabrication and testing*, describes the various processes and procedures that were developed to test and manufacture the resulting materials reliably. The various materials and process parameters and their influence upon the functional characteristics of the DNP

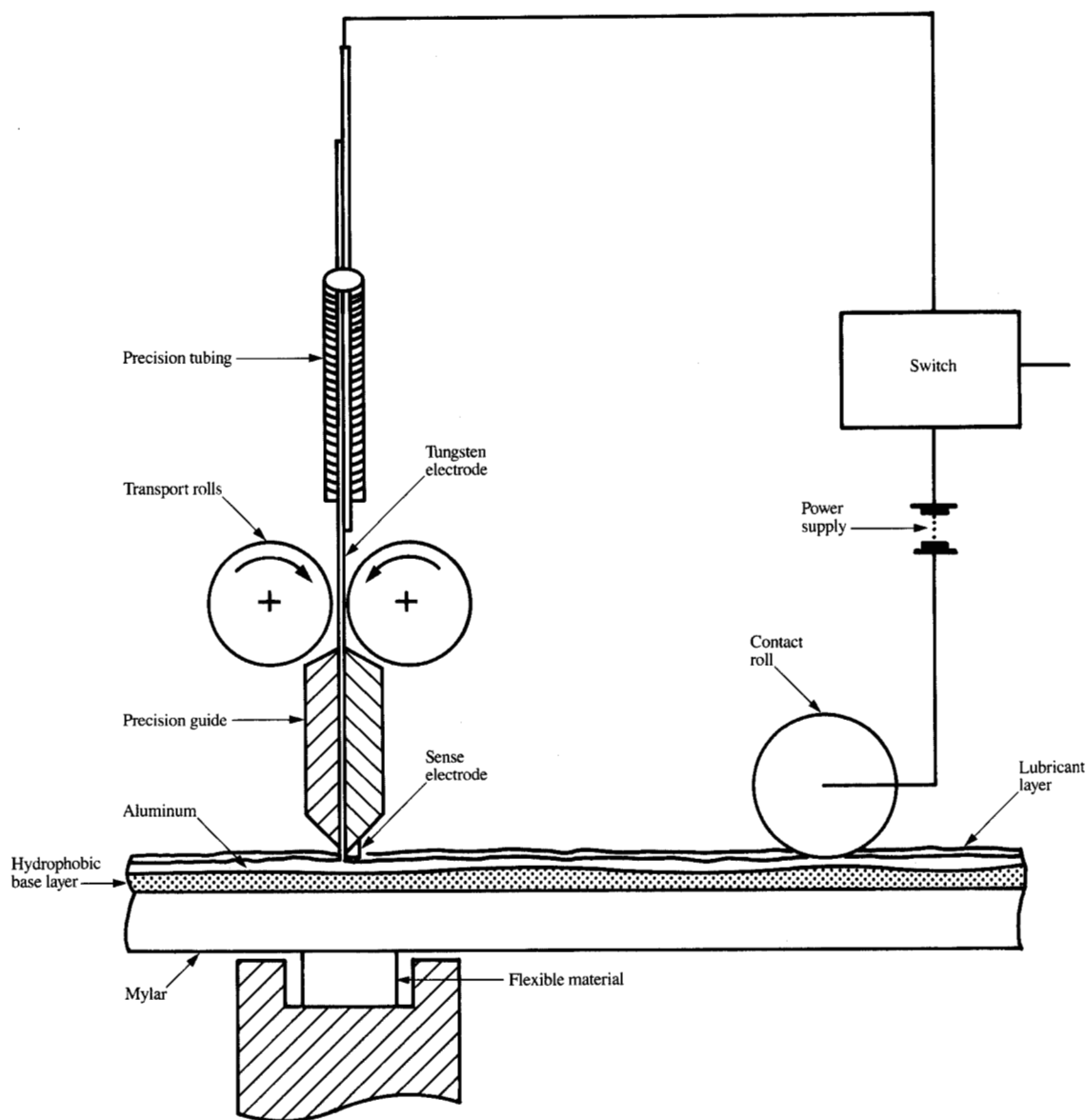


Figure 2

Schematic representation of the electroerosion (multielectrode) printer and direct negative/direct plate printing substrate. Note that the Mylar support layer and hydrophobic base layer are both transparent, allowing the printed material to be used either as a negative or as a direct printing plate.

materials are discussed, together with their potential impact upon the manufacturing process window.

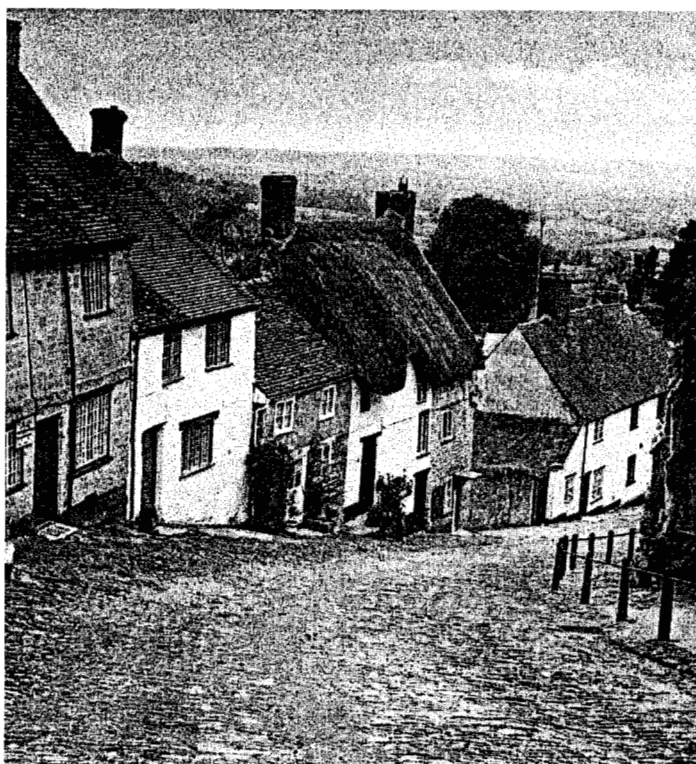
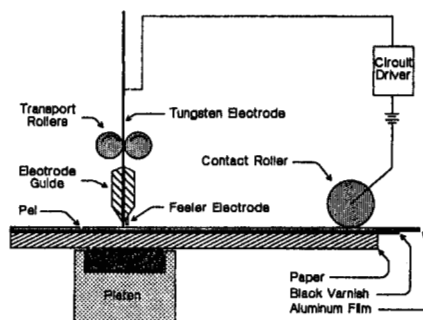
Part III, *Use of the direct negative and direct plate*, deals with most of the functional characteristics associated with the use of the DNP material in applications supported

by the IBM 4250 printer. This paper describes the application of the first released DNP product, the types of defects that have been observed in this material, and some of the technical parameters that influence the defects. In particular, we discuss the use of the DNP as an image

Using the IBM 4250 with the New Direct-Negative/Direct-Plate Material

The IBM 4250 creates text, graphics and images on a special medium by selectively vaporizing an aluminum film by a process known as "electro-erosion". This technology produces very high quality output (600 pels/inch addressability).

Either the standard aluminized paper medium or the new DN/DP medium can be used in the IBM 4250. *The new DN/DP material could give the publishing industry a revolutionary capability to go from computer to printing press with almost no intermediate steps.*



The IBM 4250 technology, when used with recent IBM Research halftone algorithms can also

produce high-resolution halftone pictures (equivalent to a standard 141 line/inch screen).

(THIS PAGE WAS PRINTED FROM A DIRECT PLATE)

Figure 3

Composite text, graphics, and halftone image created by offset printing using a direct plate printed on the IBM 4250 printer. The digital halftoning employed a randomized error carry method developed by Goertzel and Thompson [10].

negative, as well as the procedures required to use the material in direct-plate applications. More recently, we have made significant improvements in the functional characteristics of the original product. These modifications, which have resulted in considerable improvement in plate life, optical density, print quality, handling, and preparation for the press, will be described in a subsequent paper.

The DNP material which resulted from these studies and which IBM now markets under the trade name electroNEG, is a specially formulated, dual-function multilayer material that extends the capabilities of the IBM 4250/II electroerosion printer to the direct generation of negatives with no need for chemical processing, and the direct generation of (short-run) offset printing plates.

Also, but of lesser importance, the material may be used to generate high-resolution overhead projection foils. With these additional capabilities, the 4250/II provides a fast, high-quality, cost-effective way to obtain integrated text, images, and graphics from a publishing system. The output from the printer is available in any of three modalities (plate, negative, and camera-ready copy), each of which is of use in various publishing procedures and applications.

The basic principles of electroerosion printing and the structure of the new DNP material are illustrated in **Figure 2**. The print head consists of an array of small-diameter tungsten electrodes (only one shown) which contact the aluminized surface. The high current densities existing beneath an electrode when it is addressed with a current pulse result in intense local heating, culminating in a miniature localized arc discharge. The arc discharge removes the aluminum beneath the addressed electrode, thereby breaking the circuit and terminating the arc. Since the substrate is chosen to be transparent, this local erosion of the aluminum results in transparent regions in an otherwise relatively opaque aluminum film (optical density ~2.0). When printed, the resulting substrate therefore has the characteristics of a negative transparency.

The aluminum film is hydrophilic, while the polymeric underlayer is hydrophobic; therefore, modulating the current to the print head in order to erode the aluminum film to produce an image of a document immediately results in the direct generation of an offset printing plate. Thus, the DNP material allows a direct link to be made from the IBM 4250/II printer and the associated publishing system to either a plate maker or printing press without chemical processing.

Discussion of applications

There are many potential applications of the DNP technology within the general domain of publishing. Since it is inherently a relatively high-resolution, all-points-addressable nonimpact printing technology, it is well suited for use as an image-setter (i.e., a means for generating

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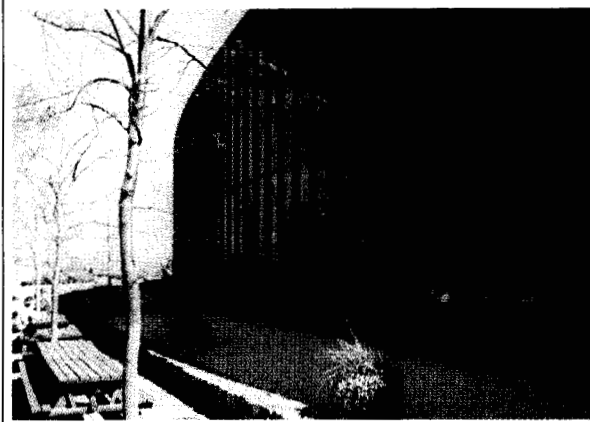


Figure 4

Color image printed from plates made from four-color separation negatives produced with the DNP material on the IBM 4250 printer. The digital color halftone screening methods used were developed by Goertzel and Thompson [11].

printable images other than typographic letterforms) in many applications. It is particularly useful when fast image-setting and the creation of multipage signatures are desired. Software has been developed to support the composition of complex documents that include text, graphics, and halftone images and to allow pages to be appropriately assembled in multipage signatures.

Depending upon the wishes of the user, it is possible to provide direct output of entire composite pages that have been formatted at a workstation and then printed out by an IBM 4250/II printer. This output can be either a direct plate (correct reading), a direct negative (mirror or wrong reading), or camera-ready copy (electroerosion paper). An example of a halftone image, combined on a page with type and a line image and printed with a direct-plate application, is shown in **Figure 3**. The "wrong reading" direct negative is made by using a software option that merely reverses the order in which the bits are read out to the printer during each scan of the print head. It allows direct-contact copying of the image onto a long-run lithographic printing plate. The direct negative mode of operation has been used by Goertzel et al. [10] to directly generate four-color separation negatives from scanned color images. These negatives were then used by a publisher to generate the appropriate imposition offset printing plates and print an entire color brochure, an example from which is shown in **Figure 4**.

In practice, these different modes of operation allow for potential improvements in both the time and procedures required in many applications. With appropriate use of these features, it is possible to eliminate many of the cut-and-paste operations frequently used in the publishing industry and to substitute for them scanned images combined with computer-generated text and graphics supported by suitable image- and text-editing programs. With appropriate applications software it is possible to generate multipage impositions (complete with the positioning adjustments required for page cross-alignment, folding, and binding) and print them on the IBM 4250 wide-carriage machine, thereby further reducing the overall handling and amount of skilled labor required for the "pre-press" process. Also, as noted above, relatively high-resolution, digitally screened grey-tone and four-color separation negatives have been generated with the use of the DNP material on the 4250. The digital screen resolution is currently limited by the resolution of the 4250 (i.e., 600 dots per inch addressable, 300 dots per inch printable). Screen resolutions of approximately 150 lines per inch with a 20% minimum grey tone have been achieved [11], and with the use of special digital halftoning algorithms it has been possible to print images with adequate quality for many low-end graphic-arts-quality printing applications (e.g., Figure 4). Ample experimental evidence indicates that the electroerosion printing technology is capable of printing at resolutions substantially higher than those achieved with the present 4250. In fact, a modified 4250 printer has demonstrated print resolution of 900 dots per inch addressable, 600 dots per inch printable. At this resolution, it is possible to create screened images at 150 lines per inch with approximately 5% minimum grey tone.

With upgrades in the electroerosion printer combined with the continued evolution of the DNP material and the supporting publishing system application software, it would be possible for a wider segment of the publishing market to directly generate plates and negatives adequate for its publishing needs and to maintain greater control over the entire publishing operation and associated costs. These and other advances in the publishing technologies will soon result in a greater ability to meet the demands of "just-in-time" publishing and will result in significant benefits to industry by reducing the time, material, and capital costs associated with publishing.

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