Océ's Mono Component, Magnetic, Conductive Colour Toner

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Abstract

Océ's Direct Imaging (DI) technology is a unique 7 colour dry-toner based printing process.[1,2] *The printing process is controlled by a subtle interplay between a magnetic force and an electrical force exerted on the inductively charged toner particles. Océ's DI technology therefore requires magnetizable and conductive colour toners.*

A major challenge was to develop colour toners that yield a sufficiently large colour gamut. Carbonyl iron has been chosen as a magnetic pigment. For a conductive coating on the toner particles fluorine doped tinoxide (FTO) is used.

The FTO coating on the toner particles is completely transparent and colourless. The carbonyl iron pigment in the toner however still absorbs a significant fraction of the incident light. By using fluorescent mixtures of dyes, in addition to colour pigments, we have succeeded in attaining vivid colours and a large colour gamut.

Introduction

Océ has already distinguished itself in black & white copying/printing technology with unique characteristics:

1. Use of mono-component, conductive and magnetizable toner development.
2. 'Adhesive' contact transfer of toner to a rubber intermediate without use of electrical forces.
3. Océ Copy Press technology: single step transfer and fusing of toner from rubber to paper.

Use of mono-component, conductive toner has resulted in a very stable and robust development process (inductive charging instead of tribo-charging, virtually speed independent, uniformity). Contact-transfer results in very high print quality and no ozone production (no electrical transfer). Océ Copy Press technology gives a very robust transfer of toner to paper and a high level of media flexibility (especially surface texture).

In the transition from B/W to colour printing we decided to develop a colour printing process based on the same characteristics as our proven B/W technology thereby maintaining before mentioned proven strengths.

Océ's Direct Imaging (DI) technology is a unique 7 colour dry-toner based print process. The technology is unique in the sense that digital information is directly converted into a toner image in a one-step process which makes it a true digital printing process. The position of each toner particle is controlled by a subtle interplay between opposite forces exerted on the toner particles. A strong magnetic force prevents the toner from being printed. An electrical force can be switched on and off by applying any desired voltage pattern on the surface of imaging drums. This electrical force on inductively charged toner particles can exceed the magnetic force and print the toner particles.

Océ's DI technology therefore requires the use of magnetizable and conductive colour toner. In this paper the composition and manufacturing process of this colour toner will be discussed.

Toner

The black toner consists of a polyester resin containing about 50 wt% of magnetite pigment (Fe_3O_4). The magnetite pigment has a mean diameter of 0,5 micrometer, a saturation magnetization of 88 emu/g and a low remanence. The magnetic pigment and the resin are co-extruded and subsequently jet-milled and classified to yield the desired particle size distribution. Finally the toner particles are surface coated with a few wt% of a conductive carbon black species.

As both the magnetite pigment and the carbon black are black, this readily yields a black toner. Obviously these materials cannot be used to make a magnetic and conductive colour toner.

In order to make a magnetic and conductive colour toner we had to find an alternative magnetic pigment and an alternative conductive coating material.

The Magnetic Pigment

The requirements for the magnetic pigment are:

- low light absorption
- high saturation magnetization (so that only a small amount needs to be used)
- low remanence
- non toxic

A material that fulfils these requirements is carbonyl iron powder. This material consists of small iron spheres that are obtained by the thermal decomposition of iron penta carbonyl. The material has a grey, metallic appearance. As the bulk of the material consists of iron, the material has a high saturation magnetization of appr. 200 emu/g and a fairly low light absorption. The material is practically non remanent. Carbonyl iron is available in different particle sizes ranging from 1±0,5 to 5±3 micrometers. In order to minimize the light absorption by the carbonyl iron it is preferred to use a coarse grade with a low specific surface area. If the carbonyl iron grade is too coarse however this will lead to an uneven distribution of the magnetic pigment over the toner particles. Here a well balanced choice was made.

Depending on the particle size of the toner particles we require a different load of carbonyl iron. The larger the toner particles, the lower the volume fraction of carbonyl iron that is required in order to exert a certain magnetic force on the toner particle. For all coloured toners the average carbonyl iron content is less than 3% by volume. The actual carbonyl iron content will vary somewhat between toner particles due to statistics.

Figure 1. Micrograph of colour toner particles showing the incorporated carbonyl iron spheres

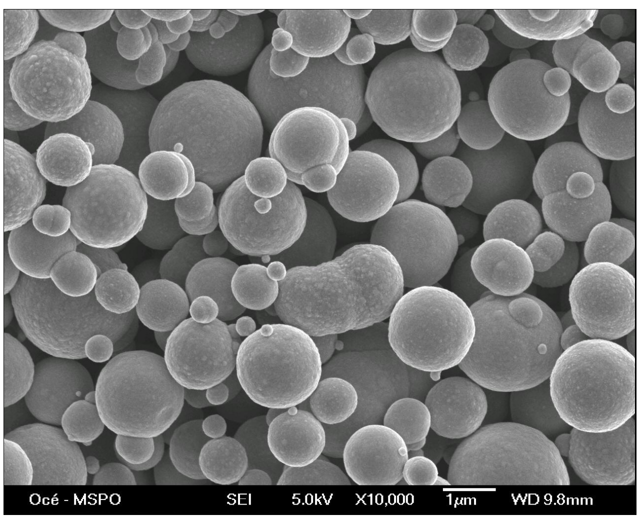

Figure 2. Electron micrograph of carbonyl iron

As alternatives for carbonyl iron there are cobalt and nickel pigments available. These materials are however not preferred because of their lower saturation magnetization and environmental issues.

The Conductive Coating

For the conductive coating we have the following requirements:

- colourless, transparent conductive material
- preferably an ultrafine powder which can be coated onto the toner in a dry process
- stable conductivity, not susceptible to oxidation or moisture
- non toxic
- cheap
- it must improve the flow properties of the toner, without affecting the fusing characteristics too much.

The materials of choice have been conductive doped metal oxides. In particular fluorine doped tin oxide (FTO) met our requirements. In contrast to antimony doped tin oxide, FTO is not classified as a hazardous material.

A special grade of FTO powder which is especially suited for the coating of toner has been developed in our laboratories.[3] The powder is off-white and has a bulk resistivity below 1 Ohm.cm. The material consists of primary particles of 20-50 nanometer. The ultrafine FTO particles are surface coated on the coloured toner particles.

In recent years conductive polymers have gained a lot of interest in both academia and industry. In our case it is possible to coat toner particles with a thin layer of conductive polymers by *in-situ* polymerisation or coacervation techniques, both in aqueous media. This has been done with polyaniline, polypyrrole and poly (ethylene-dioxythiophene) (PEDOT).[4]

With respect to the requirements posed above, PEDOT is absolutely the best conductive polymer. However PEDOT is not colourless and although it is applied as a nanometer thick film (i.e. 0,35 wt%) on the toner particles, it has an adverse affect on the colour of the toner. Furthermore the flow properties of the toner stay behind compared to FTO-coated toner.

This leaves us with the conclusion that FTO has to be preferred over PEDOT.

The Colour Formulation

The FTO coating of the toner particles is completely transparent and colourless. The carbonyl iron pigment in the toner however still absorbs a significant fraction of the incident light on the print. For dark colours like green and blue this proved to be no problem. But the light colours yellow, magenta and also red suffer from the light absorption by the carbonyl iron.

A straightforward way to improve the colour properties of the toner would be to increase the diameter of the toner particles. A larger diameter means that a lower volume fraction of carbonyl iron is required which results in better colour properties.

Increasing the diameter of toner particles however has a negative effect on the graininess and on the rendering of details on the prints. As the yellow toner is not critical is these aspects, we have chosen to use a yellow toner with a mean diameter that is about twice the diameter of the other toners. But this doesn't solve the whole problem.

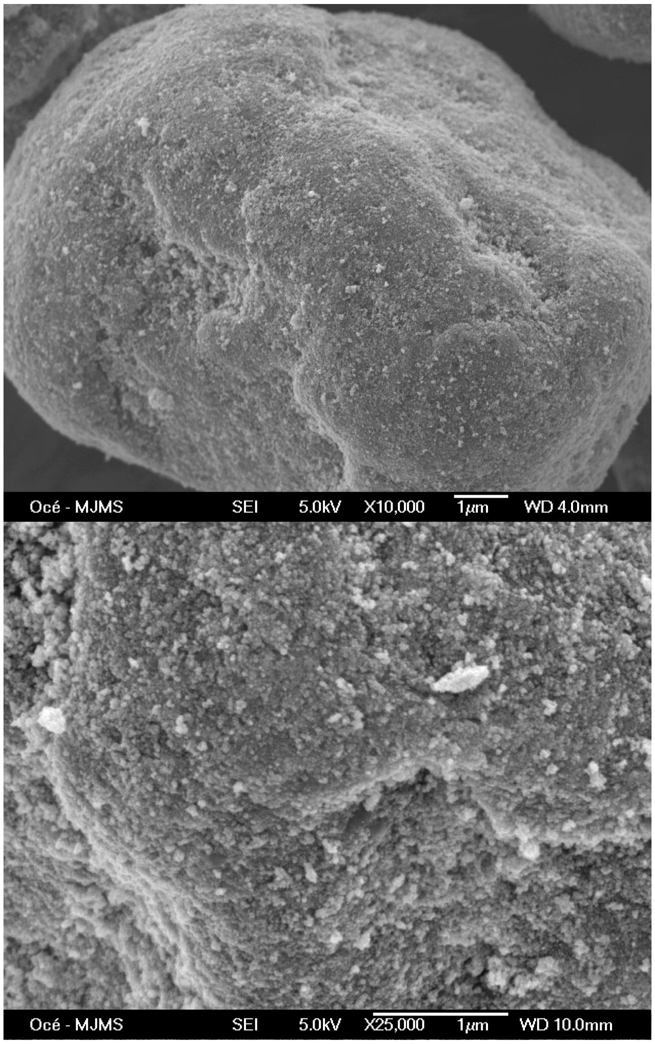

Figure 3. Electron micrographs showing the FTO coated surface of a toner particle. The FTO is visible as the granular microstructure on the surface

The problem has been overcome by using fluorescent dyes. A strongly fluorescent mixture of coumarine and xanthene dyes is used in the yellow, magenta and red toner.[5] The fluorescence of the dye mixture is stimulated by an efficient energy transfer process between the used dyes. The light emitted by the fluorescent dye mixture compensates for light absorption by the carbonyl iron. This results in vivid colours and a colour gamut close to the gamut of the traditional electrophotograpic printers.

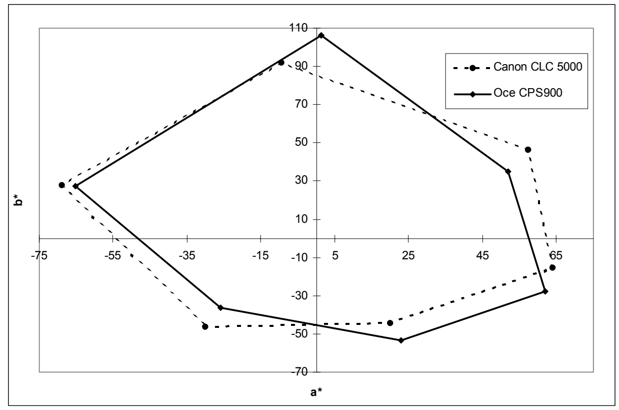

Figure 4. Colour gamut of the Océ CPS900 vs. Canon CLC5000 (100% coverage, colour copy paper, D65/10 illumination)

Conclusions

The challenge has been to develop a set of magnetic and conductive colour toners that yield a sufficiently large colour gamut. By using carbonyl iron, fluorine doped tin oxide and strongly fluorescent mixtures of dyes we have succeeded to obtain vivid colours and a large colour gamut.

We have now realized a colour printing process with the same proven strengths as in our previous B&W printers: a stable and robust printing process (inductive charging instead of tribo-charging, virtually speed independent, uniformity) and a good print quality and colour gamut.

References

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Author Biography

Marcel Everaars received his PhD in chemistry from Wageningen University in the Netherlands in 1997. Since 1996 he has been working at Océ-Technologies at the R&D centre in Venlo, the Netherlands. He has been engaged in the research on toner resins, colour formulations and toner coatings. Currently he is responsible for the development of new-generation colour toners.