Digital Ceramic Decoration

Mark van Straaten, Kurt Mampaey, Jan Bongaerts, and Lode Deprez
Xeramics International NV, Lier, Belgium

Joerg Sperlich and Maurizio Ragnetti, Ferro Gmbh, Frankfurt, Germany

Roswitha Kreiner, Rosenthal AG, Selb, Germany

Walter Ermer, BHS Tabletop AG, Selb, Germany

Abstract

Also in the ceramic decoration industry a strong pressure exists towards the development of cost efficient technologies. This pressure arises from the ever increasing demand of small series, short lead times, stock reduction, etc. Hence, there is a strong interest in the possibilities of digital printing as a replacement of the analogue existing technology for ceramic decoration, namely screen printing. Essentially, this interest in "digital" in this (niche) market is completely comparable with the movement towards digital technology in the graphical market during the last decades. Because of the technological hurdles encountered, as well as the somewhat rigidness of the market, up to now no real digital solution exists as a replacement or parallel technology to screen printing.

This paper focuses on the development of a toner based digital solution for ceramic decoration. The work aims at creating a solution by developing both a "4+1" ceramic toner set as well as the printing engine, this to guarantee a high quality and stable operation for industrial applications. So called "in glaze" pigments are used, which are typically used for the decoration of high quality dinnerware.

Introduction

The decoration of ceramic objects (dinner ware, glass, tiles,…) is based on the application of ceramic pigments and glass fluxes which are fired at high temperature into the object, e.g. a dinnerware plate or cup/mug. Up to some decades ago, the application of the colors mainly was done manually. Nowadays this "artist" work is replaced only by a small number of technologies, of which screen printing (direct and indirect) is the most important.

The indirect screen printing process with a transfer material ("decal") allows for the decoration of 90% of all dinnerware. The complete production cycle for the decoration of a ceramic object is extremely labor intensive and time consuming, which causes a transfer of the work to low cost countries. Nowadays the porcelain industry also is more focused on the creation of "designs": a careful combination of the form of the porcelain object as well as – and even or more important – the decoration generates the added value compared to the competition. This also is reflected in the production phases: the emphasis lies on the creation of the design of the shape and the decoration, rather than on the effective production of the decal which is mostly outsourced. Only the larger manufacturers have their in house (screen) printing facilities.

From the market, there is a large pressure on the decoration producers to:

- reduce extensively the response time
- produce (very) small series (< 350 decals)
- reduce stock
- produce specialty ware
- ecology: the use of heavy metals free pigments and non-solvent based systems

These aspects barely can be accomplished by the current technology for decoration, screen printing. They can, however, be met by a digital solution which on top offers distinct features: ultra small series (in the limit=1), test products, gadgets, proofing and personalization.

Digital Ceramic Solution

Xeramics International is developing a toner based solution for digital ceramic decoration. This solution is based on the development of a specific ceramic toner and the careful adjustment of a printing engine to this toner in order to guarantee in a development phase a stable operation for at least 3000 A3+ copies. The latter specification seems limited in view of the current capabilities of conventional electrophotography, but is far from evident in the case of ceramic printing, as will be shown it what follows.

Ceramic Toner

A ceramic toner essentially has the same ingredients as a normal organic toner: resin, pigments, charge and flow additives, but in significantly different concentrations. Ceramic pigments are (heavy) metal based and also much larger than organic pigments (15-20 micron versus 200 nm). The incorporation of flux particles is necessary for the adhesion to the ceramic surface and/or gloss properties. This means that the pigment and flux particles have to be milled down in order to be incorporated in the toner particle.

It is known that ceramic pigments have a very small color space. In screen printing it is therefore not common to work with 4 process colors, but instead every color is made separately and used as a "spot" color. A general design printed with screen printing therefore is made out of on the average 6-8 colors, but designs composed out of 12-15 colors are not uncommon. In view of the applicability of a digital toner based technology, it is therefore essential that a minimum color space can be reached with a 4 color system (CMYK).

For decoration purposes, the ceramic pigments are commonly divided in:

- On glaze: the pigment/flux is applied on the glaze of the ceramic substrate and will partially sink in the glaze layer during/after firing (T=700-900°C)
- In glaze: the pigment/flux is applied on the glaze of the ceramic substrate, but firing at higher temperature (T=900-1300°C) causing the pigments to sink completely in the glaze layer of the ceramic substrate. This yields a better mechanical and chemical (dishwasher) resistance
- Under glaze: the pigment/flux is applied on an unglazed ceramic substrate, which is glazed hereafter. This sometimes necessitates a double firing process. It yields an even higher resistance, but with a lower color space and intensity.

The pigment/flux load of a ceramic toner is significantly higher than in a normal system. A typical pigment/flux load is 50-60% (1), compared to typical 4-5% in a "normal" toner. Given the specific gravity of the ceramic pigments/flux, this makes a ceramic toner 2-3 times heavier than a conventional toner. This high pigment load is necessary to achieve a minimum color strength, since the intrinsic color strength of the pigments is much lower than for organic pigments. This changes dramatically the appearance of the toner (see fig. 1) and it is obvious that this high pigment load has significant impact on the printing process in a conventional electro photographic printer (see further). Hence, just changing the toner in a conventional printer to a ceramic toner will not do the job: this will by far not guarantee a stable mode of operation which is needed in industrial applications.

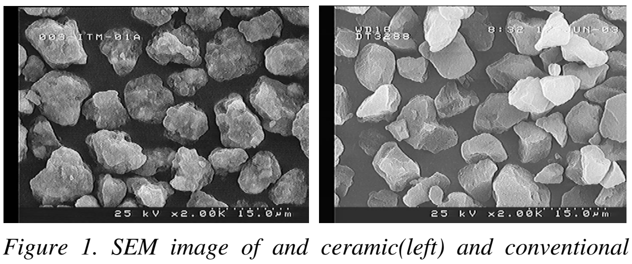

Figure 1. SEM image of and ceramic(left) and conventional toner (right)

In principle, it is possible to reduce the flux content of a toner, increasing in this way the pigment content and thus color strength. However, a minimum flux content is necessary in order to have a good adhesion of the pigments on the porcelain surface during firing (in glaze pigments) or to reach a proper gloss level after firing (on glaze pigments). In the case of on glaze pigments, a possible solution is to cover the image with an additional layer of flux toner (image wise), but this necessitates a fifth printing step (e.g. via dual pass).

The resin used in a ceramic toner only functions as a temporary means of transport, and accounts for the fixation of the pigments on the decal paper. It does not play a functional role in the image on the ceramic object, because it is carbonized during the firing process. This means that some critical demands attributed to the resin in conventional toner, e.g. the viscosity demands to reach proper gloss, can be relaxed. On the other hand, feasibility tests in our lab have shown that in certain conditions clear defects are visible when toner images are fired into porcelain. Up to now these firing defects are not always reproducible, hampering to pinpoint a clear cause. Nevertheless this needs further research since it is crucial to generate a defect free image.

Ceramic Printing Engine

Due to the high pigment load, ceramic toners have a distinctly different charging behavior compared to conventional toners. Because of their high load and size, pigment and flux particles can be partially present at the surface of the toner particles and thus play a role in the tribo electric process when mixed with carrier particles to form a developer. In spite of their glass nature, the high content of (heavy) metals yields a conductivity level which is lower than that of the pure resin. More important, the glassy nature of the pigments and flux particles, makes them an inefficient partner in the tribo electric charging process.

Overall, this causes a toner with a low Q/m (heavy particles), and a difficult controllable activation kinetics.

Other printing characteristics such as the fusing parameters, are also to be determined carefully in order to adapt the process control of the printer. Again the high pigment load causes a (very) high viscosity of the toner. This has impact on the fusing of ceramic toner on the decal.

Clearly, all these aspects have a pronounced effect on the printing performance since the process control of a standard printer is optimized for an organic toner. The process control should allow careful adaptation of all the controlling process parameters: developer toner concentration algorithm, development potential, on line/OPC densitometry, fusing temperature/ pressure/time. This means that the process control algorithm of the printer used should be open so that the necessary modifications can be developed and build in.

Experiments and Results

Based on the aspects and criteria mentioned, a parameter study with respect to ceramic toner composition was performed. The toners were prepared by extrusion melting the raw materials, followed by a milling and classifying step. A typical toner size of 10-12 micron was chosen. TiO_2/SiO_2 additives were used to improve the flowability and charging characteristics.

In glaze CMYK pigments and corresponding flux were used, milled down to an average particle size of 2 micron. An extra flux toner was prepared, incorporating only flux particles and no pigments. This flux was designed to be applied on top of the CMYK image to guarantee a proper chemical and mechanical resistance of the overall image on the ceramic object (2).

From these experiments a toner composition was selected and used to perform a more pronounced print test on a Xeikon based sheet fed A3+ engine. The process control of this engine was adapted in view of the ceramic toner/developer characteristics.

During a cycle of 3000 prints, toner concentration, development potential and print density were followed closely. On regular time intervals, also commercial images were printed of which the overall quality was evaluated. Several prints were selected and fired both in a electrical lab type oven, and in a industrial gas oven. The results are presented in fig. 2 and 3.

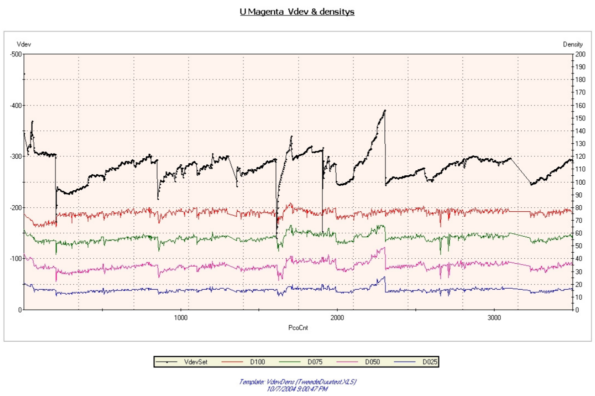

Figure 2. Process follow up during print cycle 3000 A3's

Figure 3. Examples digital ceramic decoration

Due to the dedicated toner design and the process control adaptations, a stable printing process during the complete test cycle could by achieved but still under careful operator control. A cycle of 3000 A3+'s matches with the demand of the ceramic decoration industry for which a typical job size of 1000 A3's is common, with a clear movement to even smaller job sizes. Further development is however necessary to allow a more "operator friendly" process, in which less interventions of the operator with respect to process control are necessary.

Conclusion

The present feasibility study described in this paper indicates that ceramic digital decoration for industrial applications is possible by an optimized toner design and a careful adaptation of the process control of the printing process, so that ceramic toner and printing process are matched.

For the study a four color set based on in glaze pigments is used. Because of the very limited color space which can be reached with this in glaze color set, it is obvious that for the in glaze market, this process has to be expanded to a 6-7 color set to become a viable commercial solution. This however implies a printing process capable of printing 7 colors.

For the on glaze market, already a definite potential exists for a 4 color process, since a broader color space can be reached with this type of pigments and since the applications in this segment are less demanding.

References

1. EP 0851306, Serge Tavernier, Werner Op de Beeck, Daniel Heitzmann
2. High Tech Initiative der nordostbayerische feinkeramischen Industrie 2000-2004, Project 3 Digitale Dekoration

Bibliography

Xeramics Int'l is a start up company grown out of Xeikon Int'l and is focussed on the development, production and commercialisation of toner based digital printing solutions for ceramic decoration.

Ferro is a leading producer of performance materials sold to a broad range of manufacturers. The business unit Color and Glass Performances Materials developes and produces pigments and fluxes for ceramic decoration.

Rosenthal AG is an independent company in the Waterford Wedgwood Holding and a producer of high quality dinnerware porcelain.

BHS Tabletop AG is a producer of high quality tableware for the hotel and restaurant market.