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Magnetic Flake Powders for Fingerprint Development

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ABSTRACT: Different types of fine magnetic flake powders, which could be applied to latent fingerprints using a standard magnetic applicator, were produced with the aim of identifying product ranges suitable for bright fingerprint development on dark surfaces. Impressive bright print qualities were achieved with the smooth-surfaced flake manufactured by milling of spherical carbonyl iron and austenitic stainless steel powders. Compared with the results obtained for commercial aluminum fingerprint powders, these new magnetic flake products proved almost equivalent for print development on smooth surfaces and superior for print detection on rough surfaces.

KEYWORDS: criminalistics, fingerprints, magnetic flake powders, latent fingerprints

In the United Kingdom, aluminum flake powder is recommended for the development of latent fingerprints on most smooth nonporous surfaces [*1,2*], although different powders may be selected depending on the color and texture of the background. The flake powders are usually applied using glass-fiber or animal-hair brushes, but other brush types are available. However, the brush types and brushing procedures adopted are known to affect the extent to which latent fingerprints may be partially or totally obliterated during development, an important consideration since up to 10% of prints developed at scenes-of-crime can be difficult or even impossible to identify [*3*].

In assessing the factors affecting print obliteration [*3*], impressively low damage levels were found using a "magna" brush to apply "magna" powders [*4*]. Standard magna powders are composed of a mixture of equiaxed iron particles (~50 μm in diameter) and nonmagnetic flake particles. On moving the applicator loaded with powder over the latent fingerprint, the fine nonmagnetic flake particles adhere to the fingerprint ridges, with the magnetic carrier particles forming the "brush."

A recent innovation in the use of magnetic applicators has been the replacement of standard magna powders by magnetic flake particles [*5*]. In this way, the need for a magnetic carrier medium is eliminated, allowing the magnetic flake to perform the dual functions of forming the "brush" and of developing the latent fingerprint, that is, with no coarse carrier particles present, the latent print is contacted only by fine flake capable of adhering to the fingerprint residue, so the risk of ridge pattern obliteration during

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print development is reduced even further. Preliminary studies then showed that, for dark fingerprint development on a variety of different surfaces, excellent print qualities were achieved using a commercial magnetic applicator to apply pure iron flake powders [5]. However, to extend the capabilities of the magna-brush technique, magnetic flake powders varying in color and surface characteristics must be evolved, with a particular need for highly reflective flake for bright fingerprint development. This article therefore reports the results of a major research program designed to identify magnetic flake product ranges suitable for bright fingerprint development on dark surfaces.

Experimental Procedures

Selection of Powders

Five criteria were defined for selection of materials for this program. The materials should be

(1) available in the form of powders;
(2) sufficiently ductile for the powders to be mechanically deformed to flake morphology;
(3) magnetic, so that the flake would be attracted by the field of the magnetic applicator;
(4) magnetically soft (that is, have a low remanence) so that the flake would not be permanently magnetized and would therefore detach as individual flakes when the magnetic field is removed and,
(5) highly reflective in flake form so as to appear bright against dark backgrounds.

Pure cobalt and nickel powders were chosen as fulfilling all of the above selection criteria, on the assumption that the bright appearance of these metals in bulk form would result in highly reflective flake. In addition, two types of stainless steel were considered, namely, an austenitic stainless steel, which is essentially an iron-nickel-chromium alloy and a ferritic stainless steel, which is basically an iron-chromium alloy. Although both of these stainless steels are known for their bright nontarnishing appearance, the ferritic material is slightly less ductile but more magnetic than the austenitic variety. The compositions and mean particle diameters of the cobalt, nickel, austenitic stainless and ferritic stainless powders are listed in Table 1. In all cases, the low carbon contents promote mechanical ductility and ensure that the materials are magnetically soft.

The cobalt, nickel, austenitic stainless, and ferritic stainless powders consisted of almost equiaxed but irregular shaped particles, that is, the dimensions of the individual particles were similar in all directions but the surface contours were highly irregular. The appearances of these powders are illustrated in Fig. 1*a*. Two other powders were then chosen for this program, having the smooth spherical form shown in Fig. 1*b*. The powders selected were a fine air-atomized austenitic stainless steel and carbonyl iron. The compositions and average particle diameters of these spherical powders are also included in Table 1. Clearly, by choosing two austenitic stainless steel powders differing in their initial particle shapes, the influence of initial particle morphology on finished flake quality can be assessed. Furthermore, a second comparison could be made, because the composition of spherical iron powder was similar to that of the irregularly shaped coarse iron powder used to manufacture the magnetic flake, which had proved to be highly suitable for dark fingerprint development [5].

Production of Flake Powders

Each of the six powders studied in this program were converted to flake form by high-energy vibration ball milling, using steel balls with small amounts of stearic acid added as a milling aid [6]. Preliminary trials were completed to optimize the milling conditions

TABLE 1—*Materials selected for production of magnetic flake powders.*

Material	Approx. mean size (μm)	Particle shape	Chemical composition (wt. %)				
			Fe	Cr	Ni	Co	C
Cobalt	50	Irregular				99.8	
Nickel	5	Irregular			99		.06
Austenitic stainless steel	30	Irregular	68	17	12		.02
Ferritic stainless steel	20	Irregular	87	12			.02
Carbonyl iron	7	Spherical	99.5				.05
Austenitic stainless steel	10	Spherical	68	17	11		.03
Pure iron[a]	40	Irregular	98				.20

[a]Material found previously to result in dark print development [5].

so that, for all six powders, the finished flake products had mean diameters within the range 10 to 20 μm and average thicknesses of approximately 0.5 μm. However, for a wide range of flake materials, it has been shown that a stearic acid content of 3 to 5 weight percentage led to the best print qualities [7]. For this reason, the small quantities of stearic acid added during the milling operation was removed by soxhlet washing with hot acetone. A fixed weight of powder was then milled with measured quantities of stearic acid, using glass beads. The replacement of the steel balls by glass beads guarantees that the flake dimensions are unchanged during this additional milling operation, while the gentle milling action uniformly distributes the correct quantity of stearic acid over the flake surfaces.

The appearance of the finished flake was found to be critically dependent on the initial particle morphology. The spherical powders were converted to flake having extremely smooth surface and rounded outlines. In contrast, the irregularly shaped powders resulted in flake with rougher surfaces and jagged outlines. These differences in flake morphology are evident from the scanning electron micrographs presented as Figs. 2*a* and *b*.

Development of Latent Prints

All flake samples produced from the six powders listed in Table 1 could be picked up easily with a standard magnetic applicator. Although the quantity of flake held by the wand was smaller in the case of the two austenitic steels, as would be expected with these less-magnetic alloys, no difficulties were experienced in applying these materials to latent fingerprints.

In order to ensure valid comparisons of the print qualities achieved using the different magnetic flake powders, identical sets of fingerprints were obtained from ten different donors. Donors were requested to rub their hands together to distribute the sweat evenly over fingers and palms, before pressing a nominated finger onto a clean glass plate. Repeating this procedure allowed an array of virtually identical fingerprints to be obtained for each donor. After deposition, the fingerprints were left for one day before developing, because fingerprints found at scenes-of-crime are usually approximately one day old.

The powders were applied to the prints using a standard commercial magnetic applicator. A black card placed behind the glass plate then allowed the relative brightness of the prints to be assessed as they were developed with each powder. To complete the

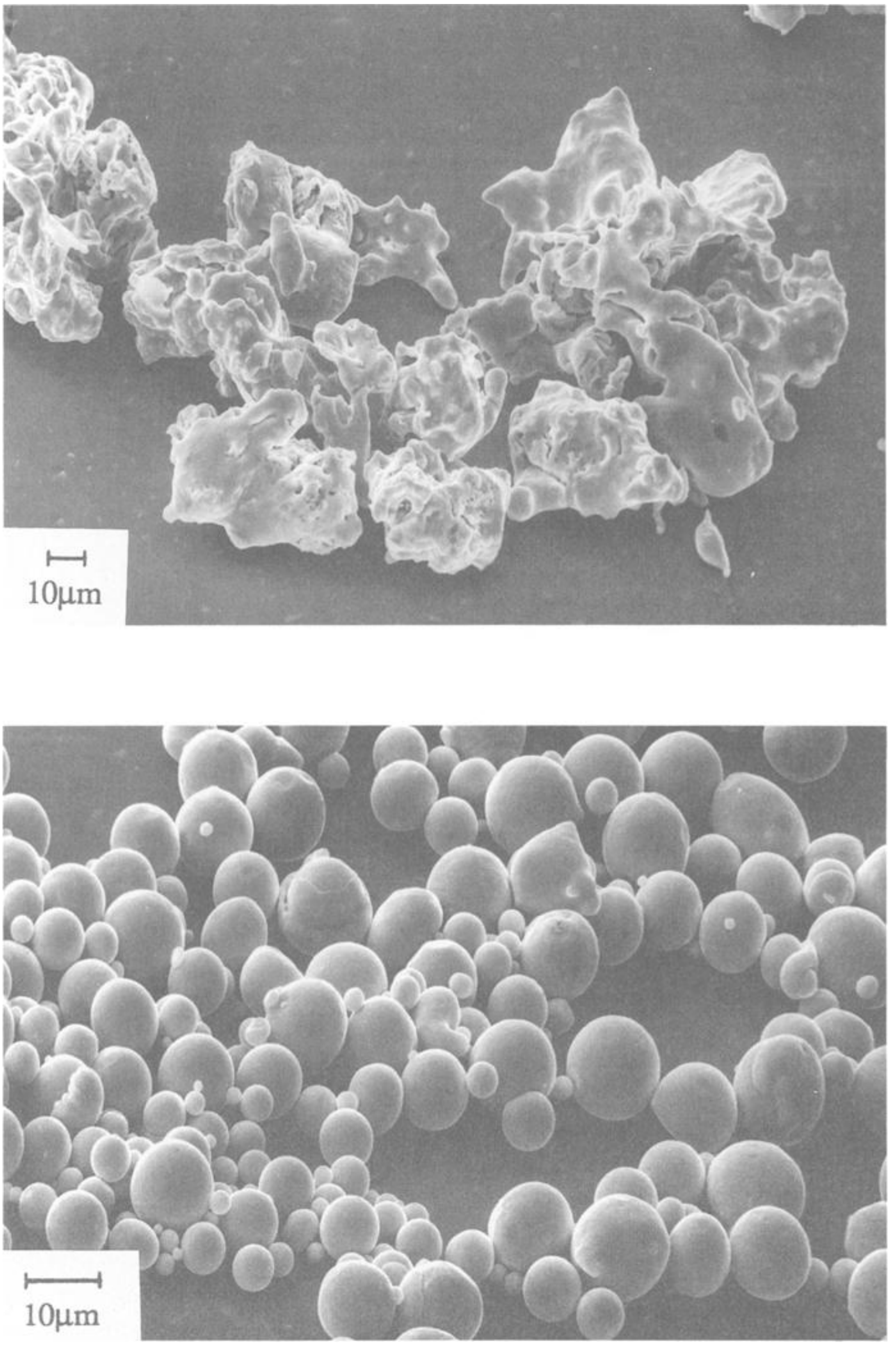

FIG. 1—*Scanning electron micrographs showing the appearance of* (a) *the irregularly shaped austenitic stainless steel powder and* (b) *the spherical austenitic stainless steel powder.*

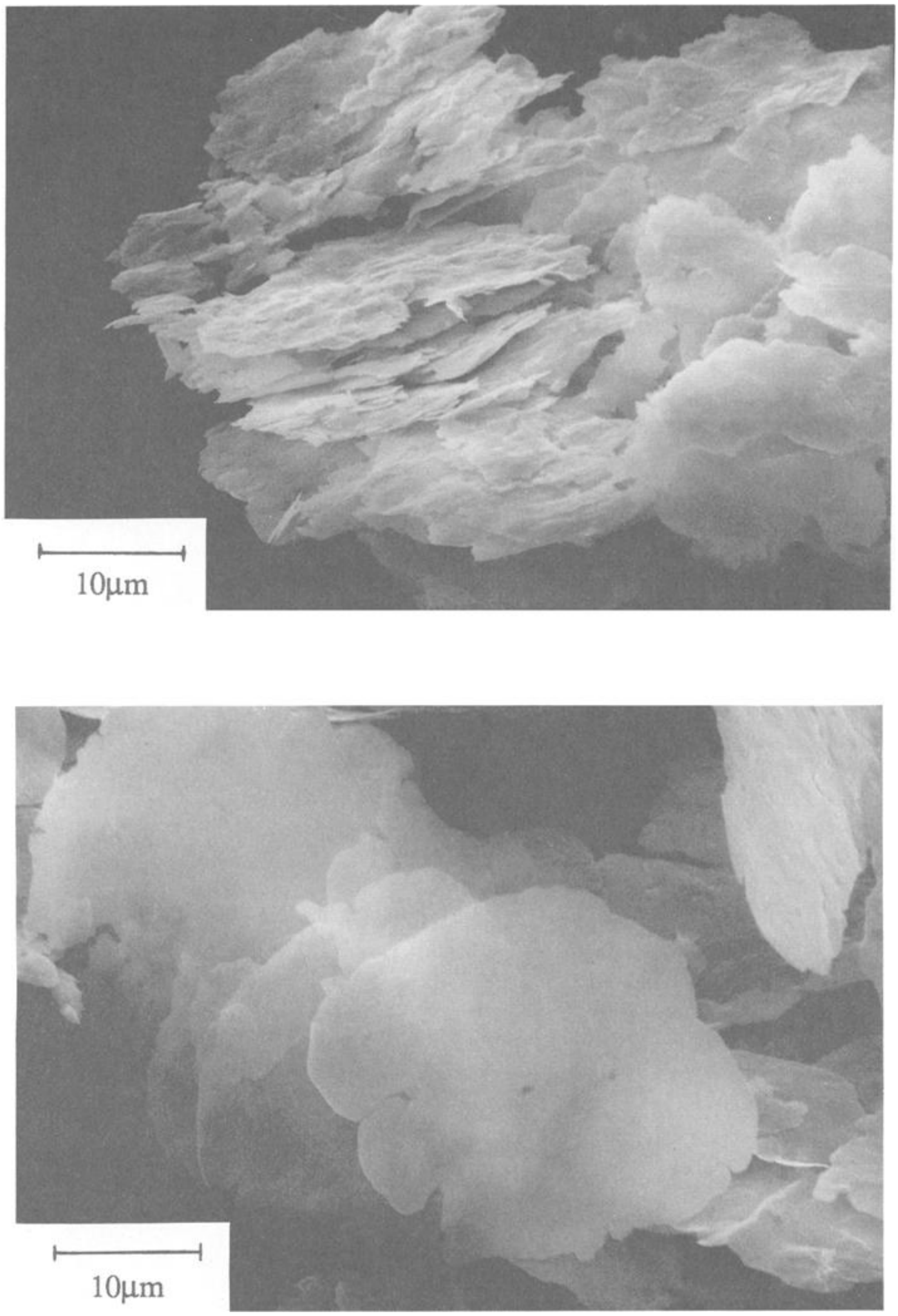

FIG. 2—*Scanning electron micrographs showing* (a) *the rough surfaces and jagged outlines of the flake produced from the irregularly shaped stainless steel powder shown in Fig. 1*a *and* (b) *the smooth surfaces and rounded outlines of the flake produced from the spherical austenitic stainless steel powder shown in Fig. 1*b.

assessment procedure, prints were also developed using a range of standard commercial powders and different application procedures. This allowed the print qualities achieved using flake produced from the present six materials to be compared with the results obtained

(a) for the dark prints developed using the magnetic iron flake powder produced for the earlier study [5];
(b) for the bright prints developed using commercial magna powders applied with the same standard magna brush; and
(c) for the bright prints developed with commercial aluminum flake powder applied with a squirrel-hair brush.

Experimental Results

Print Development Using Magnetic Flake Powders

All six magnetic flake powders produced for this study were found to be very sensitive in detecting latent fingerprints. In all cases, the powders were clearly visible against a dark background and the prints were developed rapidly. In fact, only one pass of the wand was needed. This contrasts favorably with standard brush application of commercial aluminum powders and with magnetic wand application of commercial bright magna powders, with both of these techniques requiring a number of passes to fully develop the prints. Because the extent of print obliteration can be affected by the number of brush passes [3], the risk of ridge smearing during development will be reduced by wand application of magnetic flake powders. Moreover, the magnetic flake products proved to be particularly suitable for revealing faint latent fingerprints.

In some instances, the effectiveness of the magnetic flake particles in adhering to the fingerprint residues resulted in excess amounts of flake being deposited, causing the print to be obscured temporarily. When this problem was encountered, the excess powder could usually be removed easily by passing the wand, clean of powder, over the developed print. However, occasionally, a stronger magnetic field was found to be necessary. Under these circumstances, the excess powder could be removed using a small rare-earth magnet. An example of this phenomenon is shown in Fig. 3.

Comparisons of Print Brightness

While all six magnetic flake samples produced in the present study were similar in that they were very sensitive and developed latent prints rapidly, significant differences in print brightness and clarity were observed.

Compared with the magnetic iron flake found previously to result in impressive dark print qualities [5], brighter prints were obtained using the flake produced from the irregularly shaped cobalt, nickel, and austenitic stainless steel powders. Unfortunately, the print qualities were generally poor, with a high "background." For this reason, these three materials were considered unsuitable.

For prints developed with the ferritic stainless steel flake, the background was relatively low and the prints were comparatively clean. The developed prints were brighter than those revealed using the dark magnetic iron flake [5], but certainly not as bright as those obtained with commercial aluminum powders and the commercial bright magna powders. Again, because this material could be defined as displaying only intermediate brightness levels, no further work was undertaken with the ferritic stainless steel flake.

In contrast to the poor and intermediate brightness levels achieved with the flake products manufactured from the four irregularly shaped powders, the results attained

FIG. 3—*Identical fingerprints developed with bright magnetic flake powder,* (a) *where an excess amount of flake powder has been deposited, causing the print to be temporarily obscured, and* (b) *after the excess flake powder has been removed with a small rare-earth permanent magnet, causing the ridge pattern to be revealed.*

using the smooth rounded flake produced from the spherical austenitic steel and carbonyl iron powders were impressive. These materials yielded prints with not only low backgrounds but also with brightness values comparable with those observed with commercial aluminum powders and commercial bright magna powders, Fig. 4.

Print Development on Different Surfaces

Because the magnetic flake produced from the spherical austenitic steel and carbonyl iron powders had proved highly successful for development of latent fingerprints deposited on glass plates, further studies were carried out using these products. In particular, attention was focused on print development on the variety of different surfaces likely to be encountered in practice by scenes-of-crime officers. To achieve this objective, sets of identical prints were deposited on metal surfaces, window panes, walls coated with different types of paint, wood, kitchen counters and cabinets, paper, PVC bags, etc. These surfaces had a variety of textures ranging from rough to smooth, allowing the print qualities obtained with the two bright magnetic powders to be compared with those developed using commercial aluminum and commercial bright magna powders.

Compared with the commercial bright magna powders, the two bright magnetic flake products gave superior print resolution on both rough and smooth surfaces. On the smooth surfaces, the commercial aluminum proved to be slightly better than all other products. However, for print development on the rough surfaces, the two bright magnetic flake powders were superior even to the commercial aluminum fingerprint powders. These results are fully consistent with the conclusions of previous studies which recommended the adoption of the magna-brush technique for print development on rough surfaces [*4*].

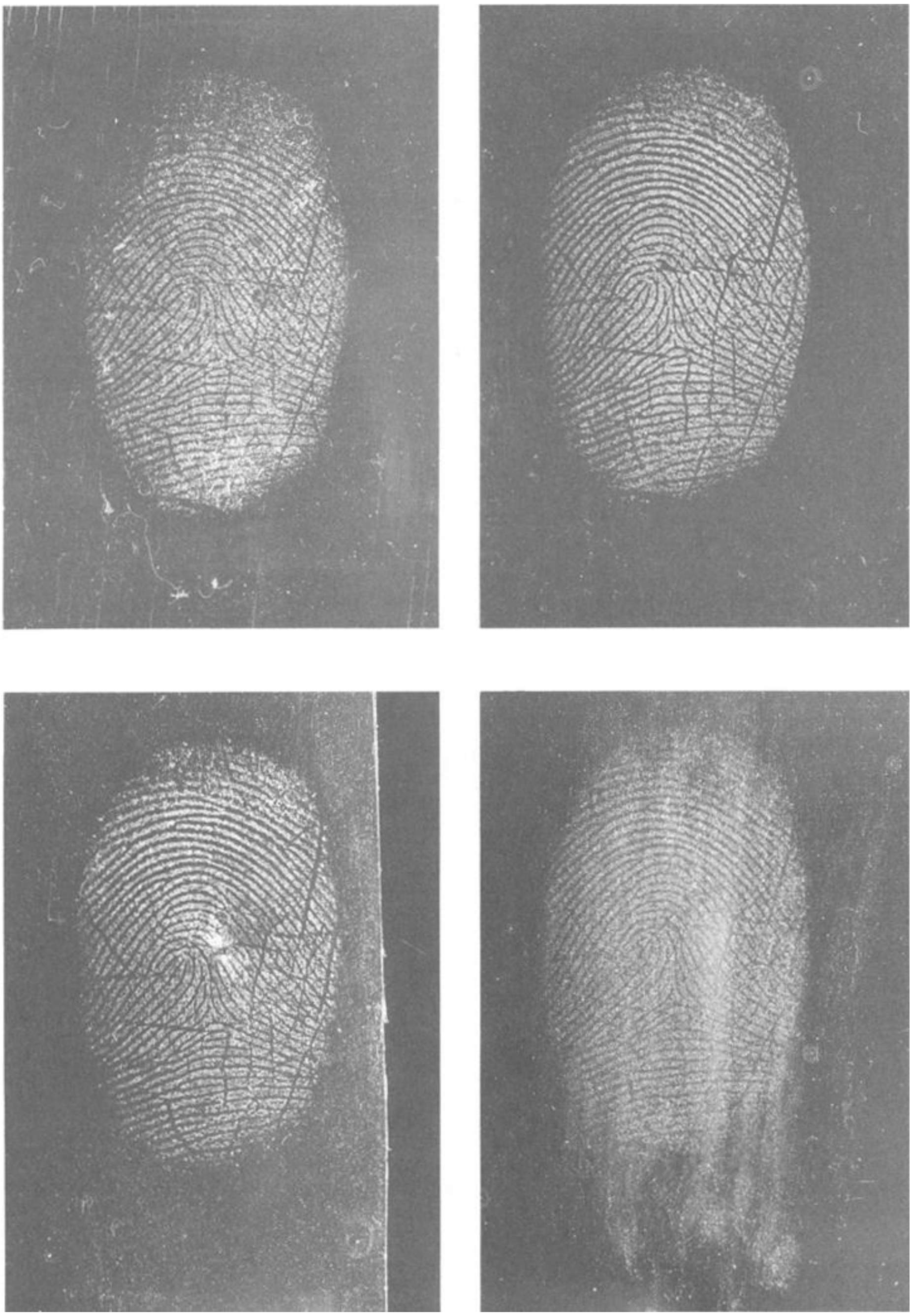

FIG. 4—*Identical fingerprints developed with* (a) *magnetic flakes produced from the smooth, spherical austenitic stainless steel;* (b) *magnetic flakes produced from carbonyl iron;* (c) *commercial aluminum flake fingerprint powder; and* (d) *commercial bright magnetic fingerprint powder.*

Discussion

Factors Affecting Print Brightness

A number of different factors affect the brightness of prints developed using different flake powders. Thus, for a range of flake materials, it has been shown [7] that increasing the flake diameter improves brightness by enhancing specular reflection. However, in this study, the milling conditions were selected to ensure that all flake powders had comparable dimensions. Thus, differences in the brightness of prints developed using the six magnetic flake products were not attributable to variations in flake diameter.

The chemical composition of the flake must influence print brightness because, for flake of similar dimensions and appearance, impressively dark prints were developed using flake produced from the irregularly shaped iron powder [5] whereas prints of intermediate brightness were found with flake obtained by milling of the irregularly shaped ferritic stainless steel powder. However, in addition to the effects of flake size and composition, this study indicates that the other major factors determining print brightness are the flake surface characteristics and general shape.

The bright flake products manufactured from the spherical carbonyl iron and austenitic stainless steel powders (Fig. 1*b*) were characterized by smooth surfaces and rounded outlines (Fig. 2*b*), whereas the dark flake materials produced from the irregularly shaped iron and austenitic steel powders (Fig. 1*a*) had rough surfaces and jagged outlines (Fig. 2*a*). Clearly, during the milling operation, which involves deformation of the small powder particles trapped between colliding steel balls, spherical particles are deformed uniformly to flake morphology. In contrast, irregularly shaped particles are compressed in a highly nonuniform manner, resulting in flake with complex surface contours and jagged outlines. In seeking to produce flake for bright fingerprint development, these results emphasize the importance of choosing spherical powders with initially smooth surfaces as the starting material.

Photography of Developed Prints

Prints developed at scenes-of-crime are normally lifted with tape and transferred to cobex sheets for subsequent examination. The ability of a developed print to reflect light is critical when lifted prints are photographed using the equipment available at UK Police Force laboratories. For example, it is well known that 'gold' and 'bronze' flake, which appear highly reflective to the naked eye, tend to give poor photographs. In order to evaluate the quality of the photographs produced from prints revealed by magnetic wand application of magnetic flake powders, further sets of identical fingerprints were developed with the bright magnetic carbonyl iron and austenitic stainless steel flake products and also with the dark magnetic iron flake manufactured previously [5]. The results were compared with prints developed by squirrel-hair brush application of commercial aluminum, gold and bronze fingerprint powders. In all cases, the developed prints were mounted to cobex sheets with standard lifting tape. Photographs were then taken with the equipment installed at many UK Police Force laboratories. The photographic procedures involved placing the cobex sheet over a black surface illuminated such that a reflected image of the ridges is focused onto standard black and white photographic paper. Subsequent photographic development gives an image of black ridges against a white background, which is suitable for comparison with stored records of linked fingerprints on paper.

As expected, the prints developed with commercial aluminum flake produced good photographs, with the two bright magnetic flake powders giving comparable results. It was then interesting to note that the dark iron flakes also gave satisfactory photographs.

In contrast, the fingerprints from the gold and bronze powders gave poor photographs even at long exposure times. This can be explained by the fact that these two flake powders are copper-based, and copper only reflects well for larger wavelengths of the visible spectrum where the photographic paper is less sensitive. In contrast, iron and aluminum reflect all wavelengths of the visible spectrum equally well and hence produce good images on the photographic paper.

Removal of Magnetic Flake Powder

Once fingerprints had been developed with the magnetic flake powder, any excess powder tending to obscure the print can be removed with the magnetic wand or a small rare-earth permanent magnet, (Fig. 3). However, if a rare-earth magnet is used, care must be taken because passing this powerful type of magnet too close to the developed print can remove flake particles from the ridges of the print in addition to any excess lying between the ridges. While this may be considered a disadvantage, the ability to remove particles from the ridges has two potential advantages. Firstly, it allows traces of the fingerprint to be easily cleaned away after the investigation has been completed. Thus, it was found that the vast majority of powder could be removed from the print by touching it with a rare-earth permanent magnet, the exact proportion removed depending on the nature of the surface. The second advantage in removing the powder is that it allows subsequent processing of the surfaces by an alternative technique. A typical example could be with paper surfaces which could first be processed with magnetic flake powder and then subsequently with ninhydrin [*4*] after removal of the magnetic flake powder. A number of experiments were conducted in this manner and, while the results from the magnetic flake powder did not surpass the conventional ninhydrin results, the use of flake powders made it easier to distinguish recently deposited fingerprints from older ones. Hence, this powder method may be particularly valuable where new prints have been deposited over older prints and ninhydrin might develop both sets, making identification difficult.

It should be noted that the ability to remove powder by magnetic means gives the magnetic flake technology an advantage not only over commercial aluminum flake powder but also over the commercial "magna" powders, where the component of the powder that actually adheres to the fingerprint residue is nonmagnetic.

Conclusions

For bright fingerprint development on a variety of different surfaces, impressive print qualities were achieved using magnetic flake powders produced by milling of spherical carbonyl iron and austenitic stainless steel powders. In addition, magnetic flake manufactured from irregularly shaped iron powder proved excellent for dark print development [*5*], while intermediate brightness levels resulted from the use of flake obtained by milling of irregularly shaped ferritic stainless steel powder. These new magnetic flake products, which can be applied with a standard magnetic applicator, are highly sensitive to latent fingerprints and give rapid print development.

The qualities of the prints revealed on smooth surfaces using the bright flake produced from the spherical iron and austenitic stainless steel powders were superior to those obtained with commercial bright magna powders and almost equivalent to those developed with commercial aluminum flake powders. For print development on rough surfaces, the bright magnetic flake products surpassed even the commercial aluminum fingerprint powders. Moreover, using the standard magnetic applicator or a small rare-earth permanent magnet, the magnetic flake materials could be almost completely removed from most surfaces, allowing subsequent re-examination using alternative techniques.

Acknowledgments

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References

[1] *Manual of Fingerprint Development Techniques*, S. R. D. B., Home Office, London, 1986.
[2] Pounds, C. A., "Developments in Fingerprint Visualization," *Forensic Science Progress*, Vol. 3, 1988, pp. 91–119.
[3] James, J. D., Pounds, C. A., and Wilshire, B., "Obliteration of Latent Fingerprints," *Journal of Forensic Sciences*, Vol. 36, September 1991, pp. 1376–1386.
[4] Olsen, R. D., Sr., *Scott's Fingerprint Mechanics*, Charles C Thomas, Springfield, IL 1978.
[5] James, J. D., Pounds, C. A., and Wilshire, B., "Magnetic Flake Fingerprint Technology," *Journal of Forensic Identification*, Vol. 41, 1991, pp. 237–247.
[6] James, J. D., Wilshire, B., and Cleaver, D., "Laboratory Simulation of Commercial Brass Flake Manufacture," *Powder Metallurgy*, Vol. 33, 1990, pp. 247–252.
[7] James, J. D., Pounds, C. A., and Wilshire, B., "Flake Metal Powders for Revealing Latent Fingerprints," *Journal of Forensic Sciences*, Vol. 36, 1991, pp. 1368–1375.

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