D_2T_2 Printing after Two Decades

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Abstract

Dye diffusion thermal transfer printing has been in the marketplace for 20 years. During that time, the technology has evolved from a special purpose curiosity to an everyday product that consumers use in their homes and drug stores. What has changed over this time to bring about this revolution? This paper will discuss the evolution of the technology over time, and the technology enablers that were key elements in the evolution.

Twenty Years of Thermal Printing

The beginning of dye diffusion thermal transfer (D_2T_2) printing can be traced to the 1980s announcement by the Sony Corporation of the Mavica, and the Sony vision of filmless photography [1]. The Mavica was a digital still camera, with magnetic storage. At that time, printing was impact printing only, either printing plates, plotters, or mass transfer type of imaging. Digital printing was virtually nonexistent, and photos were done only in the darkness of a lab processor. The simple idea of adding text to a photograph was a task that required a skilled technician, and a photo mask of the text! High-quality photographic prints can now be obtained with thermal printers in seconds, using low-priced equipment. What formerly required the equivalent of a minilab and a dark room with chemical processing can now be accomplished in one's living room with a minimum of effort.

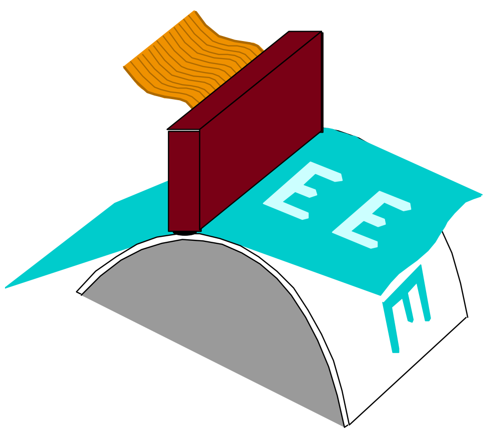

Figure 1. *Illustration of the imaging process of D_2T_2*

D_2T_2 is defined here as dye diffusion, and does not include the binary types of thermal transfer used in labels, signs, and thermal faxes. In this process, heat from a thermal printhead is used to transfer dye in a continuous tone manner from a donor to a receiver (Fig. 1.). The term "dye sublimation" is a misnomer —the process is hot diffusion of dye through polymer layers.

Some of the enablers that made it possible for the transition to today's state-of-the-art thermal printing are:

Software Compression

In 1986, a committee began work on what we now know as JPEG compression [2]. The impact that this committee has had can hardly be underestimated. The era of the 1980s was characterized by the adoption of the personal computer and the start of an unprecedented escalation in data handling. The progression of storage from early PCs with a floppy disc drive or two that stored 360 kB, to today's giant hard drives of 300 or 500 GB is a remarkable progression. Computer RAM memory has also increased from a typical 640KB up to 256 – 512 MB at a minimum. In spite of these two however, JPEG compression was needed for two principle results: (1) scaling down the time and hardware requirements for data transmission by a significant factor (a factor of 10 is usually possible without much visual impact), and (2) establishing a standard for file format that could be agreed on by camera manufacturers, printer companies, and software makers. This standard was required to avoid frustrating consumers by the complexity of digital imaging.

Perseverance on the Part of a Few Companies

In the mid-1980s, Kodak tracked the patents issued by other companies. In thermal printing, we were actively tracking the patents of approximately 100 companies. Now the number of hardware companies making significant numbers of thermal printers can be listed on two hands. Sony, Mitsubishi, Kodak, Alps, Zebra-Atlantek, Hi-Touch, Copal, Shinko, and Altech are among the major players.

In media, a few companies, such as Dai Nippon, Sony, Kodak, ICI, and Hansol, and until recently, Konica-Minolta, make most donor ribbons. Receivers are custom as well, and with some exceptions, they are generally made by the same manufacturers as the donor.

Availability of Lower Cost Components with Higher Functionality

One key enabler was the price of the printhead itself. Although published data are not available, the traditional parameters of volume and competition made huge strides in reducing printhead cost. A related enabler was the paper shuttle mechanism. Many of the original printers had paper wrapped around a drum with a printhead tangent to the circumference. However, this required an expensive drum and a large print head to allow the donor ribbon to pass under it, driving up costs. The adoption of a capstan drive for the receiver, so that the platen roller could freewheel and be very small in diameter, enabled smaller and cheaper printheads.

The vast majority of thermal printers have used a full-width printhead, leading to one of the principle speed advantages of thermal. Line time (Fig. 2.) can be used as a measure of progress over the years. This chart shows the line time change from a printer, such as the Kodak XL 7700 digital continuous-tone printer in the early 1990s, to a modern kiosk printer and typical print times for 4″ × 6″ prints in more recent times.

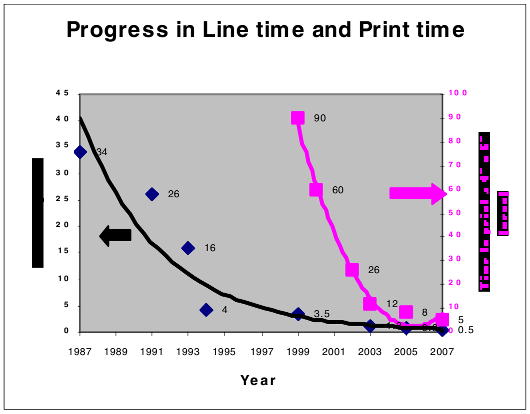

Figure 2. Line time in thermal printers over a period of 20 years

Availability of Lower Cost, Reliable Printers

In the mid-1980s, the first pictorial thermal printers began to appear, in low-quality applications first, such as small format identification cards. This was by necessity because the technology was limited by video signals, and there is not enough information in a video signal to make a 3R or 4R print with good quality.

Kodak's first entry into a photo-quality printer was the XL7700 printer introduced in 1989. While this printer won awards because it was one of the first thermal printers to achieve what Kodak considered photographic quality, it weighed over 125 lb, was sold at >$20,000, and took over 3.5 min to make an 8.5" x 11" print. Making a page-size transparency required between 3.2 and 12 min, depending on density and ribbon selection. High-quality transparencies required two passes of yellow, magenta and cyan to achieve a good transmission density.

While page size printers still require a reasonable footprint, print times have decreased to 30–45″ seconds in the latest printers.

Snapshot-sized printers for 3″x 5″ or 4″x 6″ prints have been in the marketplace for a number of years, but only in the past three years have they become prominent. Numerous snapshot printers are on the market for prices of $129–$200, some of which have remarkable features for the price, including memory card readers, Wi-Fi and Bluetooth wireless connections, and the ability to print borderless, full-bleed prints with full lamination. These printers have established a new standard in ease of use, and they have been well accepted in the marketplace.

Figure 3. *Sample printer for snapshot-sized prints*

Increased Power of Personal Computers

Thermal printers have benefited by the Moore's law trend in personal computer's performance. Early Kodak thermal printers required on-board SPARC processors and internal hard drives to avoid tying up the host personal computer for extensive periods of time while they delivered data to the printer. Of course, when desktop computers had adequate performance to handle the chore, the printers became more affordable. In addition, the on-board computer led to the forerunner of today's kiosk, the print copy station because the early printers needed only an input device such as a scanner and a monitor to complete the hardware requirements.

Software to Improve Image Quality

Software has been a hidden but crucial enabler for thermal printers. Previous papers at this conference have discussed many of these features. Software corrections that have been used commercially are:

a. Head correction software—a one-time correction for variable pixel resistance that could result in streaks down a page;

b. Parasitic resistance—a correction applied to images depending on the number of energized heating elements;

c. Thermal smear algorithm—applied dynamically down the printed page to compensate for heat build up in the printhead;

d. Assisted or automatic red-eye reduction—can be applied via application software in the host or built into the printer; and

e. Scene balance algorithm—is now available in sub-$200 printers and is used to correct poor exposure, weak flash, or high contrast scenes. In many cases, the only penalty is time to process and subsequent impact on print time.

Improved Media Quality

The principle enablers contributing to today's acceptance of thermal are:

Voided Receivers That Improve Print Density

These were developed in the early 1990s and are they still being developed today. The general principle is to lower bulk density and thermal conductivity in the receiver in order to minimize loss of heat while printing. Generally, this is practiced with a voided layer or a voided film near the printing surface of the receiver. Voided films are prepared by biaxially stretching of the films with incompatible materials in them, so that stretching induces void generation. The voids provide for lower thermal conductivity of the receiver and increased efficiency of printing. See Figs. 4 and 5.

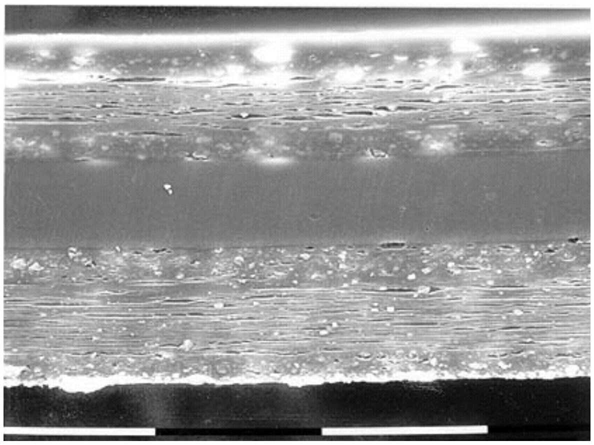

Figure 4. *SEM cross section of a voided thermal receiver, 300X*

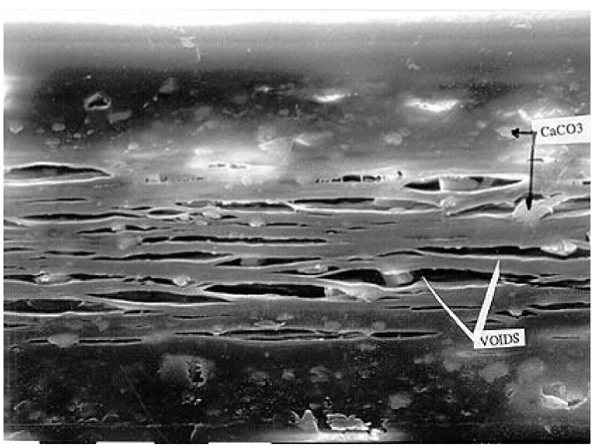

Figure 5. *Higher magnification of the voided layer, 1010X*

The improvement in density for this type of receiver is large (Fig. 6), and as a consequence, virtually all-thermal dye prints now use a voided layer of some type. Without this feature, printing requires so much more energy that other product features are degraded.

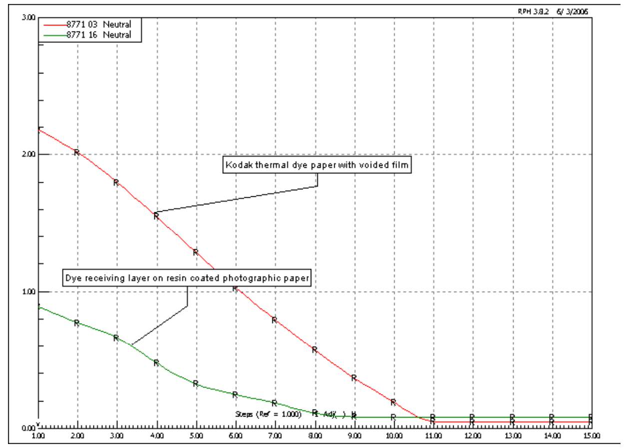

Figure 5. *Cyan sensitometric curve at equal printing energy with and without a voided layer in the receiver*

Fourth Patch Laminate

Thermal donors are ideally positioned to add a clear laminate as the fourth patch after yellow magenta and cyan printing, with little or no incremental hardware cost. This laminate protects the image against fingerprints, scratches, spills and other damage, and it can provide protection against UV light and atmospheric pollution that can reduce the useful life of the print. In some cases, the laminate is used as a means to provide custom texture to the finished print, either by printing a pattern into the surface or by otherwise modifying the surface of the laminate.

Dry Slip Layers to Prevent Retransfer

A unique problem with thermal dye donor ribbons is dye retransfer. In a rolled form, both surfaces of the donor film are in contact, and exchange of materials can occur. For example, dye can diffuse to the heat resistant layer or slip layer side of the film (1X transfer, Fig. 7). While this is undesirable, it usually results in an unnoticed loss of printable density. A problem can occur if there are two conditions present: substantial transfer of dye to the slip layer, and a change in winding geometry of the roll, such as from a master roll to a spool. Under these conditions, dye accumulated on the slip layer can transfer a second time to the dye side of the donor and cause color contamination or a colored Dmin in a print (Fig. 8). The magnitude of color contamination is so small as to be undetectable. However, 2X retransfer to a clear laminate area in the Dmin of a print can be objectionable.

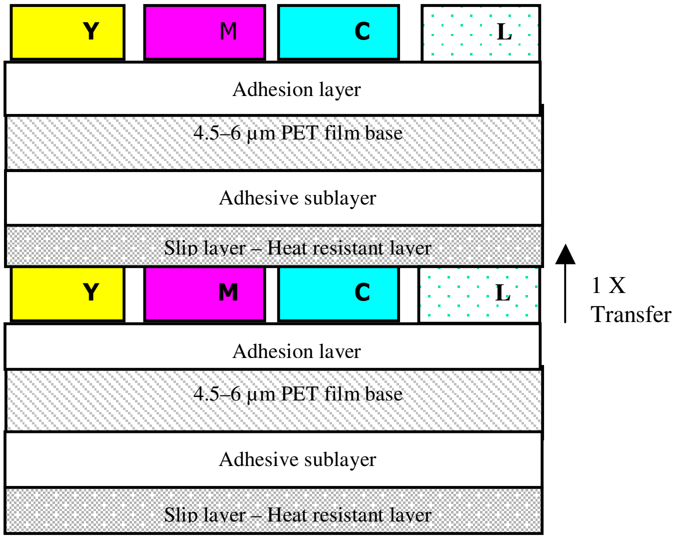

Figure 7. Typical donor ribbon configuration in a roll form

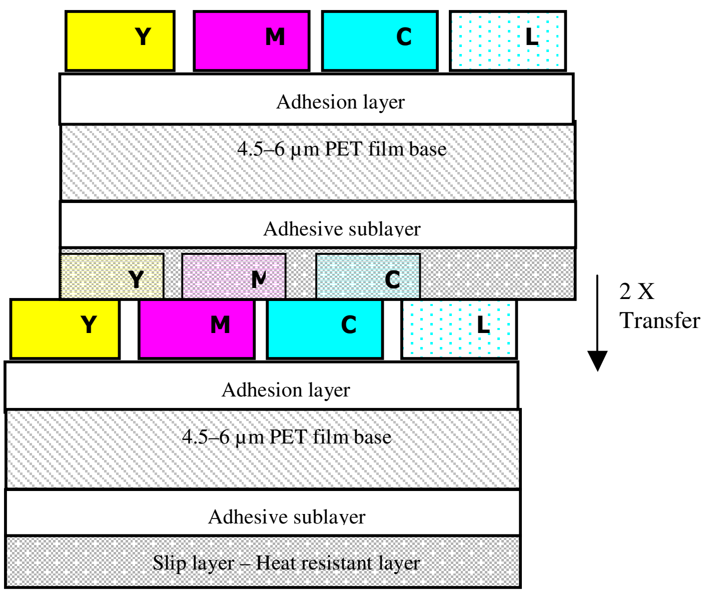

Figure 8. Donor configuration after 1X dye transfer and rewinding

Generally, retransfer is controlled by the manufacturing process, but a significant factor in reducing retransfer has been the advent of slipping layers that contain no liquid silicones.

Ease of Use

One of the primary features that has made thermal printers successful is the ease of use. In particular, kiosk printers have delivered a tremendous amount of digital imaging power to a user who has no prior knowledge of imaging software or even computer skills, with touch screen software. The consumer has the power to choose how the images are prepared, modified and enhanced. Features such as color restoration can provide in seconds what might otherwise take hours in Photoshop. On a smaller scale, home printers have worked hard to deliver more and more imaging power without increasing complexity, primarily through features such as the printer dock.

What is the Future of D_2T_2 Thermal Printing?

Thermal printers will be viable in the marketplace as long as they have unique characteristics that are marketable. Currently, these characteristics are (1) dry operation, (2) printing speed well suited for the use, (3) easy incorporation of a laminate, and (4) suitability for intermittent operation. What is required for them to continue to remain competitive and even to grow is a lower cost structure in both media and hardware. If these two principles are maintained, one can safely predict continued growth. Thermal printer kiosks in particular, have achieved a high degree of acceptance in the marketplace and we can anticipate (1) faster, (2) cheaper and (3) improved kiosks, and a more distributed network of them.

Acknowledgments

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References

[1] Sony Corporation web site; http://www.sony.net/SonyInfo/CorporateInfo/History/history.html
[2] See, for example, http://en.wikipedia.org/wiki/JPEG

Author Biography

Richard Henzel earned a Ph.D. degree in Organic Chemistry from The Ohio State University in 1972. After joining Kodak Research Labs, he learned the principles of photography in' instant' silver halide projects. The last 20 years of his career have been spent in various aspects of development of resistive head or laser thermal media.