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# Preparation and application of microcapsule-encapsulated color electrophortic fluid in Isopar M system for electrophoretic display

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ABSTRACT

The use of Isopar M as a liquid suspending fluid for electrophoretic display was studied. The dispersion stability and chargeability of pigments suspended in Isopar M were investigated. Polyisobutylene monosuccinimide (T-151) as the charge control additive in Isopar M electrophoretic fluid can provide a good electrophoretic mobility to the particles. The wall materials of a series of blue–white, red–white and yellow–white dual-particle microcapsules were prepared by in situ polymerization of urea and formaldehyde. The mass ratio of wall/core material was a key factor in influencing the yield of microcapsules. The concentration of resorcinol has an impact on the surface morphology and mechanical strength of microcapsule wall. Microcapsules' surface morphologies were characterized by optical microscopy and scanning electron microscopy. The performance of the microcapsules with different binder materials and adhesive layers were investigated. Contrast ratio of microcapsules display device were tested every 10 days for a period of 90 days. The compatibility of Isopar M with both the electrophoretic particles and bounding capsule was studied.



## 1. Introduction

Electrophoretic displays (EPDs), especially microencapsulated electrophoretic displays (MC-EPDs) have been a research focus both in academic study and in industry due to their merits of good brightness and contrast, wide viewing angles, state bistability and low power consumption [1,2]. Presently, white–black e-book has been successfully commercialized while colorful electrophoretic display devices based on MC-EPD have not been realized for practical application due to the technical matters. Therefore, the colorful MC-EPDs will become the next major research work.

Suspending fluid was used to disperse the electrophoretic particles, and it can be chosen based on concerns of chemical inertness, low toxicity and environmental impact, as well as its chemical compatibility with both the electrophoretic particle and bounding capsule. Additionally, the fluid encapsulated with polymeric materials also can be chosen to have a poor solubility to some polymers, which was helpful in dispersing polymer particles [3]. Organic solvents, such as paraffin oils [4], cyclohexane [5], tetrachloroethylene [6–9] are commonly used as suspending medium. The suspending fluid could be a single solvent. It also can contain a blend of solvents such as hydrocarbon Oil 0.8 mixed with Isopar G [10] or cyclohexane mixed with tetrachloroethylene [11]. Presently, tetrachloroethylene was more commonly used as dispersion medium in the research. However, tetrachloroethylene was toxic. It also has a good solubility to polymers resulting in a bad compatibility with electrophoretic particles and bounding capsule. In our study, we adopted Isopar M as dispersion medium. Isoparaffin may particularly suitably be used due to its good dispersibility for electrophoretic particles, good compatibility with electrophoretic particles and bounding capsule, inexpensiveness and low toxicity to human body [3].

Generally, the EPD device with a high contrast ratio is our goal. It was reported that for the dual-particle system, the red–white contrast ratio of simple EPD device and MC-EPD device reached 1.65 and 1.38, respectively [12]. In our studies, for a simple EPD device, the contrast ratio of 2.92, 2.72 and 1.33 was realized for blue–white, red–white and yellow–white electrophoretic fluid, respectively. For a MC-EPD device, the contrast ratio reached 1.86, 1.62 and 1.30 for blue–white, red–white and yellow–white electrophoretic fluid, respectively.

It is known that microcapsules for EPD can be prepared by complex coacervation [13–16], interfacial polymerization [11,17] and in situ polymerization [18–21]. In this paper, in situ polymerization method by using urea–formaldehyde resin was employed to prepare microcapsules. The microcapsules prepared for EPD by using this method are featured with regular spherical shape, smooth surface and a narrow size distribution. The microcapsules contain dual-particle electronphoretic fluid system including red–white, blue–white and yellow–white particles. In order to improve the dispersion stability and chargeability of the particles in the electrophoretic fluid, charge control agent and stabilizing agent were also added.

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## 2. Experimental

### 2.1. Materials

Isopar M was purchased from Huishuo Chemicals Co. Ltd. (Shanghai, China). Pigment Blue 15, Pigment Red 48:2 and Pigment Yellow 13 were purchased from Clariant Tianjin Co. Ltd. (Tianjin, China). Gelatin, resorcinol, urea, formaldehyde, ammonium chloride, sodium dodecyl sulphate, anhydrosorbitol ester of oleic acid, polyvinyl pyrrolidinone (PVP K90 MW 1300,000) and polyvinyl alcohol (PVA MW 77,000) were obtained from Guangfu Chemicals Co. Ltd (Tianjin, China). Hyperdispersants CH-5 and CH-11B were obtained from Sanzheng Polymer Co. Ltd. (Shanghai, China). Polyisobutylene monosuccinimide was purchased from South Oil Additive Co. Ltd. (Wuxi, China). Polyurethane (PU MW 5000) was purchased from Nanhua leather chemical Co. Ltd.

### 2.2. Preparation of red electrophoretic fluid

The red particles in this electrophoretic fluid were modified P.R.48:2 particles. The structure of P.R.48:2 were shown in Fig. 1, and the pigment particles were coated by PE through a sedimentation procedure. The morphology of modified red particles was regular and the size distribution was even.

To 100 mL sample bottle, 10 mL Isopar M as dispersion medium, 0.35 g P.R.48:2/PE as red electrophoretic particles, 0.10 g hyperdispersant CH-5 as stabilizer, 0.12 g polyisobutylene monosuccinimide (T-151) and 0.05 g anhydrosorbitol ester of oleic acid (span85) as emulsifier [22], were added. The resultant mixture was milled by the method of ball milling. It was milled for 48 h with 50 g $ZrO_2$ bead as milling medium at a stirring speed of 2000 rpm. The red electrophoretic fluid was then obtained.

### 2.3. Preparation of blue electrophoretic fluid

The blue particles in this electrophoretic fluid were modified P.B.15 particles. The structure of P.B.15 was shown in Fig. 1. The pigment particles were recrystallized by acid-leaching method and then coated by polymethyl methacrylate (PMMA) through dispersion polymerization [23]. The modified blue particles have good dispersion stability and the size distribution was even.

The blue electrophoretic fluid was obtained by the above described procedure for preparation of red electrophoretic fluid, and was made up of 10 mL Isopar M, 0.35 g Pigment Blue 15 (P.B.15)/PMMA, 0.1 g assistant-hyperdispersant CH-11B, 0.10 g hyperdispersant CH-5, and 0.15 g T151 as charge control additive.

### 2.4. Preparation of yellow electrophoretic fluid

The yellow particles in this fluid were modified P.Y.13 particles. The structure of P.Y.13 was shown in Fig. 1, and the pigment particles were encapsulated by polystyrene (PS) through a miniemulsion polymerization procedure. The morphology of modified yellow particles was spherical and the size distribution was narrow.

The yellow electrophoretic fluid was obtained by the above described procedure for the preparation of red electrophoretic fluid, and was made up of 10 mL Isopar M 0.35 g P.Y.13/PS particles, 0.15 g T151, 0.10 g CH-5 and 0.05 g span85.

### 2.5. Preparation of white electrophoretic fluid

The white particles in this electrophoretic fluid were modified $TiO_2$ particles. $TiO_2$ was grafted by KH570, and then coated by PMMA through a dispersion polymerization method [24].

The white electrophoretic fluid was obtained by the above described procedure for the preparation of red electrophoretic fluid, and was made up of 10 mL Isopar M, 2 g $TiO_2$/KH-570/PMMA white particles, 0.15 g CH-5, 0.10 g T151, 0.25 g span85.

### 2.6. Preparation of dual-particle electrophoretic fluid systems

Blue–white, red–white and yellow–white electrophoretic slurries were made by first mixing two kinds of electrophoretic fluid with volume ratio of blue/white, red/white and yellow/white at 1/6, 1/8and 1/3, respectively. The mixture was then dispersed by ultrasonic for 0.5 h to obtain a good dispersion state.

### 2.7. Preparation of urea–formaldehyde resin microcapsules

Microcapsules were prepared by in situ polymerization of urea and formaldehyde as the wall materials. 10 g urea, 1.5 g ammonium chloride, 2 g gelatin and different concentrations of resorcinol in 250 mL deionised water were adjusted to a pH of about 3.5 with aqueous hydrochloric acid (0.01 mol/L). 0.07 g sodium dodecyl sulphate (SDS) as emulsifier was added to the above solution. The resultant mixture was poured into a 500 mL flask. 3 g, 4 g, 5 g, 6 g and 7 g of dual-particle color electrophoretic fluid was added into flask respectively, and then the mixture was stirred at rate of 600 rpm for 5 min. The mixture was then stirred at rate of 350 rpm, and 25 g formaldehyde (37% aqueous solution) was dripped into the flask. The reaction was continued for another 2 h at 55 °C. The 40–70 μm microcapsules were obtained by washing with deionised water and sieving with molecular sieve.

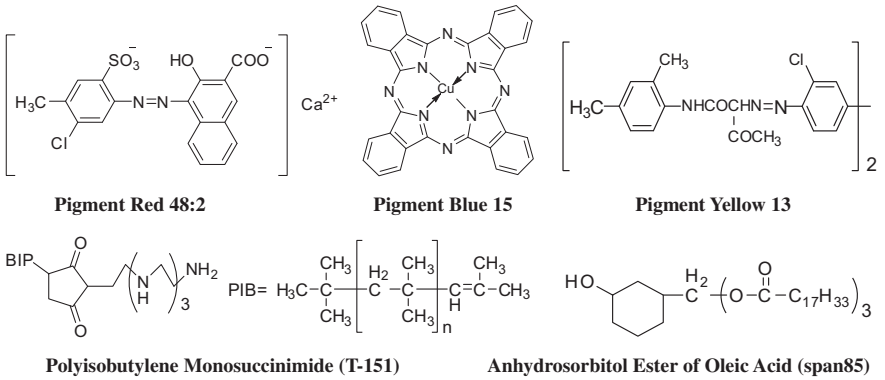


**Fig. 1.** Chemical structures of pigment and dispersant materials.