Toner Performance and Toner Properties Relating to High Speed Printing of Cheques, Bills and Targeted Mail

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Abstract

Non-Impact printed toners are being utilized more and more in industrial applications in recent years. Three such areas are billing applications, targeted mail and high volume, high speed cheque printing. All these applications place constraints in terms of toner formulation for fast non-impact printers to produce high quality documents. Billing and targeted mailings can result in fairly bulky document packages. Modern automated postal sorting systems can subject these documents to significant surface abrasion leading to a form of offset. We shall see how optimization of fixing for various fusing systems and the incorporation of low molecular weight additives can counter the effect of this abrasion.

Similarly toners when used to print the MICR line on cheques are subjected to even greater abrasion effects by high speed cheque reader sorters. Using SEM photographs of printer documents, a variety of fixing tests and thermal analysis we will show how toner formulation can be optimised to provide the desired print performance. Additionally we shall see how the properties of magnetic oxides affect check reader sorter signal levels by both measuring the magnetic properties of the toners and the signal response of printed documents.

Introduction

There is a high degree of interest in cheque printing by non-impact technology. This is due to the cost savings by the removal of the need for pre-printed stocks. In the USA there has been considerable growth in personal cheque printing for both business and the home. This has been mirrored by the growth in MICR capable laser printers and their respective toners.

Many articles have covered the needs for MICR printing in terms of print quality, font design and toner magnetic properties. Few have discussed the toner requirements to meet both printer fusing and high speed reader sorter performance. It will be seen later that these requirements are similar to toner requirements for high speed output document handling and postal sorting equipment.

Two majors issues arise from incorrectly formulated toners. MICR toner printer cheques can generate rejects from high speed reader sorters due to incorrect signal response or more often due to problems emanating from smearing and abrasion of the MICR line. High reject rates, which lead to costly manual sorting (up to $6.00 per cheque) for the clearing banks are expensive. If the failure is traced to the cheque printer these costs can be passed on and thus badly formulated toners are unacceptable.

In the UK, USA, Canada, Australia and Germany the E13B font is used for the MICR line, Figure 1, whereas in France, Spain, Italy and Latin America the CMC7 font is utilized Figure 2. In this paper only E13B will be considered although the issues for CMC7 are similar. The E13B font consists of 10 numbers and 4 special symbols to separate specific fields. The specification[1] covers height, width, stroke width, position, voids and extraneous particles (toner / ink around characters).

Figure 1

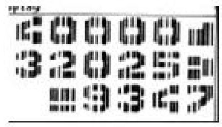


Figure 2

The high speed reader sorter first magnetises the MICR line and then a second read head measures the magnetized characters. A satisfactory toner must exhibit sufficient residual magnetization (remanence) at this stage to read correctly. As the characters cross the read head from right to left a signal is produced by the flux changes at the edges of the characters, Figure 3.

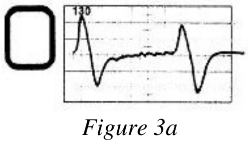


Figure 3a

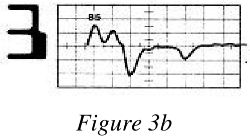
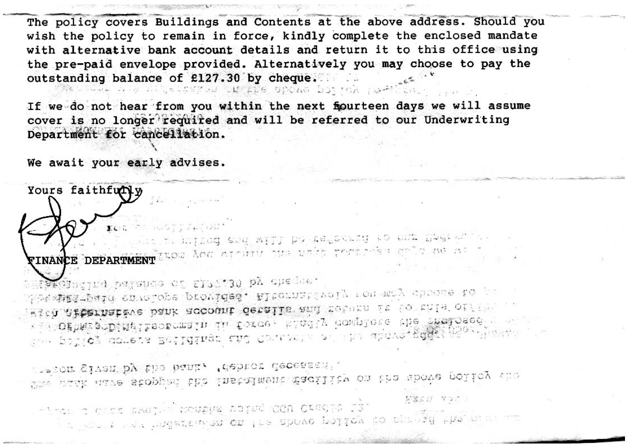


Figure 3b

A nominal signal strength range is specified for country to country. If nominal average signal for the characters is outside this range it may be incorrectly read. The overall reject rate for 20 passes of 1000 cheques is also specified, Table 1.

Table 1. MICR Specification Summary by Country

Country		USA ABA	UK APACS	CAN CPA	AUS APCA
Signal level	High	200%	200%	200%	200%
	Low	80%	50%	80%	50%
Reject Rate		0.2	0.05	0.2	0.25



The policy covers Buildings and Contents at the above address. Should you wish the policy to remain in force, kindly complete the enclosed mandate with alternative bank account details and return it to this office using the pre-paid envelope provided. Alternatively you may choose to pay the outstanding balance of £127.30 by cheque.

If we do not hear from you within the next fourteen days we will assume cover is no longer required and will be referred to our Underwriting Department for cancellation.

We await your early advises.

Yours faithfully

FINANCE DEPARTMENT

Figure 4. Postal Offset Example

Billing and mailing companies will similarly reject documents, which show a high degree of offset generated by postal sorting equipment. Figure 4 is an example of such offset from a letter of a well know insurance company probably generated on a desktop laser printer.

Magnetic Oxides for MICR Printing

A successful MICR toner must be capable of consistently printing quality characters with good nominal signal strength, typically 120 %. Non–impact toner based printers use a wide variety of development and transfer techniques for the toner. Consequently the amount of toner forming the characters can vary significantly. The required residual magnetization (Jr) of toner must similarly vary from printer to printer to provide the correct signal strength, (typically 4–8 emu/g). This can be achieved by using different oxides with various remanence, however the choice of oxides can result in an in-balance of other properties such as the saturation magnetization (Jm) or fusing. An alternative is to use a mixture of low and high remanence oxides. This can produce a relatively wide range of remanence.[2]

SEM micrographs of three oxides suitable for toners A, B, and C are shown below, figure 5.

Table 2 gives a summary of the magnetic properties of these oxides.

Table 2. MICR Toner Oxides

Oxide	Type	Jm(emu/g)	Jr(emu/g)
A	synthetic ferroferric	83	8
B	natural ferroferric	75	22
C	synthetic ferroferric	80	27

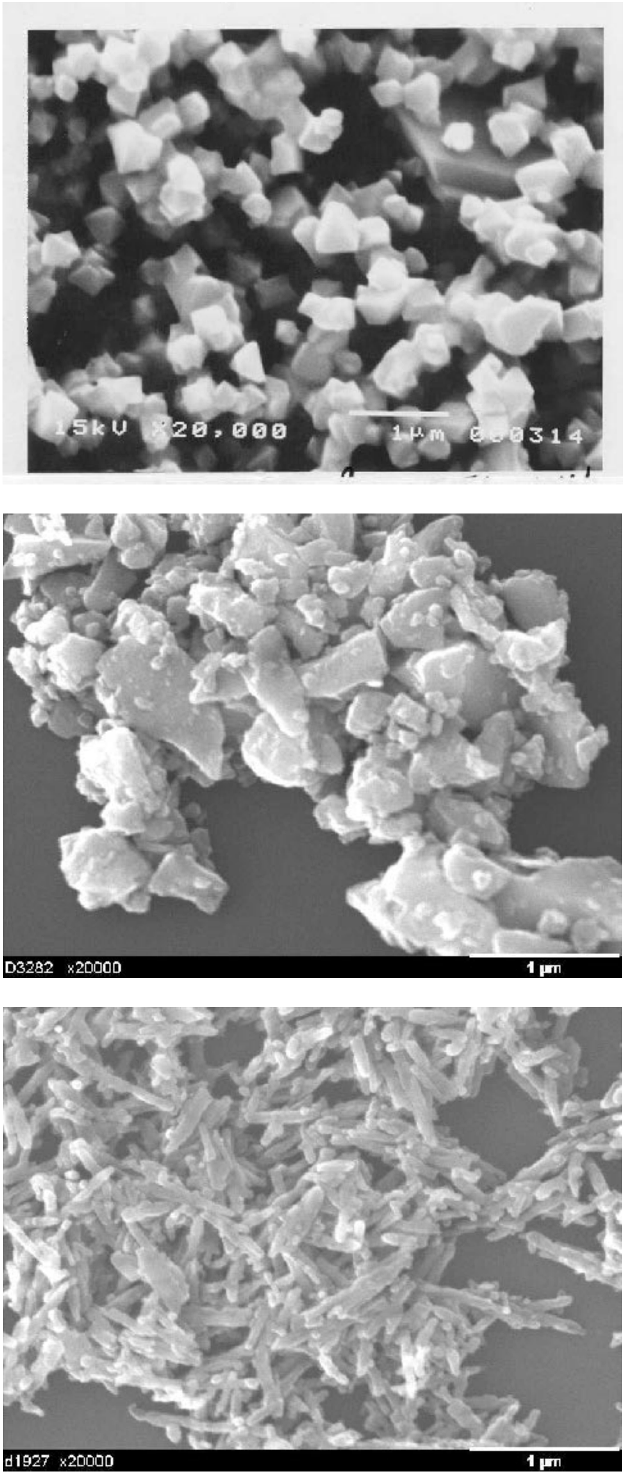


Figure 5. Oxides A, B and C

Samples of toner were prepared using a formulation of 50% oxide and 50% binder resin. A mixture of oxides A and B were used in the proportions shown in the table below. The resultant remanence of each toner was measured using the Coates extraction method. The magnetic saturation for each toner measured in a similar way was found to vary by no more than 38 +/- 2 emu/g.

The results show that a wide range of remanence is achievable by using mixed oxides, Figure 6.

Table 3. Mixed Oxide Formulations

oxide A	oxide B	Jr(emu/g)
100	0	3
75	25	5.1
50	50	6.4
25	75	8.4
0	100	9.7

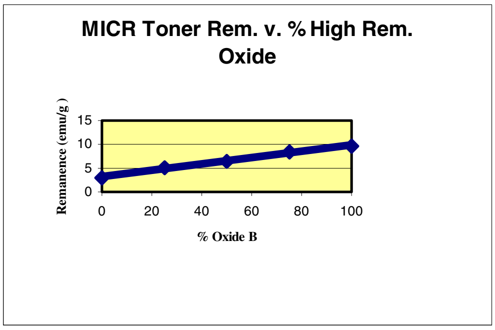


Figure 6. Variation of remanence to % oxide B

Obtaining Good Reader Sorter Performance

To produce an acceptable MICR toner, the formulation must not only have the correct magnetic and printing properties but must also be capable of withstanding severe mechanical and thermal stresses. These stresses are a consequence of the forces exerted on a cheque passing through a high speed reader sorter. The IBM 3890 TM reader sorter by nature of its design exerts such stresses. To ensure that even folded cheques are read correctly the cheques are pressed against the read head from behind by a brush. This pressure is combined with the high speed document feed of up to 8.37m/sec. Unlike MICR lines produced by offset printing a toner MICR line is raised above the surface of the paper fibres and thus can be subjected to serious frictional abrasion due to the read process.

Failure to read cheques due to this abrasion can result from at least two modes.

(i) The MICR characters are abraded and can smear or parts can break away to non image areas causing mis-reads due to voids or extraneous particles.
(ii) Toner can transfer to the read head cleaner foil producing an undesirable separation of the read head and the cheque. This results in catastrophic read failures.

Non impact toner printer devices utilize a wide range of fusing techniques i.e. hot roll, radiant, flash fuse etc. Some of these techniques such as radiant high speed printers require low molecular weight, low melting point polymers. These would therefore be expected to be susceptible to reader sorter abrasion whereas one might expect high molecular weight, high melting polymers in low speed hot roll systems to be less so.

Results

Table 4. Fixing and Reader Sorter Results

sam	printer	micr	fusing	tape	crease	R/S %
1	Laser	yes	hot roll	98%	83.1	pass(0.02)
2	laser	yes	hot roll	100%	82.4	fail (0.49)
3	electron beam	yes	radiant	100%	91.4	pass(0.10)
4	electron beam	no	radiant	100%	99.6	fail (1.52)
5	led	yes	hot roll	81%	75.2	pass
6	led	no	hot roll	99%	93.7	fail

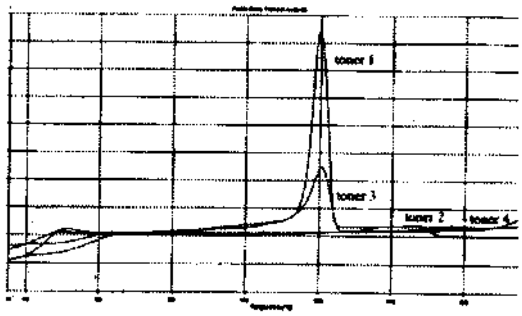


Figure 7(a). DSC of toners 1,2,3 & 4

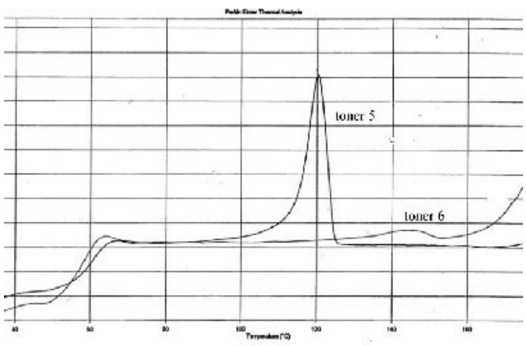


Figure 7(b). DSC of toners 5 & 6

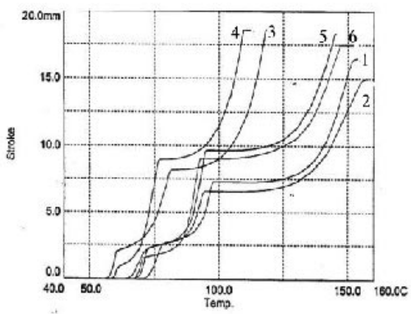


Figure 8. Capillary Rheology of toners 1 to 6

Six commercial toners MICR and non MICR were selected. Their thermal properties were examined using a Perkin Elmer DSC with a 48 Robotic sampler and a Shimadzu CFT-500 capillary rheometer. Measurements were also made on fused samples for tape and crease resistance. Cheque samples from each system were either subjected to 1000 cheques, 20 passes in a IBM 3890 $_{TM}$ reader sorter or a simulation of the abrasion effect. Damage to the MICR lines was evaluated from micrographs generated by a Nikon microscope connected to a Cohu 4712 camera, frame store and Optimas 6.5 imaging software.

From the DSC graphs, Figures 7(a) and 7(b) it can be seen that a characteristic peak at ~ 120C is present for toners 1, 3 and 5. This corresponds to the toners showing acceptable reader sorter results in Table 4.

From the Shimadzu curves, Figure 8 it can be seen that the pass R/S results do not correspond to the higher melting point toners 1, 5 and 6. The sharp DSC curve points to a low molecular weight additive. This material appears to prevent reader sorter abrasion and must act as a lubricant at the toner surface being incompatible with the polymer binder.

The SEM's of MICR lines, Figures 9(a) - 9(f) confirm that toners 1,3 and 5 do not show the severe damage after R/S of toners 2 and 4. Toner 1 containing lubricant is from a production laser printer whereas toner 2 without lubricant is from a desktop laser printer. The 6^{th} SEM is of a character from toner 2 before the reader sorter. Toner 4 although showing excellent fix results still does not withstand the reader sorter whereas toner 5 shows the reverse.

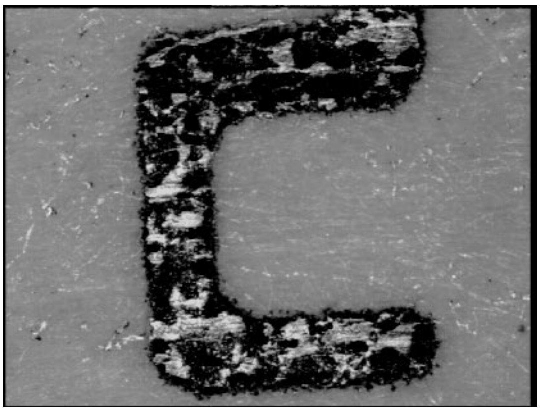


Figure 9 (a) Toner 1)

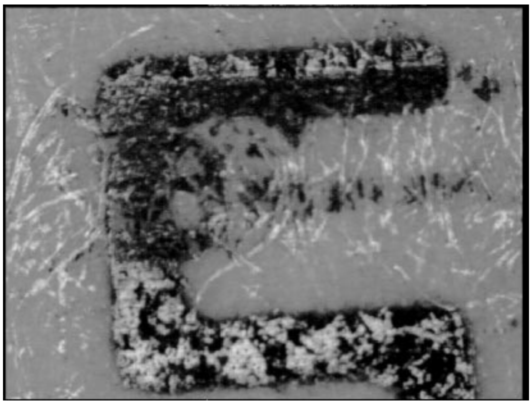


Figure 9 (b) Toner 2

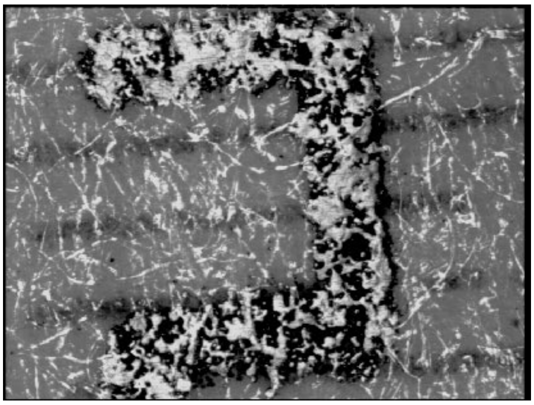


Figure 9 (c) Toner 3

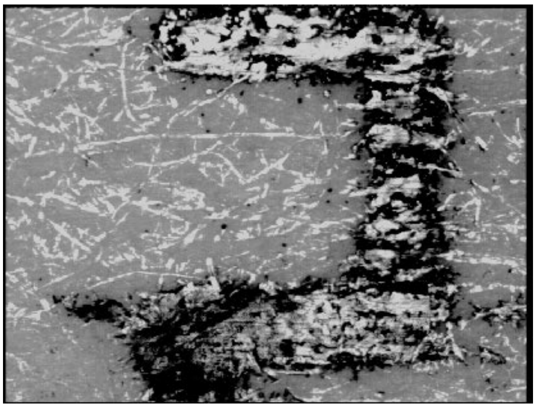


Figure 9 (d) Toner 4

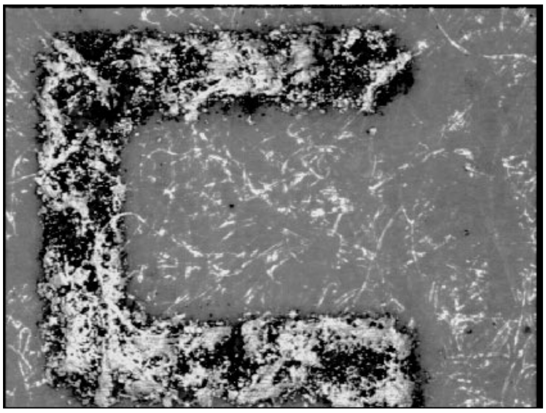


Figure 9 (e) Toner 5

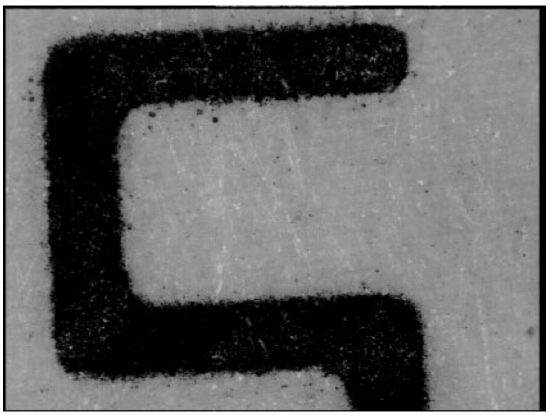


Figure 9 (f) Toner 2 no r/s

Formulating for Postal Offset

To obtain a clearer picture of postal offset a number of commercial print samples (a – h) were benchmarked.

Toners a, b, g and h are magnetic whereas all the others are non magnetic. A test for simulating postal offset was developed which under controlled conditions twists a small print sample against plain paper. The change in print density on the paper is then judged on a visual scale of 0 to 5, five being severe and 0 no postal offset. Obviously since the fuse conditions of the print samples have not been controlled the results in table 5 are purely an indication of postal offset. Tape and crease fuse properties of the samples were also compared. Sample g is from a popular desk top laser printer possibly of similar nature to that which produced the example of postal offset, Figure 4, shown in the introduction. All the others are from high speed production printers.

It can be seen in Table 5 that toners exhibiting the best tape and crease results tend to show the most desirable postal offset results. Toner a and toner b are toners for the same high speed printer. Toner b is a newer toner specifically formulated to give improved postal offset.

Table 5. Fusing and Postal Offset Benchmark

Toner	Fuse method	Tape test %	Crease test %	Postal offset
a	flash	87	83	5
b	flash	100	97	2
c	hot roll	99	89	2
d	hot roll	76	61	3
e	hot roll	99	85	1
f	hot roll	100	82	2
g	hot roll	97	74	4
h	flash	95	84	4

Table 6. Raw Material Properties

Raw mat.	Melt pt. °C	Tg °C	Mol. wt.	Effluent % Wt. Loss	Penetration 25 °C mm	Acid No.
Pol.		56		3.2		~75
A*	106		300-400	21.5	10	4
B**	127		500-600	3.3	7	3-5
C**	107		700-900	2.5	2	0

Pol. Polyester resin
* Wax A incompatible with the polyester
** Wax B, C compatible with the polyester

Table 7. Experimental Toner Formulations

Toner	Mag. Oxide	Pol.	Wax		
	%	%	A (%)	B (%)	C (%)
M1	61.5	24.5	9	-	5
M2	56	28	10	-	6
M3	51.5	31	11	-	6.5
M4	51.5	31	17.5	-	-
M5	51.5	31	-	11	6.5
M6	51.5	31	-	17.5	-

Table 8. Experimental Toner Fuse& P.O. Results

Toner	M1	M2	M3	M4	M5	M6
P.D.	1.38	1.38	1.52	1.46	1.41	1.42
Tape %	99.5	99.3	99.8	99.4	99.9	99.5
Crease %	74.8	74.4	77.3	74.8	65.1	60.8
Postal offset	4	3	2	5	2	4
Vol. wt. loss	5.5	5.5	6	7.2	1.9	2.9

Flash fusing of toners and particularly magnetic toners such as a and b can be susceptible to postal offset for a number of reasons. As will be shown high oxide loading can detract from postal offset. Also the use of fusing aids such as compatible low molecular weight soft waxes to aid fusing can lead to smear and again affect postal offset. As with the MICR, these toner formulations need to take into account print performance, blocking and in the case of flash fusing effluent levels. Owing to the high temperatures[3] reached at the surface of flash fused toners the polymers and waxes can break down leading to the release of considerable amounts of volatile materials. Selection of components for the toner must take this into account. A polyester resin and waxes were selected with properties as shown in Table 6.

These raw materials were combined with magnetic oxide to produce experimental flash fusing toners as described in Table 7.

The prepared toners were printed under identical conditions in a flash fusing high speed printer. Print samples for each toner were then subjected to the following fusing tests and analysis. Fuse properties of the toner were analyzed by two means, a conventional 3M Scotch ™ Magic ™ tape peel test and a crease test. The % crease was determined by image analysis. Effluent was measured by holding a known weight of toner at 180°C for 24 hours. The toners were then reweighed after cooling and the percent weight loss calculated.

From the above results in Table 8 it can be seen that postal offset becomes worse as the amount of magnetic oxide is increased. Toners M5 and M6 match toners M3 and M4 but replace the softer, lower melting point wax A with the harder, higher melting point wax B. This results in a lowering of the effluent but also reduces the fixing. The postal offset however is only improved by the incorporation of the much harder, incompatible wax C.

Conclusions

There are clearly similarities between the requirements for the toners needed for commercial/industrial applications. Abrasion from sources external to the non-impact processes either mechanical or both thermal and mechanical can result in smearing and offset of the printed documents. Additions of certain waxes or lubricants that are incompatible with the polymeric binders migrate to the surface of the toner on fusing and will lower friction and reduce the abrasion. This is likely to be due to reducing the friction between the source of the abrasion and the document. Low melting point materials that aid fusing help with postal offset but high levels of soft waxes can increase the smear effect. When formulating magnetic toners there appears to be a limit, certainly with flash fused toners, to the level of oxide that can be included without upsetting postal offset.

Clearly when formulating successful MICR toners and toners for other commercial applications the selection of raw materials to control the effects of external document handling systems must not interfere with the functional processes within the printer.

References

1. Rylla R. Goldberg, Magnetic Ink Printing & Evaluation Guide, 1 Seattle. First National Bank, pg no. 23
2. Arai Takaaki, Yasui Tatsuya and Moriyama Hiroaki, “Magnetic toner for MICR printer” US Patent 5,976,748
3. Mitsuya T. et al, Study of temperature and melting conditions during flash fusing Optical Engineering 30 (1), January 1991

Biography

Ian Neilson obtained a B.Sc. (Hons) Degree in Physics from the University of Exeter in 1973. From 1974 -1976 he was employed by Gestetner Ltd. as a Research Physicist. Ian joined Coates in 1976 and has been involved in the development of toners and pigmented phase change jet inks. He has formulated highly successful pressure sensitive, radiant, flash fusing magnetic and coloured toners for Electron Beam Imaging, in which Coates is a world leader. In this area he has recently been granted a US Patent for a fluid bed applied toner. Currently he is employed as Research & Development Manager with responsibility for all toner development.