Bendable ac-PDP using Fence-Structured Electrodes on Polyethylene Terephthalate Substrate

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Abstract

A possibility of manufacturing bendable ac-PDP using aluminum electrode with anodic aluminum oxide dielectric material system on PET film substrate was explored. For this structure, PET film with fence-structured aluminum electrodes was used for front plate and PET film with barrier ribs of UV curable resin for the rear plate. The results demonstrate that it is feasible to manufacture the bendable ac-PDPs using those material system and are expected to expand the applications of plasma display panels.

1. Introduction

Flexible and/or bendable displays have been regarded as next generation displays which would eventually replace current glass-based stiff TFT-LCDs and PDPs. Such flexible and/or bendable displays are being developed mainly on principles of LCD, OLED, and electrophoretic displays. There are only a few studies on bendable displays based on PDP principles. PDPs, on the other hand, have a very simple pixel structure and are self-emissive devices. Those attributes make PDP as a prime candidate for bendable flat panel displays. Goodarzi [1] et al have attempted to fabricate bendable PDP using PET as the bendable substrates. Further advances were made with the bendable PDPs using silver as metal electrode material [2]. Those studies, however, were based on structures of dc-PDPs, which may not suitable for showing images.

In order to manufacture pixels of ac-PDPs on bendable polymeric substrates like PET, several core technologies listed as follows must be developed. Firstly, metallic sustaining electrode with a high electrical-conductivity needs to be formed on the substrate within the temperature range allowable by the polymeric substrate, ~110^{o}C. Secondly, a dielectric layer that covers the sustaining electrode needs to be formed also within the temperature range. The layer should withstand sputtering of the glow discharge of the device and should have dielectric strength higher than the electric field of glow discharge. These electrical requirements put serious constraints for the selection of the dielectric layer. Thirdly, electron emission layer also needs to be formed at ambient temperatures. Finally, the bendable substrate should have low permeation coefficients for gaseous molecules.

Currently, a combination of ITO/Ag electrodes is being used as the sustaining electrode on front plate of ac-PDPs. Formation of the Ag electrode on a PET substrate via conventional thick-film technology poses a considerable challenge since Ag powder needs to be densified at much higher temperatures than the one permitted by PET substrates, typically less than 110^{o}C.

Glass layer is currently used for the dielectric coating on the sustaining electrode formed on glass substrate. The use of glass layer on the polymeric substrate is almost prohibitive as the sintering temperature of the layer is close to 580^{o}C. Polymeric layer that can be processed at ambient temperatures as the dielectric coating, on the other hand, causes sputtering as well as contaminates the discharge gas. The gaseous components formed by the sputtering such as CO_2, O_2, N_2, as well as other organic elements reduce the efficiency of glow discharge and increase firing voltages.

One of possible candidates of electrode/dielectric layer system that may meet the requirements of bendable ac-PDPs is aluminum electrode/anodic aluminum oxides dielectric layer. Aluminum has electrical conductivity high enough to serve as BUS electrode of ac-PDPs. Some manufacturers are using aluminum as an address electrode to replace expensive silver electrode material. The aluminum electrode pattern may be manufactured by chemical etching of aluminum foil at ambient temperatures. In addition, the anodic aluminum oxides can be formed on the aluminum electrode via anodizing process at ambient temperatures. The anoidic aluminum oxides are ceramic material in essence and may withstand electric field imposed by glow discharge [3]. The combination of highly conductive aluminum electrode with anodic aluminum oxide dielectric coating is expected to be economical as well as robust system for ac-PDP.

In this study, a possibility of bendable ac-PDPs using aluminum/anodic aluminum oxide system on PET substrate was explored. Test panels were prepared with the structure and its luminance and other discharge characteristics were examined.

2. Experimental

Figure 1 shows the processing steps employed in preparing aluminum electrode coated with anodic aluminum oxide layer. Firstly, aluminum foil of 18μm thick was bonded with PET substrate. For the bonding layer, UV curable resin was used. The aluminum foil was, then, coated with AZ-601 GXR and patterned in the form of fence-type electrode by chemical etching process. The electrode pattern was anodized in a solution of oxalic aicd 0.3M at 18°C to form the anodic aluminum oxide. The thickness of the oxide after the anodizing was approximately 4~5μm.

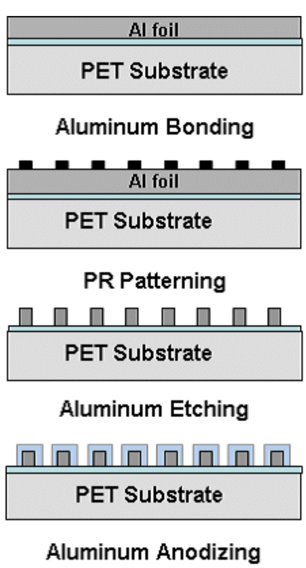

Fig. 1. Processing steps of preparing fence-type aluminum electrode coated with anodic aluminum oxide layer.

The front plate thus prepared was coated with MgO powder via electrophoretic deposition process. The front plate and rear plate were sealed together to prepare test panels. The rear panel has stripe type barrier ribs and coated with Zn_2SiO_4:Mn green phosphor. The panel size was 2 inch in diagonal and the discharge cells has a resolution of VGA grade of 42 inch panel.

3. Results and discussion

3.1. Preparation of fence-type aluminum electrode coated with anodic aluminum oxide layer

Figure 2 shows a SEM image of aluminum electrode pattern after the chemical etching process. As shown in the figure, aluminum electrode pattern was formed fairly uniformly over the surface of the PET substrate. Cross sectional image revealed that aluminum and bonding glass layer are bonded together tightly without any defects (not shown here).

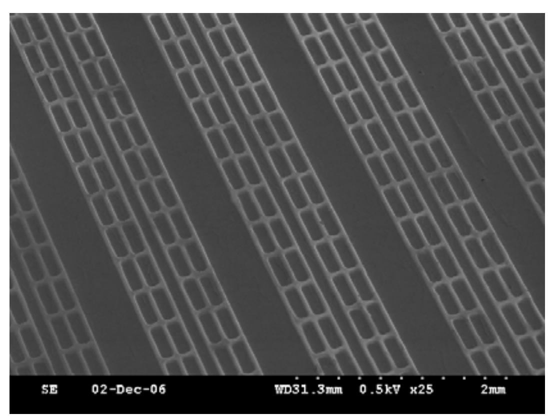

Fig. 2. SEM Images of aluminum electrode after chemical etching step.

After the chemical etching process, the aluminum electrode was anodized to form anodic aluminum oxide layer on its surface. As shown in Fig. 3, uniform anodic aluminum layer was formed by the process. The anodic aluminum oxide on the surface of PET substrate protects the substrate from sputtering of glow discharge.

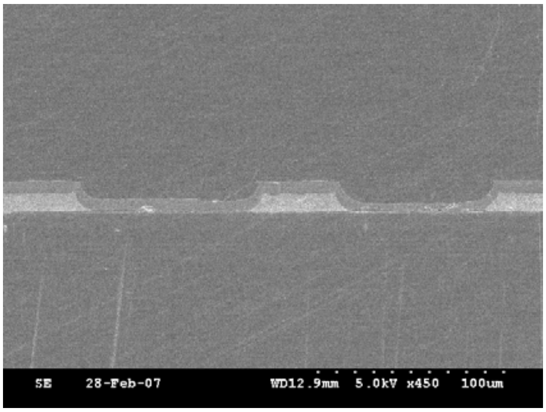

Fig. 3. SEM images of anodized aluminum electrode.

Figure 4 shows the bending characteristics of the front plate with the aluminum electrode/anodic aluminum oxide dielectric layer. Bending of the plate did not cause any delamination of the layer from the substrate.

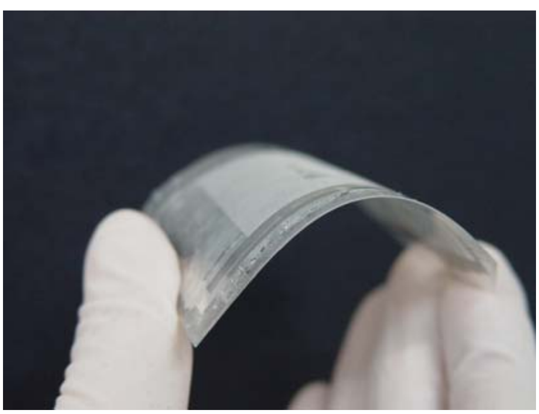

Fig. 4. Flexibility of front plate formed by aluminum electrode/anodic aluminum oxide dielectric system on PET film.

3.2. Discharge characteristic of test panel with fence-type aluminum electrode coated with anodic aluminum oxide layer

Figure 5 shows a bended front plate with aluminum electrode coated by anodic aluminum oxide dielectric layer during glow discharging in a chamber. For this test, the discharge gas was pure Ne. As noted form the figure, the panel emits Neon light over the surface of the plate. The glow discharge occurred stably even under bended condition. The firing voltage of the panel was 170 volt, which is comparable to glass based ac-PDP.

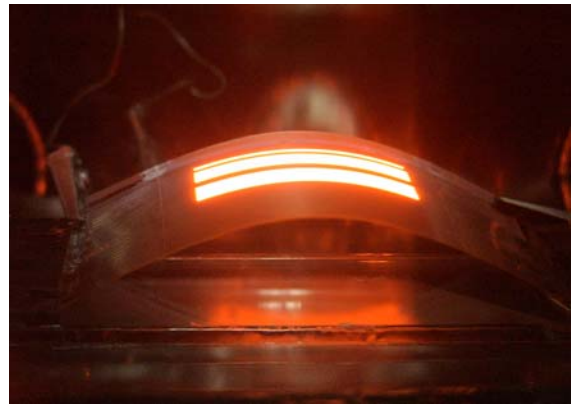

Fig. 5. Luminance of a bended 2-inch front plate within a chamber atmosphere.

The front plate was combined with rear plate coated with a green phosphor. The discharge produced the green light emission as shown in Fig. 6. As noted from the figure, fairly uniform luminance was obtained.

Fig. 6. Luminance of a 2-inch test panel at 185V.

Luminance of the test panel was measured (Fig. 7). The driving frequency was 30kHz and discharge gas was Ne-4%Xe mixture. As noted from the figure, the luminance of the test panel with anodic aluminum oxide layer appeared to be lower by 30~40% than that of conventional test panels using Ag electrode with glass dielectric layer. The power consumed was similar to that conventional test panels. In this study, the luminance efficiency was not estimated since the capacitance of the anodic aluminum oxide dielectric layer was not optimized.

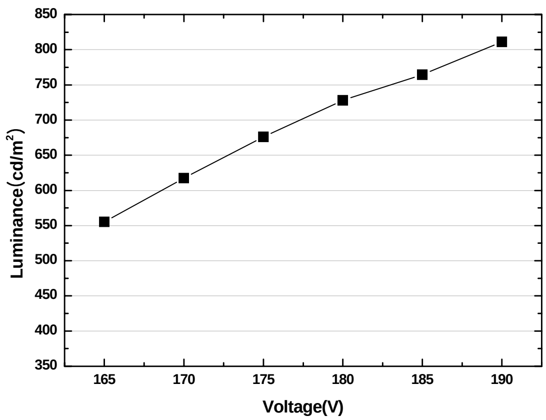

Fig. 7. Luminance of test panels with anodic aluminum oxide layer.

4. Summary

A possibility of bendable ac-PDPs was explored in this study. For the structure, aluminum electrode coated with anodic aluminum oxide layer on PET substrate was used. The anodic aluminum oxide layer was used as the dielectric layer on the aluminum sustaining electrodes for ac-PDPs. The results indicate that fence-type aluminum electrode with anodic aluminum oxide layer may be feasible for the development of bendable ac-PDPs. The bendable PDPs should open up new potential applications for ac-PDPs.

5. References

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