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Review paper

Recent development on preparation of ceramic inks in ink-jet printing

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Abstract

The ink-jet printing has been widely applied in the decoration of ceramic tiles in last ten years since its excited characteristics provide the possibility to produce the customized ceramic tiles with higher image definition at a lower cost in a shorter duration. The number of ink-jet printers in operation worldwide increased rapidly in recent years. Besides the printer, one of the critical factors for an effective printing is inks. This paper focuses on the ceramic ink and reviews recent development on the preparation of ceramic inks by various methods, such as sol–gel, reverse microemulsion, polyol, hydrothermal and mechanical grinding. Some aspects for future development are proposed based on the application of ceramic inks in industries.

Keywords: Ceramic; Ink-jet; Ink; Preparation

Contents

1. Introduction

Ink-jet printing has been developed as a non-contact direct-write technology for the decoration of ceramic tiles [1–6]. Since 2000, the ink-jet printing for the decoration of ceramic

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tiles has attracted recent attentions. The conventional printing processes used for ceramic tile decoration are flat screen printing in the 1960s, rotary screen printing in the 1970s and flexographic and intaglio printing in the 1990s [7]. It is necessary for the printing with the conventional methods above to contact the printer with ceramic tiles. However, ink-jet printing as a non-contact deposition method can provide a low-cost, high-definition, efficient use of materials and waste elimination process. Also, the contamination is minimized in ink-jet printing.

1.1. Characterization of ink-jet printing

As a promising technique, ink-jet printing is suitable to produce complex patterns. All ink-jet printing techniques are based on the digitally controlled ejection of drops of fluid from a print head onto a substrate. The ink-jet printers are classified as either continuous (CIJ) or drop-on-demand (DOD) [8]. The drop-on-demand (DOD) mode is widely applied in ink-jet printing for various industrial applications, which deposits a precise quantity of functional ink in the form of droplets on a substrate. The inks consist of a solute dissolved or dispersed in a solvent. The process essentially involves the ejection of a fixed quantity of ink in a chamber, from a nozzle through a sudden, quasi-adiabatic reduction of the chamber volume via piezoelectric action. A chamber filled with liquid is contracted in response to application of an external voltage. This sudden reduction sets up a shockwave in the liquid, which causes a liquid drop to eject from the nozzle. The ejected drop falls due to gravity and air resistance until it impinges on the substrate, spreads under momentum acquired in the motion, and surface tension aided flow along the surface. The drop then dries through solvent evaporation [9]. In addition, a direct-write technique named electrohydrodynamic printing was developed to perform ceramic patterns, such as nano-sized hydroxyapatite, lead zirconate titanate (PZT), etc., with a higher resolution when compared to conventional ink-jet printing [10–12].

In recent years, the ink-jet printing applied in the decoration of ceramic tiles has become more popular. Many manufacturers have adopted the ink-jet printing to produce patterns on the ceramic tiles since the ink-jet technique has the following advantages:

(a) The ink-jet printing is a non-contact method with a lower noise, compared to the conventional printing techniques. The sole forces that are applied to the substrate result from the impact of tiny ink drops. Hence, fragile substrates and non-flat substrates, which are difficult to be treated in the conventional printing methods, can be processed.
(b) The ink-jet printing is a totally digital process. The process from design to product is simplified, leading to the time saving and lower details loss. It is effective for the ink-jet printing to obtain the high image definition and the better image performance. The location of each droplet of inks deposited on the substrate can be predetermined and also can be changed in real time. Hence, the different patterns of tile can be processed in sequence or even together. The ink-jet printing provides a more realistic representation of natural material such as stone and wood. It is possible for the ink-jet printing to produce the customized products with a lower cost in a shorter duration, compared to the conventional processes. The edge-to-edge printing in ink-jet printing allows the uninterrupted patterns across tile boundaries.
(c) A wider color gamut is performed in ink-jet printing by using the inks of different colors, such as the standard four colors (i.e., cyan, magenta, yellow and black) and six colors.
(d) The use of inks (ceramic colorants) is more efficient.
(e) A wide range of materials can be deposited. The material is in a liquid form with its physical properties (i.e., mainly viscosity and surface tension) lying in an appropriate range. Pigments, dyes, glass frits and metallic particles are readily printed from suspensions, as well as a wide range of other materials, which can be used to perform optical and electronic functions.
(f) The machine footprints for the ink-jet printing are smaller than those for the conventional processes [6,13–15].

1.2. Inks

Some dominant factors affecting an effective printing process are the printer performance, ink properties and substrate characterization. The physical and chemical properties of inks are the critical parameters in ink-jet printing, which have a great influence on the generation of ink droplets, the interaction between ink droplets and substrate, and drying of ink droplets to form a pattern. For applications, the ink chemistry that directs the hardware selection and drives the implementation should be defined. There are four major types of ink-jet inks, i.e., phase-change, solvent-based, water-based, and UV curable. Some inorganic materials such as ZrO_2, Al_2O_3 and Pb$(Zr_{0.53}Ti_{0.47})O_3$ (PZT) were applied in the phase-change inks. Meanwhile, Au/Cu, $BaTiO_3$, ZrO_2, NiO and ceramic pigments in the solvent-based inks can be used in ink-jet printing. Solvent-based inks use alcohol or a mixture of alcohols such as ethanol, isopropanol, 2-methoxyethanol and terpineol as a vehicle. It is necessary for the drying of UV curable inks to use UV radiation [8,16–25].

The preparation of the inks is often complicated due to the challenging requirements of ink-jet inks. Except for the conventional requirements (i.e., long shelf life and proper color properties), the inks must possess the physico-chemical properties that are specific to the various printing situations. The effect of each component of the ink on the overall performance, from storage in the cartridge, through jetting, to its behavior on the substrate and on human health and environment should be evaluated. The factors like ink stability, viscosity, surface tension, pH value and electrolytes, dye/pigment content, solid loading, foaming and defoamers have to be considered in the process of formulating an ink [8,26].

2. Decoration of ceramic tiles by ink-jet printing

Decoration is a major aspect of the production of ceramic tiles. The price of ceramic tiles is closely correlated to the