Dye Transfer Printing by Laser Heating

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1 Abstract

High quality hard copy of electronically stored images can be produced by thermal dye diffusion printing (Hann and Beck (1990)). Such copies are of near photographic quality and have been used in such diverse areas as medical imaging and credit card personalisation. In this paper we shall study laser induced thermal dye diffusion, a process which might replace the conventional thermal head process in some applications. We shall consider in particular the ICI Imagedata L2T2 system as it is described in Hutt(1992).

Before considering the L2T2 system we shall describe briefly the conventional D2T2 thermal head system of ICI Imagedata. In this system a thin 2μm dye layer is sandwiched between a 6μm carrier layer of PET and a relatively thick receiver sheet of thickness 150μm. Heat is supplied to this layered system by a thermal printer head which is pressed against the top surface of the carrier PET layer.

When the thermal head is switched on heat conducts across the layered system. Once the dye layer has reached a sufficiently high temperature the dye molecules diffuse into the melinex and the receiver sheets. Experimental evidence shows that this is a diffusion process rather than a sublimation process. The diffusion coefficient, is a sensitive function of temperature. After about 6ms the thermal head is switched off and the system cools leaving a 'dot' of dye in the receiver sheet. In colour printing this process is repeated three times with three different ribbons (cyan, yellow and magenta). The final image in the receiver sheet is formed by a large number of dots, typically 50-300 dots per inch. Each dot is produced independently by a single printer

element in a long row of printer elements. The amount of dye transferred to the receiver sheet in each dot is controlled by altering the heating time, the wattage being the same for all the heater elements.

Although this process successfully produces high quality hard copies, it does have its disadvantages. Firstly the overall speed of the process is controlled by the time it takes for heat to conduct across the PET layer. Secondly, in order to produce high temperatures in the dye layer, the thermal head and the PET layer have to withstand even higher temperatures (350^{o}C typically). Moreover the dye will tend to diffuse into the PET layer which is at a high temperature, rather than into the relatively cold receiver sheet as is required, unless some barrier layer is applied.

In the ICI Imagedata L2T2 system heat is supplied directly to the dye-coat layer by a laser (see Figure 1). A suitable infrased absorbing material such as copper phthalocyanine is incorporated into the dye coat layer which absorbs radiation strongly at about 800nm. The dye therefore diffuses rapidly into the receiver sheet. The total amount of dye transferred depends on the temperature (via the diffusion coefficients).

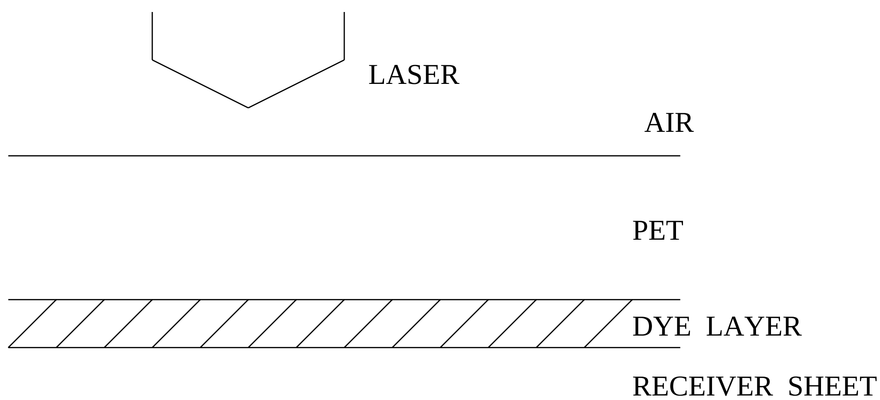

Figure 1: Typical laser system. Heat is generated in the dye layer.

As heat is supplied directly to the dye layer the transfer of dye is much more rapid than in the D2T2 system leading to more rapid and efficient printing. Typically laser heating for only 100μs is required. Another benefit of the L2T2 system is that higher resolution can be obtained since smaller dots can be produced by using lasers with a diameter of 30μm say. The diameter of a typical thermal head in the D2T2 system is 120μm.

The number of theoretical studies in the open literature of dye diffusion via laser heating is very small. Egashira et al (1993) have published a paper in which they propose a mathematical model of the process and compare it with experiments. However their treatment of the diffusion equation appears to be incorrect, and the effect of the laser has been modelled by a sheet heat source whereas in fact it is a volume heat source. Nevertheless the structure of their model has similarities with that presented here, though they consider relatively wide laser beams. A theoretical treatment of the temperature field due to a moving laser has been published by Irie et al (1993) for a similar problem, but they did not discuss the dye diffusion problem.

In this paper we first formulate the equation which control the production of heat within the dye-coat layer. The axi-symmetric temperature field produced by this heat source is then determined on the assumption that the thermal properties of the plastic layers are constants. The mass of dye which diffuses into the receiver sheet when there is a temperature dependent diffusion coefficient is determined using a quasi-one dimensional model. It is shown that, because the diffusion coefficient is a sensitive function of temperature , the dye concentration field exhibits a sharp front. A local analysis of this front fields an ordinary differential equation for the position of the front as a function of time. During the heating phase the temperature on the front is almost constant.

References

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