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# Low density and fast response silica coated with ionic liquid polymer nanoparticles towards electrophoretic displays

Yaping Zhang [a,*], Bin Zhen [b], Ruonan Li [a], Shuxian Meng [a], Xianggao Li [a,c], Yaqing Feng [a,c,*]

[a] School of Chemical Engineering and Technology, Tianjin University, Tianjin 300072, People's Republic of China
[b] College of Chemistry and Chemical Engineering, Tianjin University of Technology, Tianjin 300384, People's Republic of China
[c] Collaborative Innovation Center of Chemical Science and Engineering (Tianjin), Tianjin 300072, People's Republic of China

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ABSTRACT

In this paper, silica nanoparticles and silica coated with ionic liquid polymer nanoparticles (PIL/$SiO_2$) were prepared. They are both monodisperse and smooth spheres, and also own suitable densities and excellent chromaticity. Porous silica benefits their low density, which decreases the gravitational sedimentation and avails electrophoretic mobility. The ionic liquid polymer coating of PIL/$SiO_2$ not only favors hydrophobicity and dispersity stability, but also helps the enrichment of trace polar impurities around the particles, which makes for ionization effect and electrophoretic mobility. The PIL/$SiO_2$ show greatly improved hydrophobicity and electrophoretic mobility. The PIL/$SiO_2$ in the fabricated EPD prototype with thickness of 0.2 mm shows response time of 155 ms, much faster than the silica nanoparticles, $TiO_2$ previously reported and commercial EPDs.



## 1. Introduction

Electrophoretic displays (EPDs) have attracted much attention owing to their paper-like appearance, ultralow power consumption, good flexibility [1,2]. White electrophoretic particles are one of the key parts in EPDs. Now response time of white electrophoretic particles in commercial EPDs exceed 260 ms, which cannot meet with the requirement of 40 ms of dynamic video play (25 frames per second). To achieve smooth play effect, white electrophoretic particles with fast response are in urgent demand. $TiO_2$ is always used to prepare white electrophoretic particles due to its excellent optical, electrical and chemical properties [3,4]. However, large density of $TiO_2$ makes it very easy to sediment in suspending fluid. Hollow $TiO_2$ particles have been attempting to use as electrophoretic particles [5,6], but their poor mechanical strength is an unavoidable limitation. $TiO_2$ coated with polymer have also been applied [7–9], and their polymer coating could reduce particle density and improve dispersion stability effectively. For now, polymer coatings are mostly coated onto the surface of particles through weak physical interaction, causing swelling problem and affect their lifetime badly. Besides, polymer coatings always offer poor charge performance and slow response to the applied electric field [10].

Porous silica is another candidate pigment. The rich pores and thick pore walls inside offer the particles with light density and excellent mechanical strength. Besides, the rich surface hydroxyl groups outside are propitious to surface modification [11,12]. In this work, porous silica nanoparticles were prepared through a sol-gel process in reverse microemulsion. To adjust density and surface property of the silica particles, an ionic liquid polymer coating was introduced and silica coated with ionic liquid polymer nanoparticles (PIL/$SiO_2$) were obtained. The structure and electrophoretic properties of the obtained nanoparticles was investigated, and the influence of ionic liquid polymer coating was analyzed.

## 2. Experimental

### 2.1. Materials

Analytically methylamine solution, tetraethoxysilane, n-hexane, n-hexanol, and triton X-100 were purchased from Sinopharm Chemical Reagent Corporation (Beijing, China). Analytically n-dodecyl bromide, triethoxyvinylsilane, 1-vinylimidazole, divinylbenzene and potassium persulfate were purchased from Aladdin Industrial Corporation (Shanghai, China).

* Corresponding authors at: School of Chemical Engineering and Technology, Tianjin University, Tianjin 300072, People's Republic of China (Y. Feng).
*E-mail addresses:* zhypin126@126.com (Y. Zhang), yqfeng@tju.edu.cn (Y. Feng).

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### 2.2. Preparation of PIL/$SiO_2$

Firstly, n-hexane 35.80 g, n-hexanol 19.62 g, triton X-100 30.00 g and methylamine aqueous solution (20 wt%, 3 mL) were mixed together, then an n-hexane solution of tetraethoxysilane (10 wt%, 30 mL) was added. After reacted at 35 °C for 60 min, the solution were transferred into autoclave and rotated at 120 °C for 2 h. After washing with ethanol and calcining at 550 °C, the silica nanoparticles were achieved. Secondly, 0.84 g triethoxyvinylsilane and 1.0 g silica were added into 10 mL deionized water, and reacted at 100 °C for 24 h. After washing with acetone and drying, the white particles were obtained and noted as V-$SiO_2$. Thirdly, [VDoIm][Br] ionic liquid was synthesized according to reported work [11]. Finally, 0.64 mmol [VDoIm][Br], 0.2 g V-$SiO_2$ and 0.32 mmol divinylbenzene were added into deionized water, and initiated by 0.16 mmol $K_2S_2O_8$ at 70 °C for 3 h. After washing with ethanol and drying, white PIL/$SiO_2$ were obtained.

### 2.3. Characterization

SEM images were conducted on S-4800 field emission microscope. FTIR spectra were collected on Nicolet 380 infrared spectroscopy. Particle size dispersity and zeta potential analysis was carried out using Beckman Coulter Delsa™ Nano C particle size & zeta potential analyzer. TGA was carried out on TA Instrument SDT Q500. XRD was conducted on Ultima Ⅳ X ray diffractometer (Rigaku, Japan). CIE chromaticity diagrams were measured by X-Rite Eye-one pro colorimeter.

### 2.4. Fabrication of EPD prototype

Two pieces of ITO-coated glass substrates were arranged in parallel-plate capacitor geometry with conducting surfaces face to face, and a polyurethane film was sandwiched to form a cell of 10 × 20 × 0.2 mm. The electrophoretic liquid, a dispersion of sample particles in tetrachloroethylene with an addition of CH-5 additive, was injected into the cell to observe the display performance under the electric field intensity of 30 V/μm.

## 3. Results and discussion

As Fig. 1A showed, all of the obtained particles own uniform spherical structure and piled loosely, indicating their excellent monodispersity. Compared with the silica nanoparticles and V-$SiO_2$, the PIL/$SiO_2$ show larger average diameter (Table 1). The characteristic vibration peaks assigned to imidazole groups and benzene groups could be found in FTIR spectra [11], and obvious weight loss could also be observed in the TG curve of PIL/$SiO_2$ (Fig. 2). All of the analyses prove the formation of PIL/$SiO_2$.

For silica nanoparticles, the density, average pore diameter, pore volume and specific surface area tested are 1.8125 g/$cm^3$, 62 nm, 0.415 cc/g and 22.745 $m^2$/g, respectively. XRD pattern (Fig. 1C) indicates the pores inside are amorphous. The rich pores inside benefit light density of silica, and large specific surface area affords enough active groups for surface modification. After surface polymerization, the density of PIL/$SiO_2$ decreased to 1.2634 g/$cm^3$,

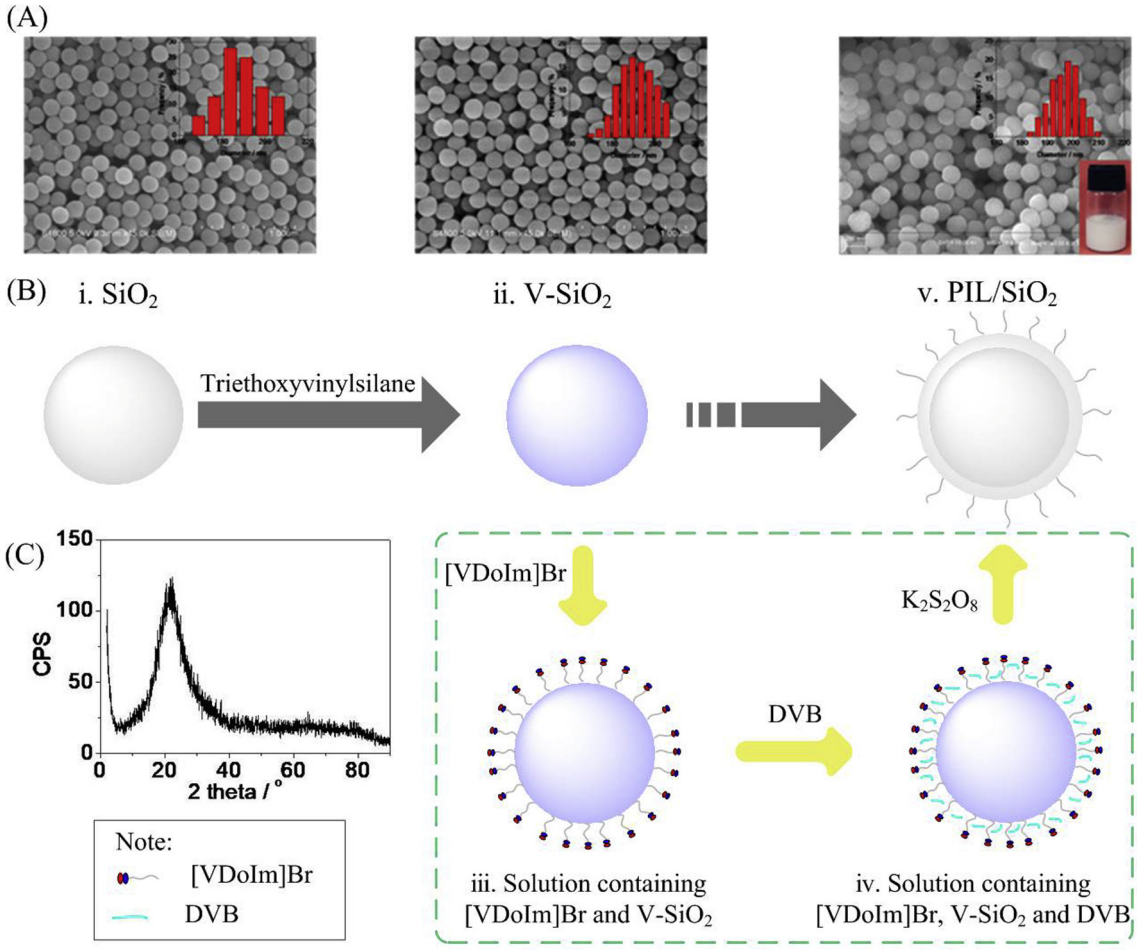


**Fig. 1.** SEM images (A), formation scheme (B) and XRD pattern (C) of particles.