

Manufacturing of Positively Charged White Electronic Ink by Latex Particles for Electrophoretic Display

Dong-Guk Yu^a, Jeong Ho An^a, Jin Young Bae^a, Yong Eui Lee^b,
Sung Duk Ahn^b, Seung-Yeol Kang^b, and Kyung-Soo Suh^b

^aDept. of Polymer Sci. & Eng., Sungkyunkwan University, Su-Won 440-746, Korea

^bElectronics and Telecommunications Research Institute, Daejeon, 305-350 Korea

Phone : +82-31-290-7298 , E-mail : ydk63407@etri.re.kr

Abstract

In this study, we have investigated the positively charged polymer particles using emulsifier-free emulsion polymerization for applications in electrophoretic displays. The FT-IR, Zeta potential and SEM characteristics showed that by emulsifier-free polymerization, the positively charged polymer particles were manufactured. Using these particles, we can obtain well-dispersed white latex particles in dielectric suspending media.

1. Introduction

Electronic papers have recently been of great interest for applications in information displays requiring low cost, low weight, and low power consumption. The displays with these requirements can be achieved by the methods using microencapsulated electrophoretic particles¹⁻³, twisting balls⁴, and cholesteric liquid crystals⁵.

The microencapsulated electrophoretic display (EPD) can be fabricated by a roll-to-roll method, so its manufacturing cost is expected to be even lower than any other displays. For the image retaining property of the EPD, the pigment particles should be well dispersed in the dielectric suspending medium in a long time and the agglomeration of the particles should be prohibited.

TiO₂ particles are the most promising white pigments for the EPD, because of their excellent whiteness. However, the density of it is nearly 4.2g/cc, which is so high that polymer coating is necessary for the density matching with usual dielectric suspending media. But, the coating method is not well established. Surfactant and polymeric materials adhering to the particles, preventing close contact between them, also confer stabilization. However, surfactant molecules are not credit for long-term stability. And, this coating

method is necessary to attach charge control agents (CCA) on the particles for the electrophoretic behavior. This is known as the steric hinderance. In the case of the EPD, the dispersion is normally stabilized by a combination of both of these. However, in this present study, we have manufactured positively charged polymer particles as model colloids. Moreover, the charge control agents (CCA) is not used.

2. Experimental

Methyl methacrylate (MMA) was distilled under a nitrogen atmosphere and reduced pressure prior to polymerization. Water was redistilled and deionized. The cationic initiator (V-50) and the other chemicals were analytical grade and were used without further purification.

The PMMA positively charged latexes were synthesized by the method of emulsifier-free emulsion polymerization under the condition listed in Table 1. The polymerization was carried out in a 500ml four-necked round-bottomed glass reactor with a Teflon paddle stirrer operating at various stirring rate (200, 250, 300, 400rpm).

Table 1 Recipes for preparation of latexes by emulsifier-free emulsion polymerization

Ingredient	Amounts (g)	Remarks
MMA	30	
V-50	Variables	0.15, 0.3, 0.6
Water	300	
Reaction conditions	Temp.: 65°C Time: 4h Stirring rate (rpm): 200, 250, 300, 400	

A Fourier-transform infrared spectrophotometer (FT-IR) was used to characterize the functional groups

of the polymer particles. The polymer sample was ground with dried potassium bromide (KBr) powder, and compressed into a disc. The KBr disc was subjected to analysis by an IR spectrophotometer. The particle size and particle size distribution was measured by dynamic light scattering (DLS, Brookhaven). The samples for DLS were prepared by dilution with water. The surface morphology was observed field-emission scanning electron microscope (FE-SEM, Hitachi S-4300). The zeta potential and electrophoretic mobility of the polymer particles were determined using a laser electrophoresis zeta potential analyzer (Zetasizer 2000 from Malvern Instruments). The analyses were carried out at room temperature and zeta potential was an average fifty measurement.

3. Results and discussion

Fig.1 shows that the FT-IR characterization of positively charged polymer particles was performed using a Mattson 5000 FT-IR spectrometer Unichem corporation (signal averaging 32scans at a resolution 4cm^{-1}). The experimental results showed that in Fig.1 The spectrum in figure supports the view that the PMMA particles are composed of carboxyl ($\nu \text{C=O}$) $1700 \sim 1740\text{cm}^{-1}$ and ($\delta \text{-N=N-}$) $1500 \sim 1200 \text{cm}^{-1}$ (azo initiator characteristic peaks) and bands at 2851cm^{-1} ($\nu \text{-CH}_2$) and 2920cm^{-1} ($\nu \text{-CH}_3$) corresponding to PMMA main chain. The assignments are reported in the figure.

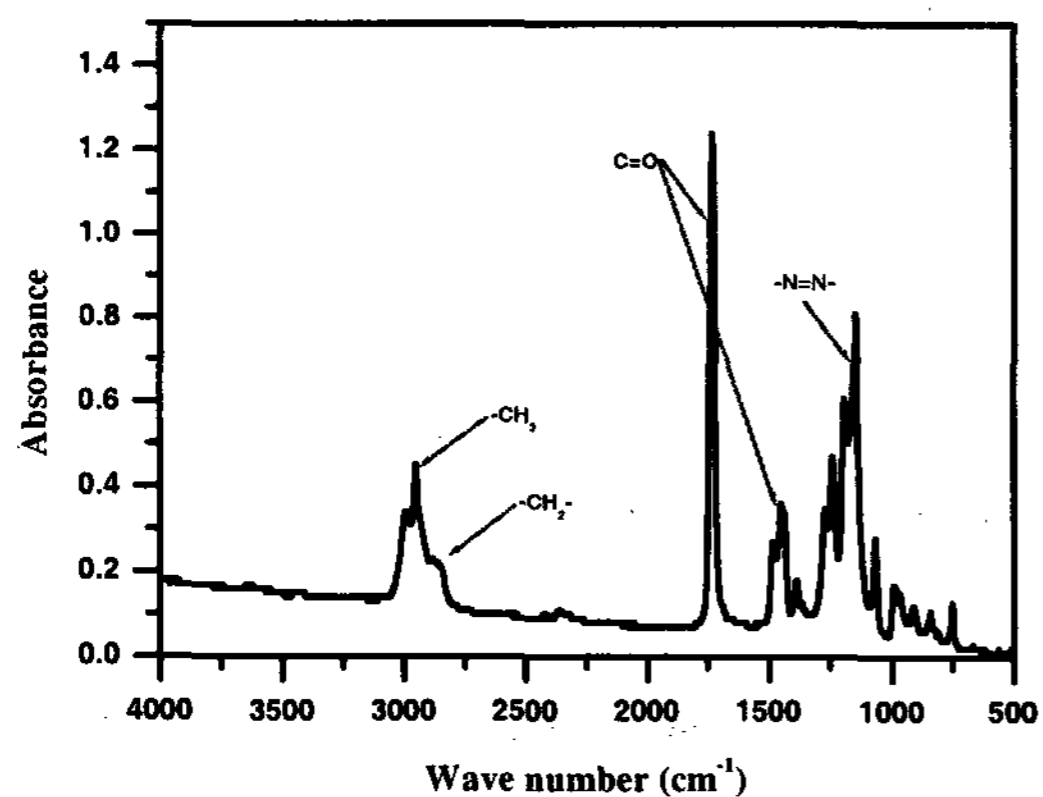


Fig. 1 FT-IR spectra of positively charged latex

The results for the variation of particle diameter as a function of the stirring rate at 65°C , constant

monomer, and a constant initiator concentration is given in Fig.2. The result shows that a slightly decrease in the stirring rate, under constant condition, result in an increase in the particle size. The distribution of particle size is increase as the stirring rate increase. This is due to the formation of size-distributed nuclei, which results in larger particle size distribution.

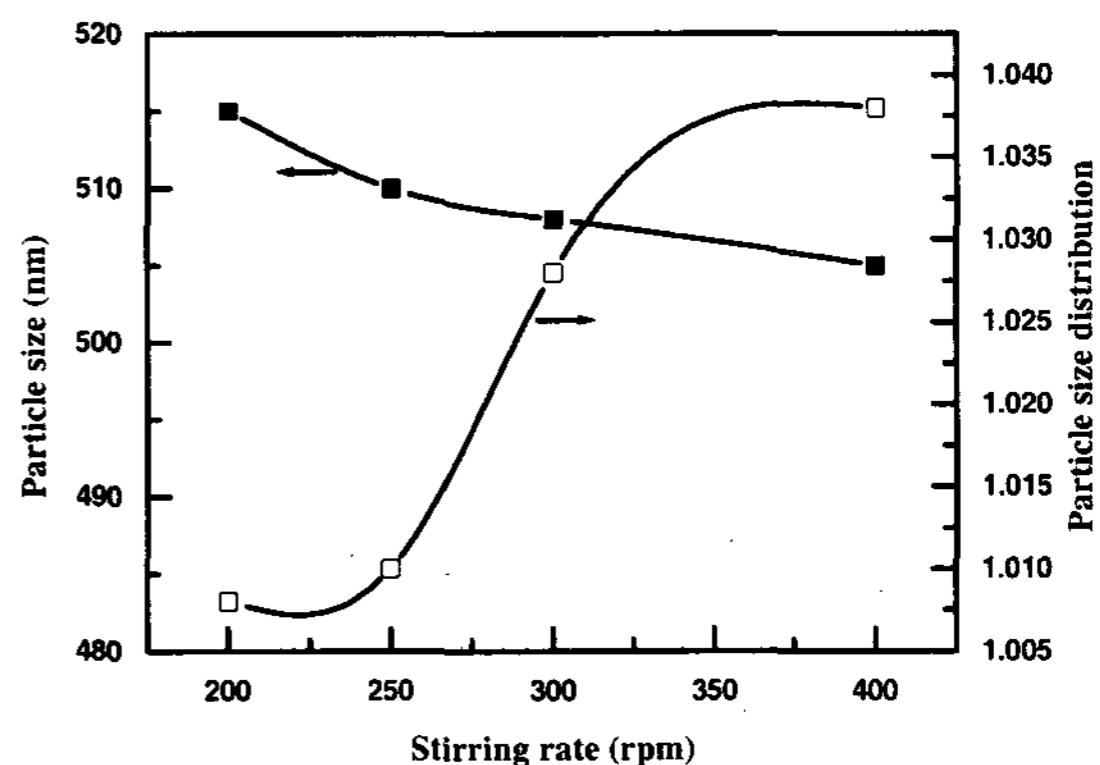


Fig. 2 Particle size and particle size distribution versus stirring rate

Another experiment results show that the variation of particle diameter as a function of the initial concentration of initiator is given in the Table 2. The results clearly shows that a decrease in the initiator concentration, under constant condition (monomer concentration, and stirring rate 250rpm), result in an increase in the particle size. This is due to the time during which the viscosity of the latex particles permits coalescence is increase, producing large particle size.

Table 2. Variation of particle diameter with different amount of initiator

Initiator concentration ^a (%)	Particle diameter (nm)
0.5	522.4
1	510.6
2	490.8

^a Total monomer weight base

The morphology of manufactured polymer particles is uniform size and the particles size distribution is very narrow. Fig.4 illustrates the representative morphology of polymer particles (in the case of stirring rate 250rpm, initiator concentration 1%). It has been found that polydispersity increase with increasing the initiator concentration. However, polydispersity of latex particle is slightly increased with decreasing the stirring rate. (not shown)

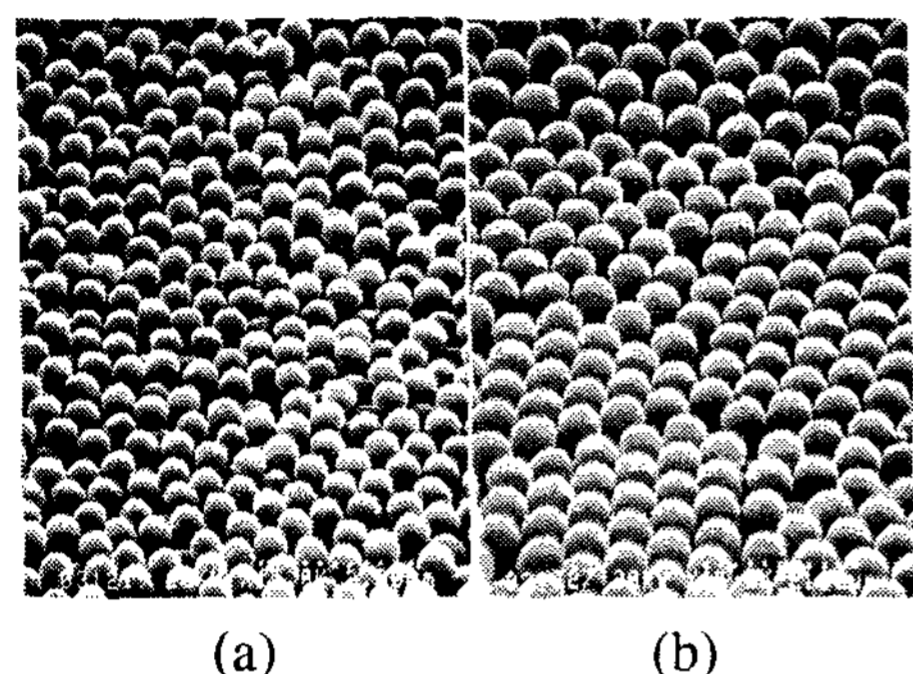


Fig. 4 PMMA positively charged latex particles
(a) 2 wt.% of initiator and (b) 0.5 wt.% of initiator.

The experimental result (Table 2) shows that the zeta potential is 84.6mV and electrophoretic mobility is $3.658 \times 10^8 \text{ m}^2\text{V/S}$ in the condition of 200rpm and 0.5wt.% initiator concentration. The zeta potential and electrophoretic mobility decrease as the increase-stirring rate.

Table 3 Zeta potential and electrophoretic mobility of various experiment conditions.

Experimental condition		Zeta potential (mV)	Electrophoretic mobility ($10^8 \text{ m}^2/\text{V}\cdot\text{S}$)
Stirring rate (rpm)	Initiator concentration ^a (%)		
200	0.5	84.6	3.658
	0.5	82.4	3.575
250	1	78.3	3.428
	2	69.7	3.145
300	0.5	62.5	2.948
400	0.5	48.4	2.621

^a Total monomer weight base

This is due to the particle size distribution effect of polymer particle. Generally, the zeta potential and electrophoretic mobility of colloids were affected the particle size distribution. In the case of fixed stirring rate 250rpm, the zeta potential and electrophoretic mobility decrease as the increasing initiator concentration.

4. Conclusion

In this paper we have investigated the positively charged polymer particles using emulsifier-free emulsion polymerization for applications in electrophoretic displays. (EPD) By the emulsifier-free emulsion polymerization, we can obtain the positively charged uniform size latex particles. This latex will be optimized for the good dispersion of the particles in suspending media. Using these particles, we can obtain good electrophoretic characteristics.

5. Acknowledgments

The Korea Ministry of Information & Communications financially supported this work.

6. References

- [1] B.Chomiskey, J. D. Alvert, H. Yoshizawa, and J. Jacobson, *Nature*, 394 253 (1998)
- [2] Y. Chen, K. Denis, P. Drzaic, *SID 01 Digest*, 157 (2001).
- [3] K. Amundson, J. Ewing, P. Kazlas, R. McCathy, J. D. Albert, R. Zehner, P. Drzaic, J. Rogers, Z. Bao, K. Baldein, *SID 01 Digest*, 160 (2001).
- [4] N. K. Sheridan, E. A. Richley, J. C. Mickkelsen, D. Tsuda, J. M. Crowley, K. A. Oraha, M. E. Howard, M. A. Rodkin, R. Swidler and R. Sprague, *J. SID*, 7 141 (1999).
- [5] S. A. Swanson, M. W. Hart, and J. G. Gordon II, *SID 00 Digest*, 29 (2000).