Characteristics of Inorganic Silica-Neodymia Alloy Films as a Dielectric Layer of the Plasma Display Panel

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Abstract

Application of inorganic silica-neodymia alloy films grown by sputtering technology to the dielectric layer of plasma display panel (PDP) is presented. The experimental results reveal that dielectric constant of the alloy films increases with neodymia concentration. Also, the alloy films act as band rejection color filter owing to sharp absorptions originating in the intratransition within the 4f shell of the Nd^{3+} ion. In the optical band pass region, the transmittances of the alloy films show higher than those of commercial glass-like dielectrics. As a result, the luminance of PDP device with the alloy dielectric layer is higher than that of device with conventional dielectrics, indicating wider color gamut and higher color purity.

1. Introduction

It has been known that the functions of dielectric layer in plasma display panel (PDP) are to limit the discharge current and to stabilize the plasma in the discharge cell. [1]

Currently, two kinds of glassy dielectric layers in the front panel of PDP are used. The lower dielectric layer near the substrate acts as an electrode protective layer and the upper one under the MgO layer acts as a high transparency layer. [2] However, the glass-like dielectrics have exhibited some weakness such as the coloration [3] due to reaction with Ag electrode and the cracks of MgO layer [4] due to thermal expansion mismatch with each other, which affect to the image quality and discharge stability. Furthermore, a lower dielectric layer has low optical transmittance and rough surface because of being fired near softening point.

Recently, we have introduced the neodymium-containing transparent dielectrics as a multifunctional layer in PDP design. [5] However, when the neodymium-containing transparent dielectric layer is applicated to PDP devices, a dielectric layer for electrode protection is always needed, resulting in the low luminance and luminous efficiency of PDP devices. Therefore, for the improvements of luminance and luminous efficiency, new dielectric material and structure are prerequisite.

In this study, we have investigated the electooptical properties of inorganic silica-neodymia alloy films and their applications into the PDP devices.

2. Experiments

The silica-neodymia alloy films were grown by using a conventional RF-magnetron sputtering technique at room temperature on the ITO (In_2O_3:Sn)-coated glass substrates (PD-200). The base pressure in the chamber was adjusted to 2×10^{-6} Torr and the pressure during the deposition was maintained at 15 mTorr of Ar and O_2 gas mixture to suppress the formation of oxygen defects. The detail preparation conditions are summarized in Table 1.

The microstructures of silica-neodymia alloy films were analyzed by help of the scanning electron microscope (SEM, Hitachi S4200). The composition ratio in the films was determined by electron probe microanalyzer (Shimadzu EPMA 1600). Optical transmittances of the films were measured by means of an UV-VIS-NIR Spectrophotometer (Varian CARY5G) in the visible region. Electrical properties of the films were measured in the metal-dielectrics-metal configuration with alternative ITO and Pt electrodes.

Table 1. The sputtering conditions of silica-neodymia alloy films

Deposition Parameter	Value
Substrate-Target Spacing	5 cm
Base Pressure	2×10^{-6} Torr
Working Pressure	15 mTorr
Ar : O_2	8 : 2
Substrate Temperature	Room Temperature
RF Power	140 Watt

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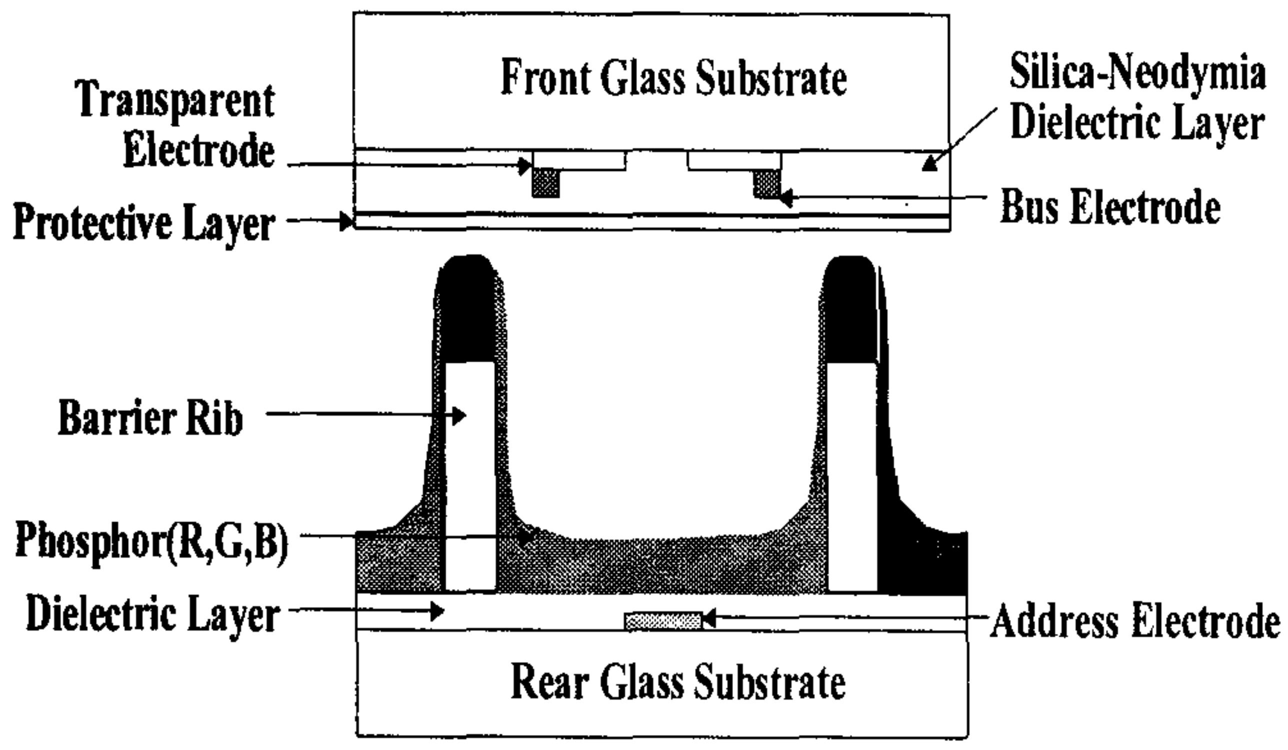


FIG. 1. A schematic cross-section of surface-type PDP device with silica-neodymia alloy dielectric layer.

Investigation for the electro-optical properties of the alloy dielectric layer was carried out on set of a surface-type PDP device, seen in Fig. 1. In the experiments, a He-Ne-Xe gas mixture of 400 Torr pressure for surface discharge and commercial $BaMgAl_{10}O_{17}$:Eu, Zn_2SiO_4:Mn, and $(Y,Gd)BO_3$:Eu phosphors were used in the panel. The square driving pulse with frequency of 30 KHz was applied to the panel. All measurements were performed at room temperature.

3. Results and discussion

Figure 2 shows the dependence of dielectric constants of silica-neodymia alloy films on Nd_2O_3 concentrations. When Nd_2O_3 concentrations increase, dielectric constants of silica-neodymia alloy film increase. This tendency can be expected by the macroscopic dielectric theory that predicts a downward bowing between end members in a mixed materials system. However, the dielectric constants are not reconciled with values estimated from a linear extrapolation between the dielectric constants of SiO_2, 4, and Nd_2O_3, 19. The discrepancy with the values from macroscopic dielectric theory may be attributed to the changes of network structure by composition ratio. [6]

In general, dielectric layer in PDP is required to be low dielectric constant because higher dielectric constant results in higher power consumption.

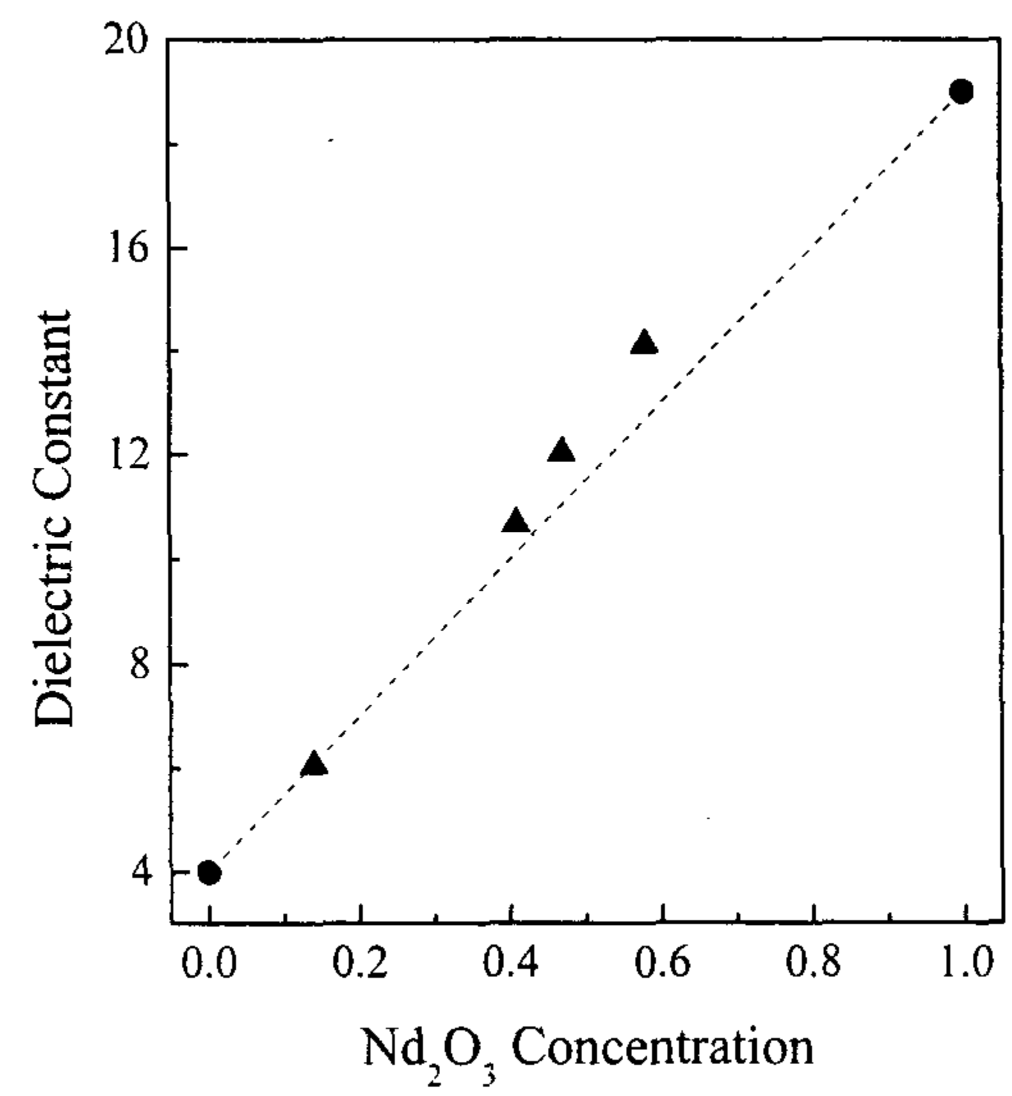
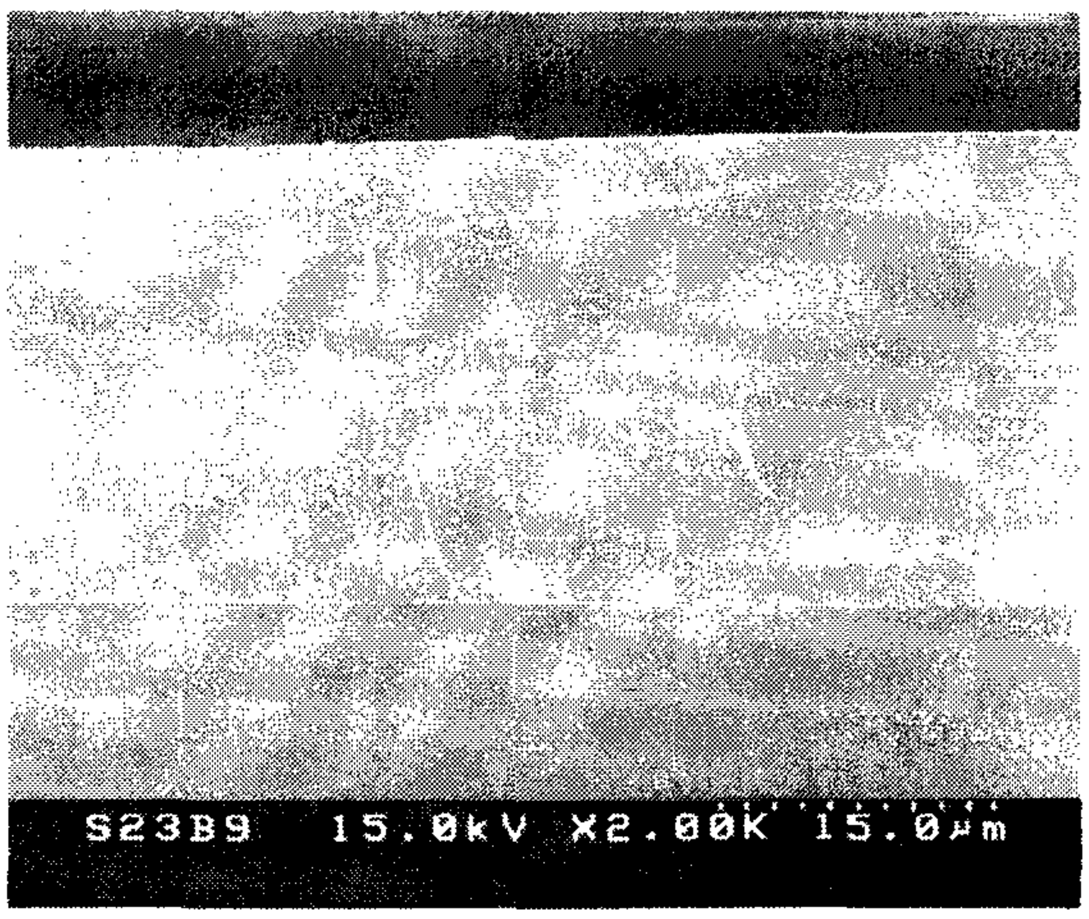


FIG. 2. Dielectric constants of silica-neodymia alloy films as a function of Nd_2O_3 concentrations.

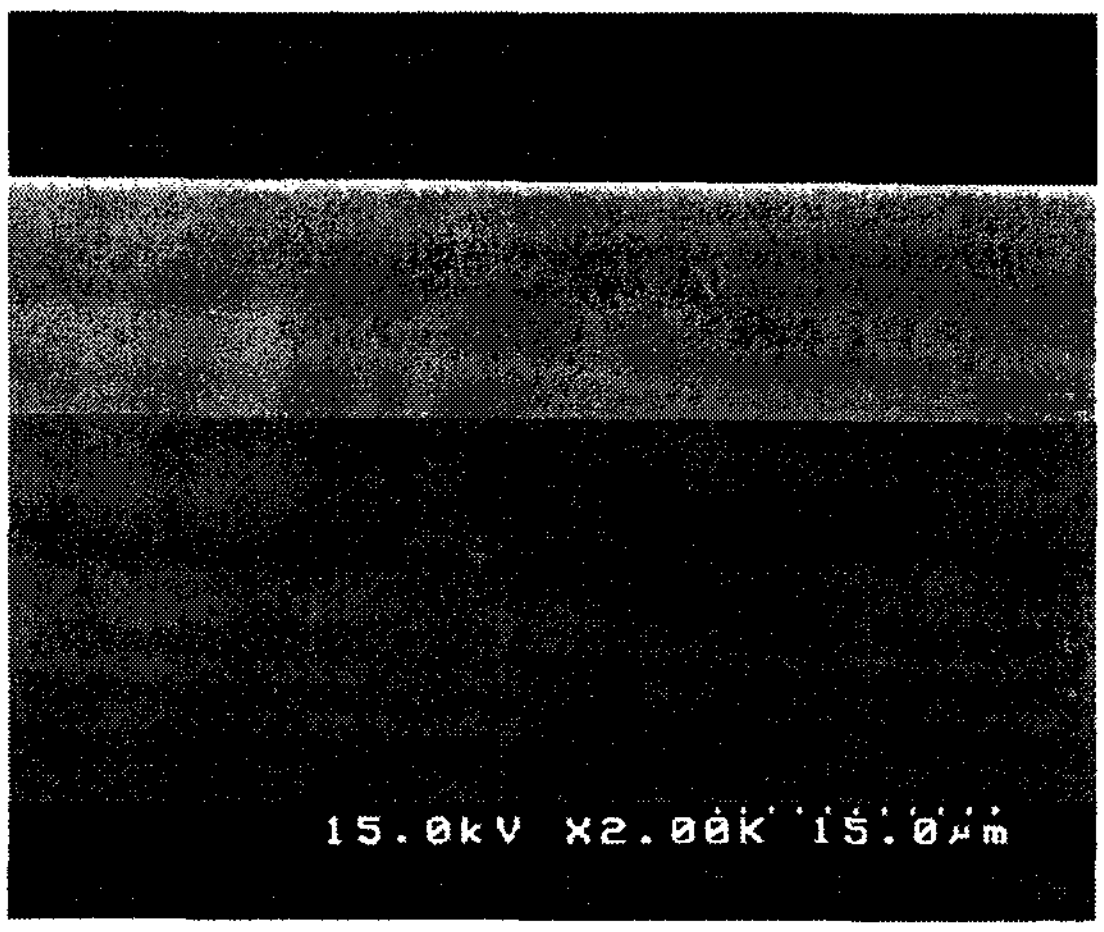
Although dielectric constant of the alloy films increases with neodymia faction in film, dielectric constant of $(SiO_2)_{0.53}(Nd_2O_3)_{0.47}$ film which shows good color filter performance [7] is about 12, which is satisfactory to the above requirement.

The microstructural features of conventional glass-like dielectrics and silica-neodymia alloy films are illustrated in Fig. 3. As shown in Fig. 3(a), void and pinholes can be observed in glass-like dielectrics. Theses void and pinholes may be related to the burnout of organic vehicle in firing process and cause the dielectric breakdown and light scattering. However, it is difficult to eliminate such defects by normal screen printing method. On the other hand, the silica-neodymia alloy dielectrics show a dense film without any porosities and void, as shown in Fig. 3(b). Therefore, the silica-neodymia alloy dielectrics have more fine structure than conventional glass-like dielectric layer.

The optical transmittance of silica-neodymia alloy film is shown in Fig. 4. For comparison, transmittance of conventional glass-like dielectrics is also indicated. It is found that the transmission spectrum of silica-neodymia alloy dielectrics represents good characteristics of band rejection color filter.



(a)



(b)

FIG. 3. The cross-sectional SEM images of conventional glass-like dielectrics (a) and silica-neodymia alloy film (b), respectively.

The absorptions in silica-neodymia alloy film are due to the transitions between the ground state manifold, $^4I_{9/2}$, and a number of excited states within the 4f shell of the Nd^{3+} ions. The prominent absorption bands of Nd^{3+} ions are identified, [8] as shown in Fig. 4. Meanwhile, the optical transmittance of silica-neodymia alloy film in band pass region is higher than that of glass-like dielectrics. This result means that in spite of performing color filter functions, the brightness of PDP devices can be improved.

Figure 5 shows the visible emission spectra from PDP device with silica-neodymia alloy dielectric layer.

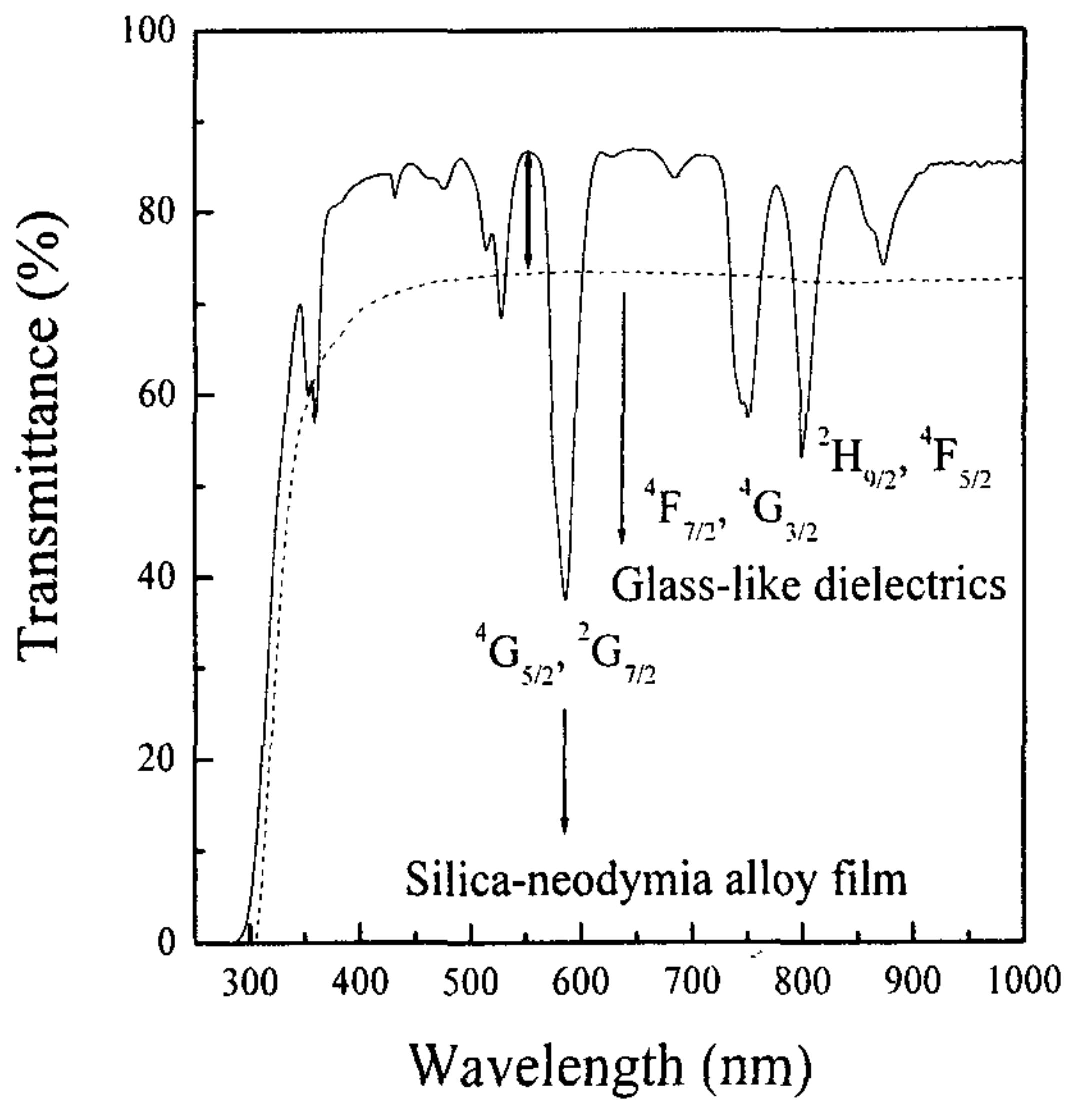


FIG. 4. Optical transmittance of silica-neodymia alloy dielectric layer.

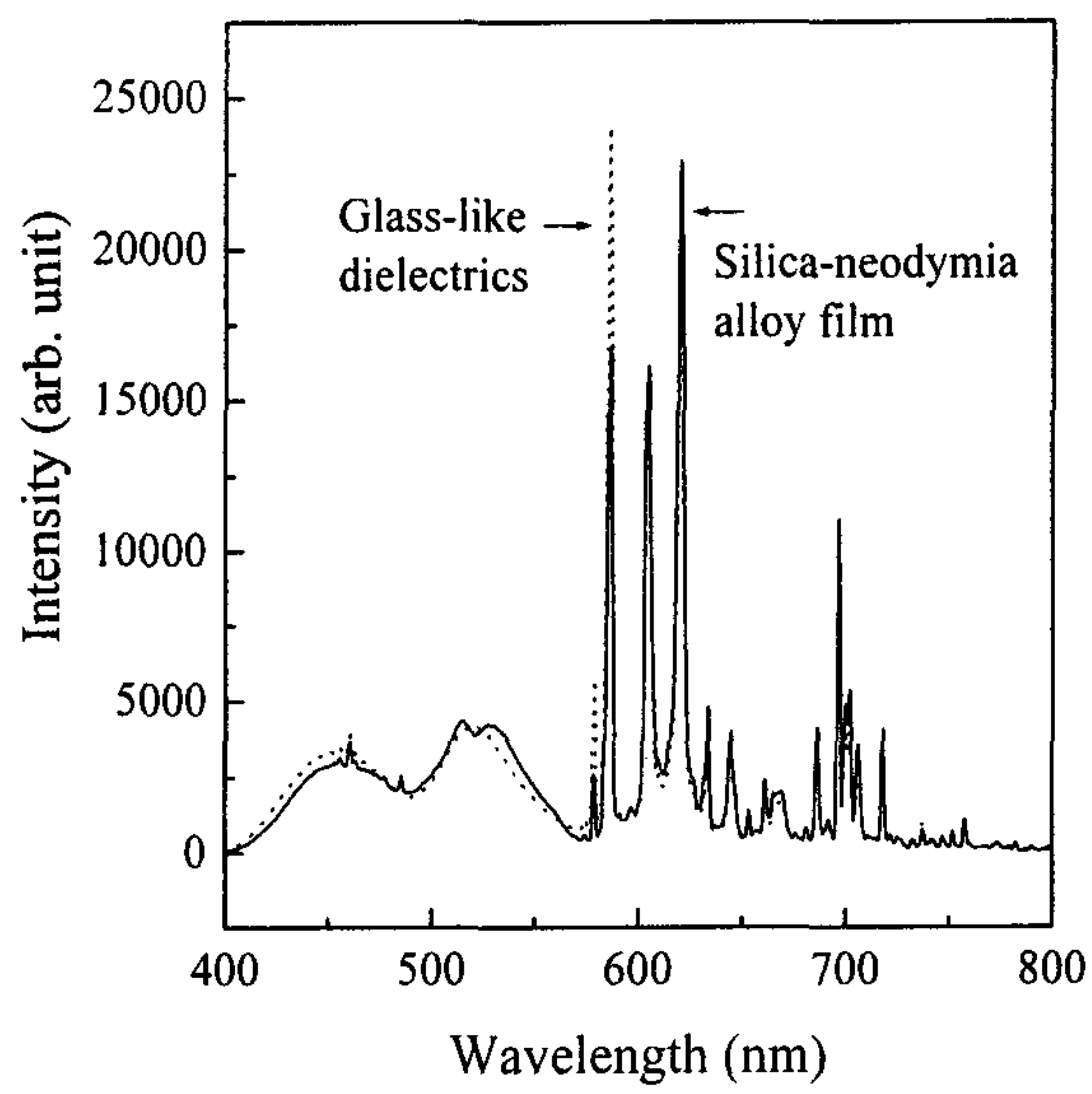


FIG. 5. Emission spectrum from PDP device with silica-neodymia alloy dielectric layer.

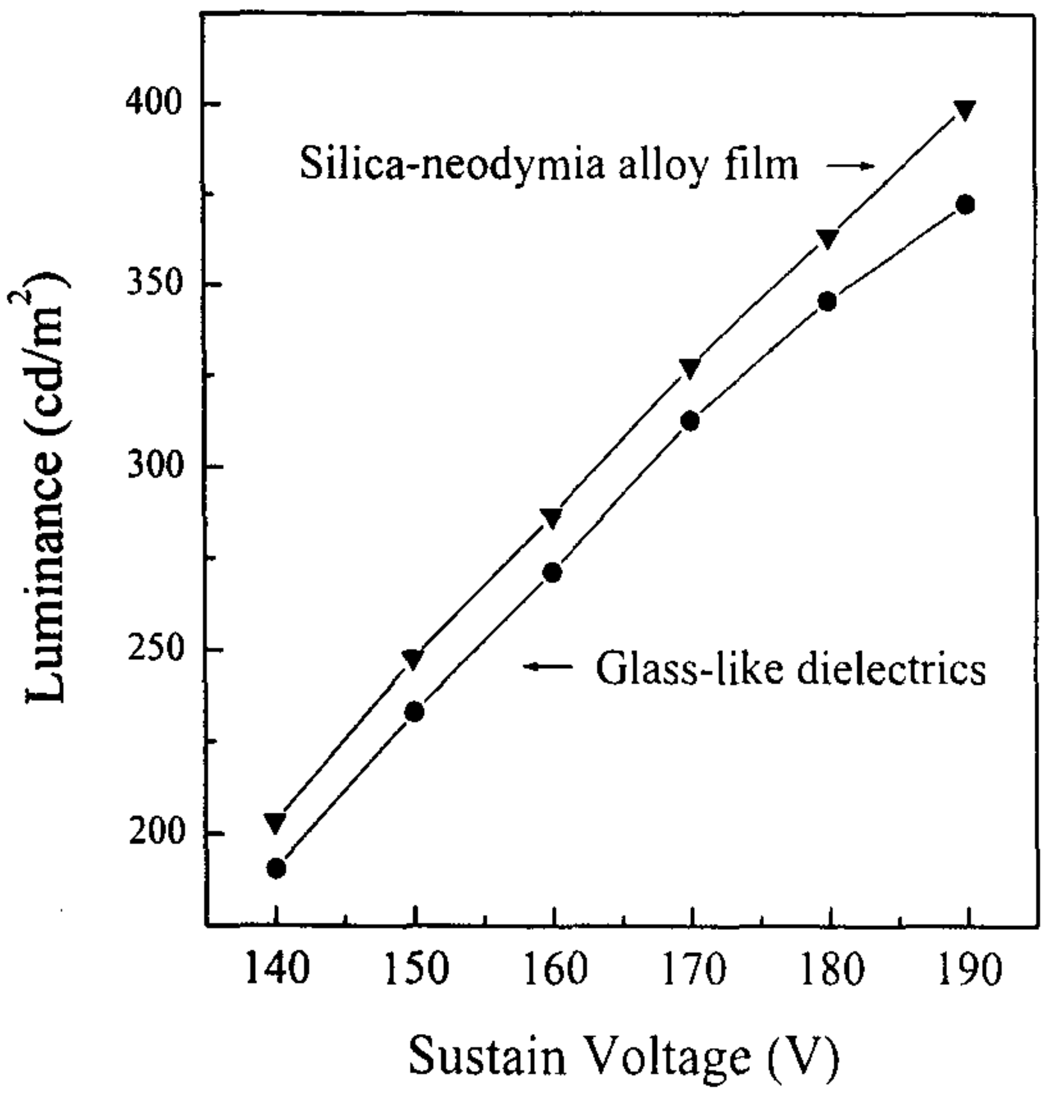


FIG. 5. Luminance of PDP device with silica-neodymia alloy dielectric layer.

By virtue of the strong absorption band due to the $^4I_{9/2}$ to $^4G_{5/2}$, $^2G_{7/2}$ transition of Nd^{3+} ions near 586 nm, the emission of Ne gas discharge at 585.2 nm greatly decreases. In addition, the spectra side-bands of red, green, and blue phosphors are removed, then transmitted band widths of phosphors become narrower. As a result, the color purity and color reproducibility of PDP device with the alloy films are improved, compared with that of glass-like dielectrics

Figure 6 shows the luminance of PDP device with silica-neodymia alloy dielectric layer. As shown in Fig. 6, the luminance of PDP device with silica-neodymia alloy film was higher than that of the device with glass-like dielectrics. This enhancement of luminance is due to the higher optical transmittance of silica-neodymia alloy film in transmission region, as mentioned above. Also, the brightness of PDP devices increases with driving voltage. This may be attributed to the increase of power consumption with increasing voltage.

4. Conclusion

In summary, we have prepared the silica-neodymia single dielectric layer by the sputtering technology and investigated their electrooptical properties. The dielectric constant of the alloy films increases with neodymia concentration. Due to absorptions originating in the intra-transition within the 4f shell of the Nd^{3+} ion, the alloy films indicate sharp absorptions in specific region. Also, in the band pass region, the optical transmittances of films show higher than those of glass-like dielectrics. As a results, it is found that the luminance of PDP device with alloy dielectric layer shows higher than that of device with conventional dielectrics, indicating wider color gamut and higher color purity. Our experimental results suggest that the silica-neodymia single dielectric layer is suitable for the dielectric layer in PDP devices.

5. References

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