Digital Ceramics and Glass Decoration with Thermal Transfer Printing

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Abstract

The decoration of ceramic and glass articles is primarily accomplished with analogue printing methodologies today. Images are printed onto transfer decals with inks containing inorganic pigments and glass frits. The decals are mass produced with silk screen and other printing methods. In a secondary operation, these decals are used to transfer the printed image onto the glass or ceramic article. However, demands are increasing for more customization in these types of printing applications. Current analogue technologies like silk screen printing have expensive set-up costs, making short runs impractical. Digital printing technologies offer a solution for inexpensive short runs for such applications. However, the types of inorganic pigments and glass frits used in glass and ceramic decoration are not compatible with many non-impact printing methodologies. Thermal transfer printing has been found to be an effective approach to digitally print transfer decals for glass and ceramic decoration. The pigments and frits used in such applications are dispersible in thermal transfer inks. In tern, these inks are coated onto thermal transfer ribbons. The ribbons can then be used to digitally print images onto the conventional transfer decals commonly used in this industry.

Introduction

Glass and ceramic decoration dates back nearly as long as the pottery and glass being embellished. The artistic methods employed at that time included painting, glazing, etching and firing. However, with advent of the Industrial Revolution and mass production, glass and ceramic décoration needed to evolve. Analogue printing methodologies began to be used for the decoration of ceramic and glass articles. To facilitate printing onto irregular surfaces, image transfer methods were devised. This was accomplished by printing the desired image onto a releasable transfer sheet or decal. The inks used to print the image contained inorganic (metal oxide) pigments and glass frits. These images were then transferred off the decal and adhered onto the glass or ceramic substrate. The substrate could then be fired to develop the image and permanently affix it. Such decals are mass produced today with silk screen and other printing methods.

However, demands are increasing for more customization in glass and ceramic decoration. Custom designs and images are often desired. Current analogue technologies like silk screen printing have expensive set-up costs, making short runs impractical. Digital printing technologies offer a solution for inexpensive short runs for such applications. However, the types of inorganic pigments and glass frits used in glass and ceramic decoration are not compatible with many non-impact printing methodologies.

Thermal transfer printing has been found to be an effective approach to digitally print transfer decals for glass and ceramic decoration. The pigments and frits used in such applications are dispersible in thermal transfer inks. In tern, these inks are coated onto thermal transfer ribbons. The ribbons can then be used to digitally print images onto the conventional transfer decals commonly used in this industry.

Applications for Digital Glass and Ceramic Decoration

A large business has developed for Promotional materials (glassware, plates, awards) with a company name and logo or a popular location. Frequently, variable data such as names, numbers, color, etc are desired. Country clubs and restaurants frequently desire custom decorated china. While the initial order may be large enough to support the set up costs of silkscreen printing, replacement orders are typically too small. A pent up demand for one of a kind architectural glass windows and doors exists. This market could be well served with a digital decoration process. Wineries and Breweries are making more and more special or custom runs. Such bottles often require custom decoration.

Thermal Transfer Based Overview

The development of Thermal Transfer (TT) as a digital printing methodology began in the early 1980's. The first application for this digital printing technology was for word processor printers. However, it quickly evolved into a variety of other commercial and industrial printing applications. Some applications of thermal mass transfer, such as color office printing, have since been displaced by other digital printing methods such as inkjet and color electrophotography. However, thermal transfer remains the dominate printing technology in other areas such as auto-identification, barcode, flexible packaging, tag and label printing. The reasons for this dominance include fast printing speeds, printer reliability, broad receiver latitude, high image durability and low ribbon cost.

Thermal transfer printers use parallel printing (printing one line at a time) and commonly operate in the range of 15 cm/sec to 30 cm/sec. Some TT printers for the flexible packaging market can print at 56 cm/sec. In comparison, Inkjet printers use serial printing and a typical office type Inkjet printers operate at speed of only 3.8 cm/sec.

Thermal transfer printers are highly reliable. They are designed to operate in a wide range of environments (Shipping Docks, Factory Floors, Offices and Homes). These printers have very few moving parts as they are parallel printers, printing one line of information at a time. The linear thermal printheads are very durable as well often printing 100 km of or more of substrate before replacements are necessary. Another reason for the high reliability of these printers is the separation of function built into the ribbons. The backcoating on the ribbons controls the printhead-ribbon interface. Such backcoats are designed to lubricate the printhead over the wide printing temperature range (100^o-400^oC), providing a coefficient of friction which is relatively independent of temperature. The face side of the ribbon contains the imaging coatings which are thermally transferred to a receiving sheet in response to heating from the printhead. These imaging coatings providing the desired printing characteristics (speed, durability, color, etc.) for the ribbon. In contrast, ink jet inks must combine both functions. This greatly restricts ink formulations latitude and reduces the overall reliability of inkjet printheads.

The types of inorganic pigments and glass frits used in glass and ceramic decoration are not compatible with many non-impact printing methodologies such as inkjet. The pigments are dense and difficult to disperse into a stable, jetable ink. However, the separation of functions in thermal transfer printing make it easy to apply such pigment, in a thermoplastic binder, to the imaging side of a thermal transfer ribbon. The ribbon can then be easily printed onto the transfer sheets or decals used in glass and ceramic decoration.

New Process for Digital TTR Production of Ceramic Decals

The face side imaging coatings of a thermal transfer ribbons for glass and ceramic decoration must supply all of the necessary imaging materials required for the decoration. The colorants used in such processes must be extremely heat and light stable and thus typically metal oxide pigment are used. However, the temperatures required to melt and fuse such pigments is extremely high. By using various low melting silicon dioxide based glass frits as vehicles for the metal oxide pigments, much lower processing temperatures are required for developing and fixing the image onto the glass or ceramic substrate. On there own, mixtures of glass frits and metal oxides are not suitable thermal transfer printing. However, when dispersed in a thermoplastic binder and coated onto the face side of a thermal transfer ribbon, they become quite printable.

The selection of thermoplastic binders and additive for this application are critical, however. These binders merely facilitate the thermal transfer of the image first onto the transfer sheet and then onto the final substrate. After this, their job is done. However, these materials, being organic in nature, will not survive the harsh firing conditions required to develop and fix the image. In our work, we have found that binders and additives must be selected both for their excellent TTR print characteristics and for their ability to firing cleanly. In our studies we have found that no aromatic rings or triple bonds may be present in these binders or additives. Most desirable are saturated binders, such as paraffin waxes, which burn cleanly and are not very exothermic when oxidized. Binders which rapidly release large volumes of gas can disrupt the ceramic image, causing bubbles or other visible defects. We have found that oxygen containing binders, such as acrylic resins, burn cleanly in this process.

Transfer paper or decals for glass and ceramic decoration are commonly available in two varieties, heat transfer and waterslide. Heat transfer sheets are typically used for indirect image transfer where a hot silicone pad is used to pick the image off the transfer sheet and then apply it to the substrate. Water slide transfer sheets allow the image to directly transfer onto the substrate. After printing, the waterslide sheet is soaked in water to swell the gelatin layer beneath the image. The image can then be released from the paper and applied to substrate. Whether using heat transfer or waterslide paper we have found that a covercoat of clean burning thermoplastic binder needs to be applied, either above or below the image, to the transfer sheet to protect the image during the transfer process. The image, being very thin and fragile, requires a tough, protective coating to prevent tearing or distortion which may easily happen in the transfer process.

In our studies, we have found that the metal oxide pigments and the glass frit need not be mixed together in the same layer. However, sufficient quantities of glass firt are required in the image to completely encapsulate the metal oxide pigments during the firing process. Depending on substrate being fired (glass/porcelain/ceramic/glassy ceramic) determines the specific type of glass frit which must be used. Thermal transfer ribbons may be prepared with separate glass frit and metal oxide imaging layers. Such imaging layers may be over one another on a single thermal transfer ribbon or coated on separate ribbons. We have also found that glass frits may be added to the covercoat formulation and that such covercoats may be printed to the transfer sheet from a thermal transfer ribbon.

In order to prepare complex, colored images for glass and ceramic decoration, some form of process color printing must be employed. Unfortunately, a pure process color pallet of metal oxide pigments (yellow, magenta and cyan) is not available. However, enough metal oxide colors exist that complex color images can be built up using multiple image layers of these different pigments, each formulated into a separate thermal transfer ribbon. We have found that it is essential to interleave a glass frit image between each of the color layers. Actually, if we print an image and then overprint (or underprint depending on the transfer method) one layer of frit, the image is durable. Essentially, the frit layers help to seal the color layers together and permanently affix them to the substrate.

We have also found that the separation of frit and pigment into separate layers aids in the development of color intensity while still working within the confines of TTR ribbon technology. It also allows for more flexibility and fewer ribbons as metal oxide ribbons can be used with different frit ribbons, depending upon the substrate that the image will be affixed to. Firing schedules are dependent on the type of substrate (glass, porcelain, ceramic, etc) as well as the dimensions of the substrate. In general, glass substrates require the lowest firing temperatures, porcelain intermediate and ceramic the highest temperatures. The glass frits are optimized to soften and adhere to these substrates at temperatures just slightly below the softening points of the substrates themselves.

Conclusion

A digital imaging process, utilizing thermal transfer printing, has been described for use in glass and ceramic imaging applications. This process uses specially formulated thermal transfer ribbons to print images onto transfer sheets and decals. These images, made up of metal oxide pigments and glass frits, may then be either directly or indirectly transferred to the glass or ceramic article being decorated or imaged. The articles are then fired to develop the images and permanently affix them to the substrate. This digital imaging method enables the mass customization of such articles at costs considerably lower than the analog printing methodologies typically used today. Complex, high resolution color images can now be easily formed on glass and ceramic substrates for applications such as dinnerware, tiles, doors, windows, architectural building panels, promotional and novelty items and awards.

Biography

Daniel J. Harrison, Vice President, Research and Development. Dan joined IIMAK in May, 1998. Prior to joining IIMAK, Dan was employed for 16 years at Eastman Kodak and most recently held the position of Manager, Thermal Print Media Research and Development. Dan is an inventor on over 80 world wide patents in the Digital Printing field. He holds a B.S. in Chemistry and a Ph.D. in Polymer Science from the University of Connecticut and an MBA from the Simon School of Business, University of Rochester. Dan is a member of the American Chemical Society, The Society for Imaging Science and Technology, the Society for Coating Technologies and the Association for Color Thermal Transfer.