Nano-Sized Phosphor by Reverse Emulsion Process and Precision Nozzle Phosphor Patterning

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Abstract

A novel ink-jet printing method was investigated for fine patterning of phosphor layer in PDP using a precision nozzle printing. A reverse emulsion method was developed for the synthesis of nano-sized phosphor powder that could be formulated in the phosphor ink. The composition of the phosphor ink including charge controlling agents, solvent, dispersant and nano-sized phosphor powder was optimized for the fine patterning of phosphor layer for high resolution PDP.

1. Introduction

The phosphor pattern on the plasma display panel (PDP) has been fabricated by several methods including screen printing, electrodeposition and photolithographic methods. Although screen printing and photolithographic methods have been currently used widely for patterning of phosphor layer in PDP, those methods are disadvantageous in that they are relatively intricate processes and suffer extra loss of expensive phosphor material. Thus, ink-jet printing with the precision nozzle is considered to be the method of choice for phosphor patterning in manufacturing of high resolution PDP [1-4]. The structure of the AC-PDP and the procedure of ink-jet printing method are shown in Figure 1 (a) and (b), respectively.

In this work, we synthesized nano-sized green phosphor by reverse emulsion method [5-10]. Formulation of phosphor ink consisting of nano phosphor powder, charge controlling agents, dispersant and solvent (distilled water) was investigated for application to phosphor patterning by ink-jet process.

2. Experimental

2-1 Materials

$Zn(NO_3)_2$ (Aldrich, 98%), $MnCl_2$ (Aldrich, 98%) and Na_2SiO_3 (Sigma) were used as received. Cetyltrimethyl ammonium bromide (CTAB) was purchased from Aldrich Chemical Co. n-Butanol and isooctane were obtained from Duksan Co. and used as received.

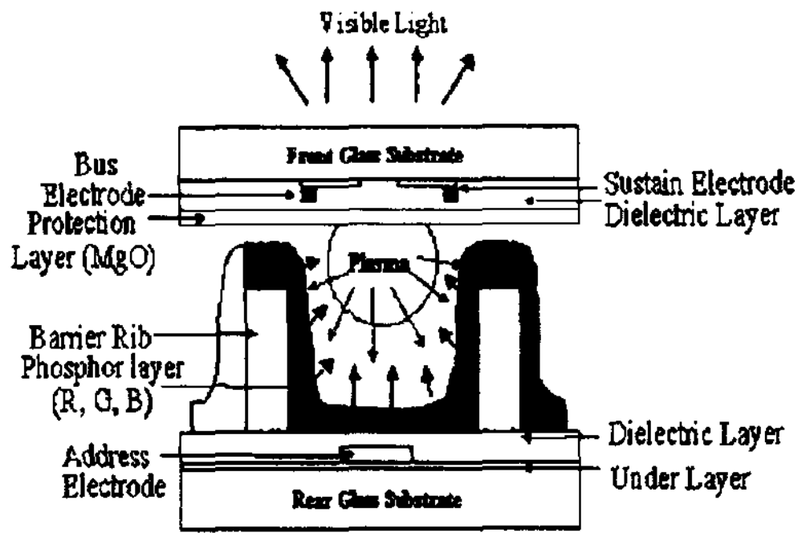


Figure 1. (a) Structure of AC-PDP and (b) procedure of ink-jet printing method.

2.2. Preparation of nano phosphor powder and phosphor ink

Nano-sized green phosphor (Zn_2SiO_4:Mn) powder was prepared by stirring Zn^{2+}/Mn^{2+} and SiO_3^{2-} sources in reverse emulsion solution composed of water/CTAB/isooctane/n-butanol, as presented in Figure 2. Green phosphor ink suitable for ink-jet printing was prepared by mixing the nano-sized green phosphor (Zn_2SiO_4:Mn) powder with aminosilane as a charge controlling agent, solvent and a dispersant. This mixture was milled with 400 μm of zirconia bead for 6hr or 48hr to get stable dispersed phosphor ink, as shown in Figure 3.

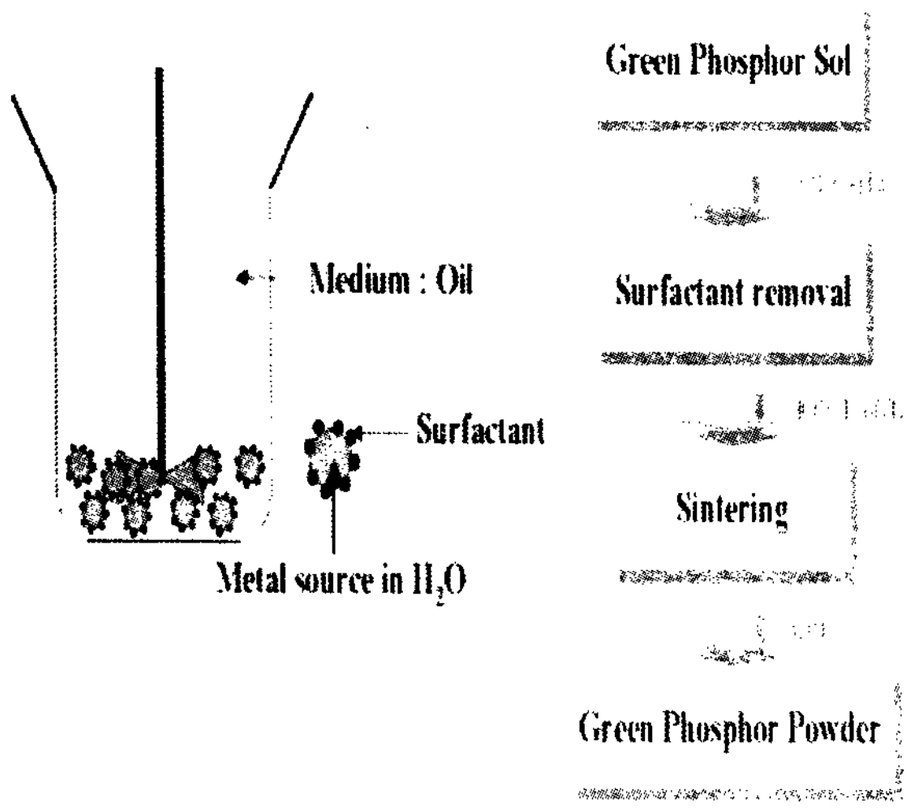


Figure 2. Synthetic process of the green phosphor powder by reverse emulsion method.

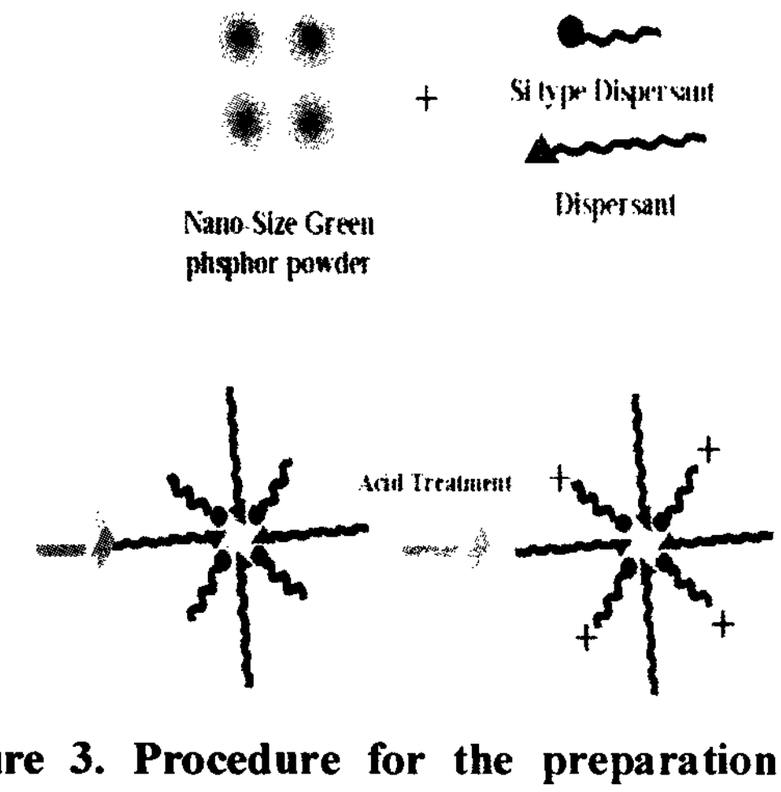


Figure 3. Procedure for the preparation of the phosphor ink.

2. 3. Measurement

The shape and size of green phosphor powder prepared by reverse emulsion method was observed with scanning electron microscope (Hitachi S-4200). Zeta potential and mobility of the charged particles were measured by using zeta potential analyzer (Otsuka electronics, Model : ELS-8000). Colloidal stability was analyzed by using Turbiscan (Formulaction Expert). Brightness was measured with Optical Emission Spectrometer (Ocean Optics S2000).

3. Results and Discussion

For optimizing rheological properties of the phosphor ink for the ink-jet printing with precision nozzle, nano-sized green (Zn_2SiO_4:Mn) phosphor powder was prepared by reverse emulsion method. From SEM image as presented in Figure 4, the size of the synthesized Zn_2SiO_4:Mn phosphor powder was found to be in the range of 100 – 500 nm.

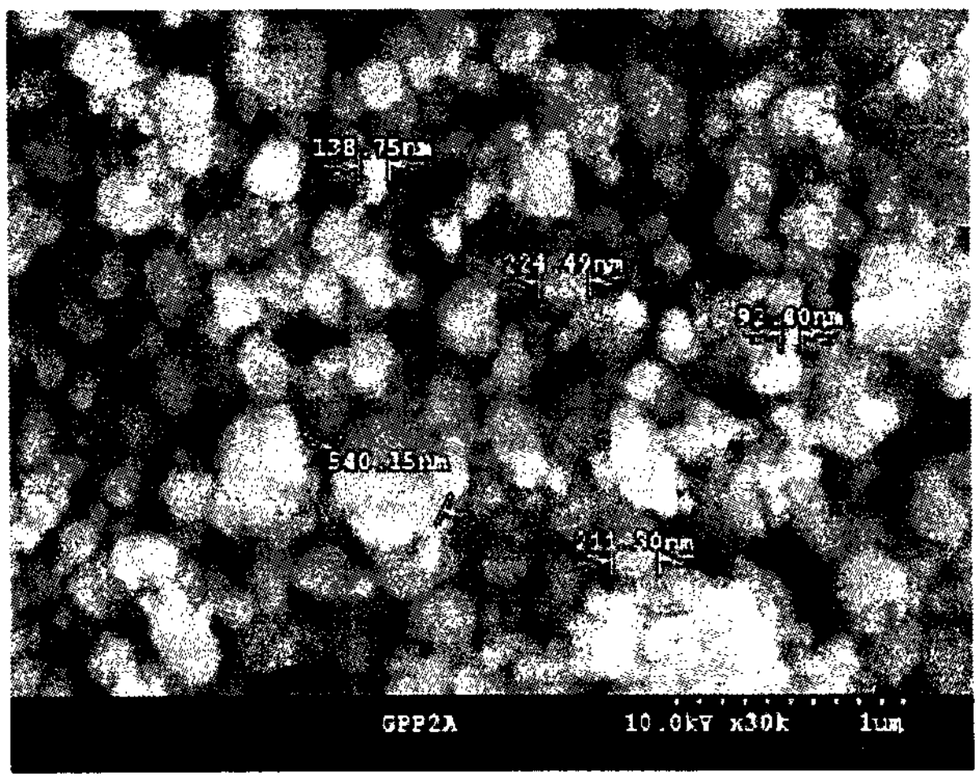


Figure 4. SEM image of the phosphor powder.

Phosphor ink suitable for ink-jet printing was formulated by introducing cationic charges on the surface of phosphor powders, resulting in narrow size distribution of phosphor ink. It was confirmed from Figure 5 that the average size of phosphor power in ink formulation was measured to be 220.7 nm.

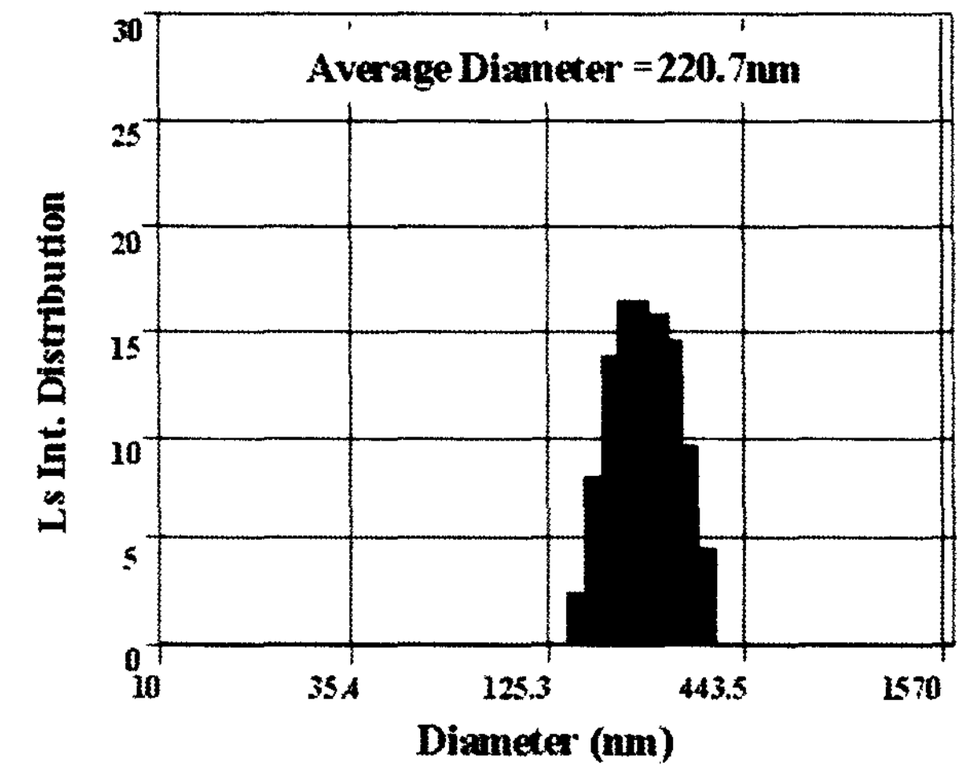
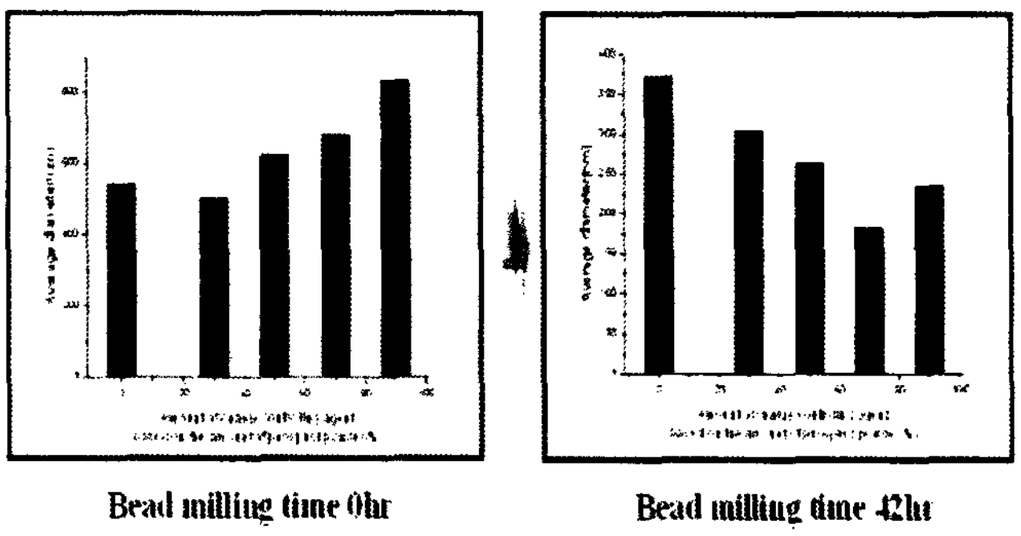
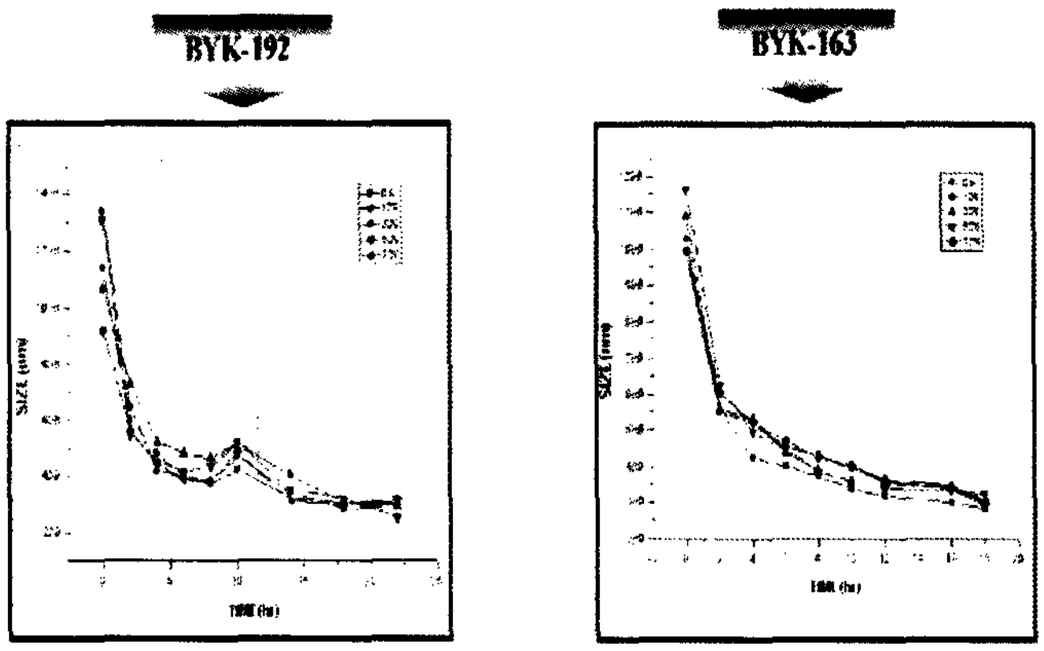


Figure 5. Average size distribution of phosphor ink.



(a)



(b)

Figure 6. Effect of the content of charge controlling agents (a) and the types of commercial dispersant (b) on the size distribution of phosphor ink

The effect of the amount of charge controlling agents added and types of commercial dispersants on size distribution of phosphor inks was further investigated. As presented in Figure 6 (a), it was observed that smaller size of phosphor ink was achieved at 70% of charge controlling agent based on the amount of phosphor powder after 48h of milling time. Figure 6 (b) represents the effect of two types of commercial dispersants, BYK-163 and BYK-192. In the case of BYK-163 and BYK-192, little effect was observed on the size of phosphor ink. However, BYK-163 showed good dispersion stability on phosphor ink.

Dispersion stability of the prepared phosphor ink was tested by using colloidal stability analyzer, Turbiscan. As presented in Figure 7, the rate of precipitation of phosphor ink was measured to be 25㎛ per min. This result shows the phosphor ink has excellent dispersion stability.

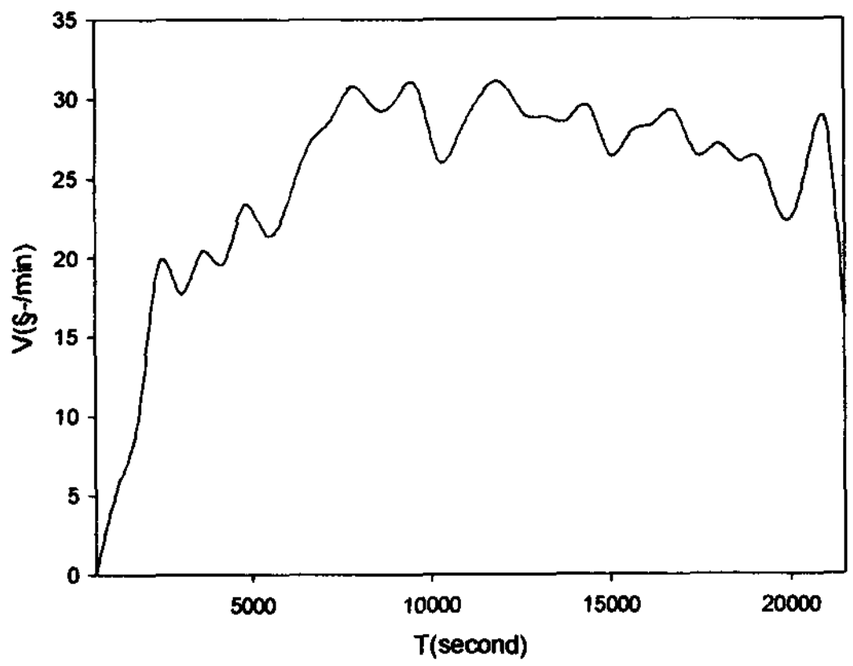


Figure 7. Dispersion stability of the phosphor ink.

The phosphor ink was patterned with a precision nozzle on the back panel of PDP with barrier ribs. The phosphor was fired at 530℃ and then chromaticity diagram was obtained. As shown in Figure 8, the green phosphor layer obtained with the nano-sized powder exhibited chromaticity value close to that of NTSC green. It was also observed from Figure 9 that the brightness of the ink prepared by using nano-sized green phosphor powder was higher than that of other inks containing commercial grade powders.

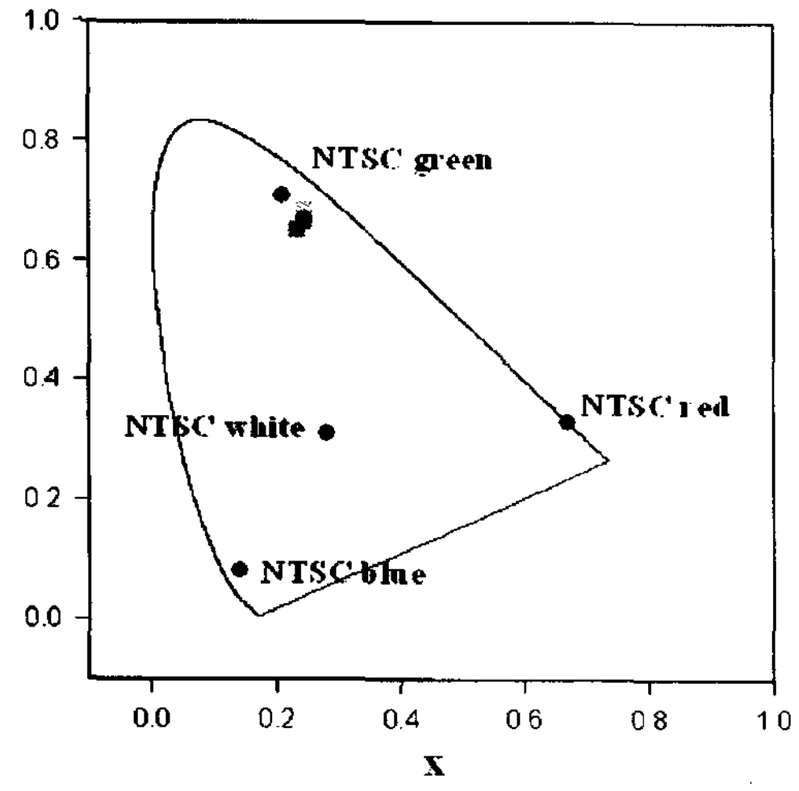


Figure 8. X-Y chromaticity diagram of the phosphor ink.

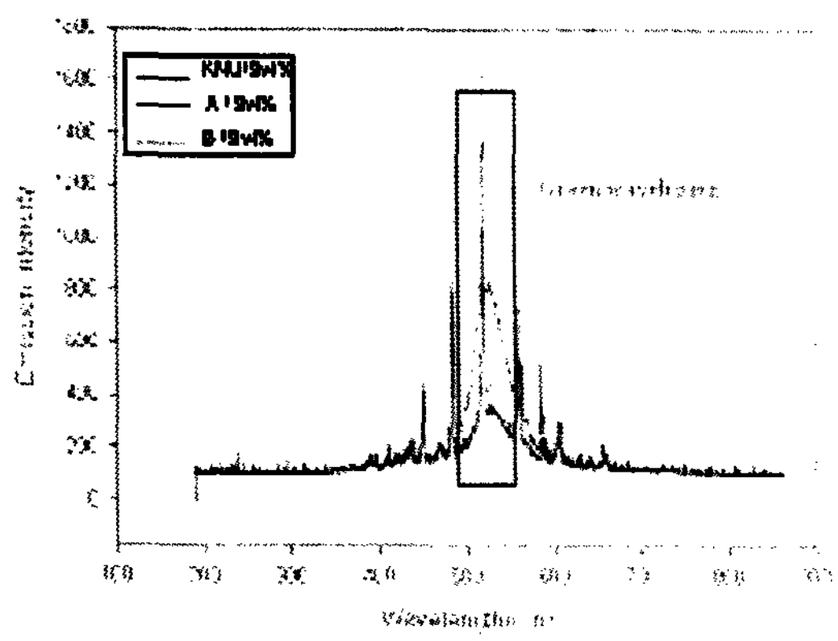


Figure 9. Brightness of PDP prepared using three different phosphor inks.

4. Conclusion

Green phosphor powder with 100 - 500 nm of average diameter was successfully prepared by reverse emulsion method and then formulated with additives to provide phosphor ink suitable for ink-jet printing with precision nozzles. It was found that the phosphor ink prepared using green nano-sized powder exhibited excellent storage and dispersion stability. This formulatin of phosphor ink could be used in the patterning of phosphor layer on back panel of PDP by ink-jet method. After firing, the chromaticity value of the green phosphor layer was close to that of NTSC green.

5. Acknowlegements

This work was supported from Information Display R&D Center, one of the 21st century Frontier R&D Program (MI-020-KR-01-0001-02-K18-01-025-1-2) funded by the Ministry of Science and Technology of Korea.

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