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Study of the adsorption performance and preparation of functional nano-silica pigment particles

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ABSTRACT

Multifunctional recording coatings for ink-jet printing (RC-IJP) materials were prepared greenly and successfully using nano-silica. An amphiphilic oligoester was grafted onto the surface of nanoscale inorganic silica pigment with toluene-2, 4-diisocynate as a coupling agent. Multifunctional recording coating materials were prepared with homogenized modified silica and polyvinyl alcohol. When the modified silica is exposed to water, the hydrophobic moieties (alkyl chain) curl, and the hydrophilic moieties unfold. In addition, upon exposure to organic solutions, the surface of the silica transitions to a stable energetic hydrophilic state with unfolded aliphatic hydrophobic groups. The prepared RC-IJP can adsorb both water- and oil-based ink effectively and can present color images clearly.

1. Introduction

With the growth of the ink-jet market, ink-jet printing material, as its main consumable, has increasingly received user attention. Ink-jet printing has been applied in various fields, such as organic materials [1–4], electronics [5–7], nanotechnology [8–10], and tissue engineering. The recording coating used for ink-jet printing (RC-IJP) has important effects on printing quality. In this preliminary work, we performed a rapid quantitative analysis of the quality (surface infiltration time and weight per unit area) of a recording coating for ink-jet printing [11].

Outdoor advertising involves the use of printed oil-based inks, which can be water-resistant but cause environmental pollution. Water-based inks are used in indoor print and present clear images, but their water resistance is poor. To overcome such limitations, all-purpose oil-based ink has been considered as a candidate for highly selective patterning methods in outdoor advertising and indoor print. To date, studies on recording coatings for the simultaneous absorption of water- and oil-based ink are scarce in the RC-IJP field. Currently, oil-based recording coatings can absorb oil-based ink, and hydrophilic recording coatings can absorb water-based ink during ink-jet printing. To extend the application of such recording coatings, we developed green and multifunctional RC-IJP materials that can simultaneously adsorb both water- and oil-based ink media well.

Recording coating materials are mainly composites of adhesives, pigment, and some additives. The adhesives mainly used binder-polyvinyl alcohol [12,13], the pigment particle is mainly included the nano-silica [14,15]. As a potentially excellent pigment, nanoscale silica has received great attention because it can be made to adsorb ink [16]. To enhance its dispersibility in aprotic polar solvents and compatibility with polymer matrices, we studied silica using bifunctional group modifiers because a bifunctional modifier can introduce hydrophilicity and hydrophobicity simultaneously into the same molecule, which provides a possible method for inducing dispersibility in both organic and aqueous solutions.

The aim of this study was the preparation of multifunctional RC-IJP materials that can adsorb both water- and oil-based ink well. First, an amphiphilic oligoester was grafted onto the surface of silica (SiO_2), with toluene-2, 4-diisocynate (TDI) serving as a coupling agent. Next, the modified silica and polyvinyl alcohol (PVA) as a binder were mixed to obtain a recording coating for ink-jet printing. When the modified silica was exposed to water, the hydrophobic moieties curled, and the hydrophilic moieties became unfolded, making the modified silica stably disperse in water. In addition, upon exposure to an organic solution, the surface of silica

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transitioned to a stable energetic state exhibiting hydrophilicity with unfolded aliphatic hydrophobic groups. The application of a bifunctional group modifier can enhance the compatibility of silica with both organic and aqueous solutions.

2. Experimental

2.1. Preparation of the bifunctional modified silica

An amphiphilic oligoester was synthesized by the polycondensation of sebacic acid and poly(ethylene glycol) with a molecular weight of 600 in a toluene solution containing trace amounts of sulfuric acid as a catalyst [17,18]. Toluene-2, 4-diisocynate (TDI) was added to the nanoscale silica (mass ratio SiO_2:TDI = 1:0.03). Then, the mixture of SiO_2-TDI and oligoester in toluene was stirred at 80 °C for 8 h under nitrogen. After the suspension was centrifuged, the product was dried at 60 °C under vacuum and designated bifunctional modified silica.

2.2. Preparation of RC-IJP

First, modified silica was added to distilled water (solution concentration 10%) in a homogenizer (Fluko Equipment Shanghai Co., Ltd.) for 30 min. In addition, PVA-1788 was dissolved in distilled water for 30 min and placed in a 90 °C water bath for 40 min to obtain a PVA-1788 solution (solution concentration 8%). The dispersed modified silica solution was added to the PVA solution (mass ratio SiO_2:PVA = 1:1) and dissolved by homogenization for 10 min. Finally, the resulting product was placed in an oven at 40 °C for 60 min and designated the recording coating.

The blade-coater method was used to prepare the RC-IJP. To enhance the polarity of a polyethylene terephthalate (PET) film, the surface was etched by corona treatment, and the recording coating was then coated on the PET film. The excess solution was removed with a blade coater. To evaporate the solvent, the PET film with the recording coating was then moved through a dry tower. Finally, the RC-IJP was wrapped by the take-up mechanism.

2.3. Instrument characterization

The RC-IJP adsorptive ink weighing equipment is shown in Fig. S1. The multifunctional RC-IJP materials were characterized by transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FT-IR), X-ray photoelectron spectroscopy (XPS), and Branauer–Emmet–Teller analysis (BET, determination of the specific surface area of samples). TEM images were obtained

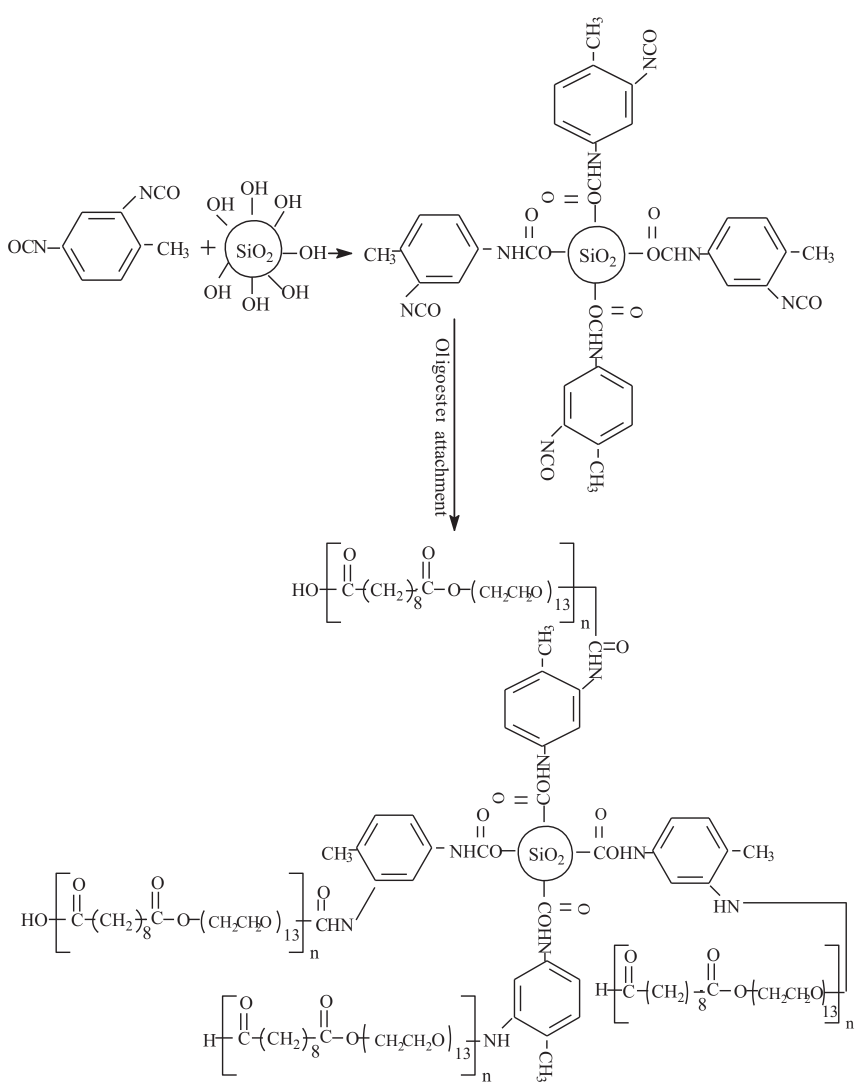

Fig. 1. Schematic of silica modification process.