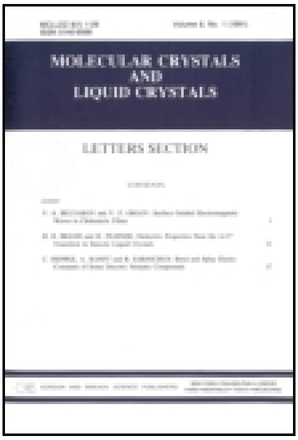

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Vibrations in Alternating Current Plasma Display Panels (AC-PDPs)

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The vibration in AC-PDPs was investigated to understand the relationship between electric and mechanical oscillations. The vibration peaks from AC-PDPs were observed at 4900, 9750, 14650, and 19550 Hz. These peaks were corresponded to the frequency components of applied power. The vibration intensity at different peaks was linearly increased with rising applied voltage regardless of discharge, and this implied the effects of discharge on vibrations were very small. From these results, the origin of vibrations in AC-PDPs was mainly the electric field due to displacement current.

Keywords AC-PDPs; Fourier transformation; noise; plasma display; vibration

Introduction

Alternating current plasma display panel (AC-PDP) has been considered as a promising display device because of its large scale, slim profile, wide viewing angle and excellent image quality [1–3]. In spite of the progressive developments of AC-PDP devices [2,3], there are some problems still unsolved such as image sticking, acoustic noise and high power consumption [4–6]. Especially, the problem for the acoustic noise has not been studied in depth, although the acoustic noise (or unusual sound) from AC-PDPs gives direct troubles to users. The acoustic noise is closely related to the vibration factors on AC-PDPs. Vibration is a mechanical phenomenon that is oscillated about an equilibrium position, and this oscillation is usually periodic in highly ordered structure. The acoustic sound is usually generated by the oscillation of structures, and also unusual sound (or acoustic noise) is implied there are some defects in structures. In AC-PDPs, the front and rear substrate are oppositely positioned, and the end of the substrates is tightly sealed by glass fritz materials. This type of structure is similar to a string that both sides are bounded to wall, and the vibration of string begins, when an oscillation source is introduced into the system. Similarly, there are many electric switching components to operate the panels [7,8], and these act as acoustic sound sources. Usually, the level of noise in AC-PDPs can

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be reduced by reduction of the pressure inside the panel, and this means that the increase of the force exerted on the panel due to pressure difference between panel inside and outside causes the weakness of vibration on the panels.

In this study, the vibrations in AC-PDPs were investigated in the range of audio frequency from 20 to 20000 Hz, and the origin of vibrations was studied in depth. In addition, vibrations in AC-PDPs with different noise-level were measured, and the difference in vibration patterns was investigated.

Experimental Details

AC-PDPs of 7.5 inch size were used to investigate the vibrational properties of AC-PDPs in this study. The cell structure of the plasma panel was composed of a closed-well type rib with a height of 125 μm, and the barrier rib was formed by a sand blaster method. The gap of ITO electrodes was 66 μm, and the cell pitch for width and height was 270 μm and 810 μm, respectively. The pressure of the plasma panel was 480 Torr with gaseous mixture of Xe (8%) and Ne (92%). AC-PDPs were located on the extruded polystyrene foam which functions as external vibration-absorbing material, and the power source was located at different table to isolate the vibrations from the power source. The power supply with a frequency of 10 kHz was used to operate the AC-PDPs, and the voltage-current waveforms were measured using an oscilloscope (Tektronix, DPO 3014). The vibration in the panels was measured by a vibration analyzer (Brüel & Kjær, 3560B) with a piezoelectric sensor (Digi-Key). The piezoelectric sensor is usually used for touch, vibration and shock measurement, and the principle of measurement is as follows; the movement of structures causes the acceleration of structures, and the piezoelectric sensor can generate charges when physically accelerated. The noise-level on AC-PDPs was acquired by a sound-level measurement system (Brüel & Kjær, 3560B) with a microphone (Brüel & Kjær, 4190L), and the measurements were carried out in an anechoic room.

Results and Discussion

The waveform of applied voltage and discharge current on AC-PDPs is shown in Fig. 1. The square waveform with a frequency of 10 kHz was used to operate AC-PDPs, and the measured current as a function of time exhibited two peaks due to discharge and displacement current in one-cycle. Figure 2 shows the current-voltage (I-V) characteristics as a function of applied voltage. As the applied voltage increased, the current gradually increased up to 250 V, and this current was corresponded to the displacement current due to dielectric layer. The discharge was ignited at about 250 V, and the current linearly increased above a firing voltage. This current was corresponded to the sum of displacement and discharge current in AC-PDPs. In this study, the vibration in AC-PDPs was instantly detected below firing voltage, when the power was applied to the panels. The relationship between vibration intensity and applied voltage was almost linear and this means that the displacement current plays an important role to vibrate the structure in AC-PDPs. Figure 3 shows the vibration spectra of AC-PDPs (noise level: 25 dB) at different applied voltages, and the vibration peaks were observed at 4900, 9750, 14650, and 19550 Hz. These frequencies had a linear relationship and were simply expressed by:

$$F_{\mathrm{n}} = nf_1(n = 1, 2, 3, 4) \tag{1}$$

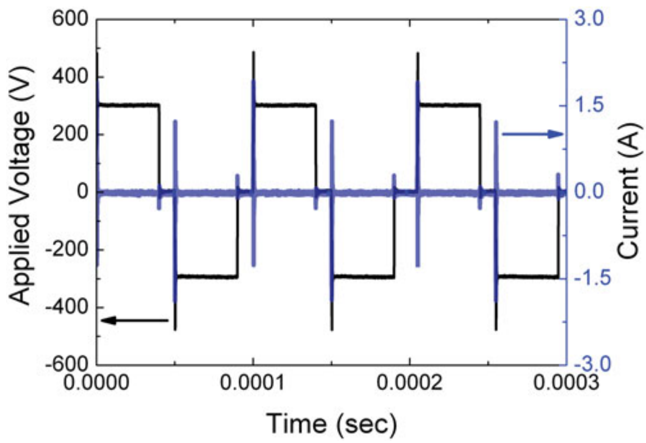

Figure 1. The oscillogram for waveforms of driving voltage and discharge current.

where, f_1 is the 4900 Hz, f_2 is the 9750 Hz, f_3 is the 14650 Hz, and f_4 is the 19550 Hz. These frequencies were similar to the frequency components of applied power, which implied there was strong relationship between vibration and applied voltage. Figure 4 shows the fast Fourier transformation (FFT) of applied voltage, and the distinctly observed peaks were located at 4998, 9955, 15092, and 19437 Hz. In addition, the vibration intensity at different peaks was linearly increased with rising applied voltage and this linearity for applied voltage implied that the effects of a discharge current on vibrations were very small. As shown in Fig. 2, the total current as a function of applied voltage had nonlinear relationship because of discharge current. However, the vibration intensity had a linear relationship whether the discharge was on or off. This meant the displacement current played a crucial role in the vibration of AC-PDPs. On the other hand, the sudden increase of vibration intensities at 4900, 9750, and 14650 Hz was also observed above the applied

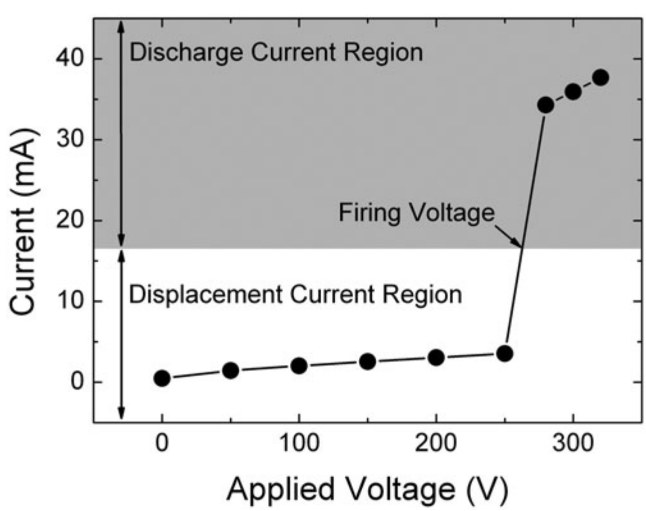

Figure 2. Current-voltage (I-V) characteristic curve in AC-PDPs.

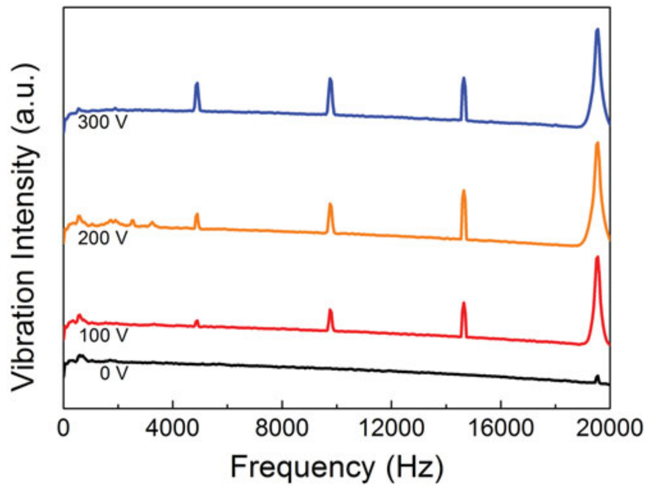

Figure 3. Vibration spectra of AC-PDPs according to applied voltages (panel noise level: 25 dB at the applied voltage of 300 V).

voltage of 320 V and the reason was thought to be from the discharge un-stability. The vibration intensity of different peaks as a function of applied voltage is shown in Fig. 5. From these results, the origin of vibrations in AC-PDPs was considered to be mainly from the electric field due to displacement current, and this meant that vibrations in AC-PDPs could be simply predicted using the information from the driving waveform. Consequently, the electrical oscillation in applied power was equivalent to mechanical vibration, and the simple RLC circuit for AC-PDPs [9,10] could be used to analyze the mechanical vibration on AC-PDPs.

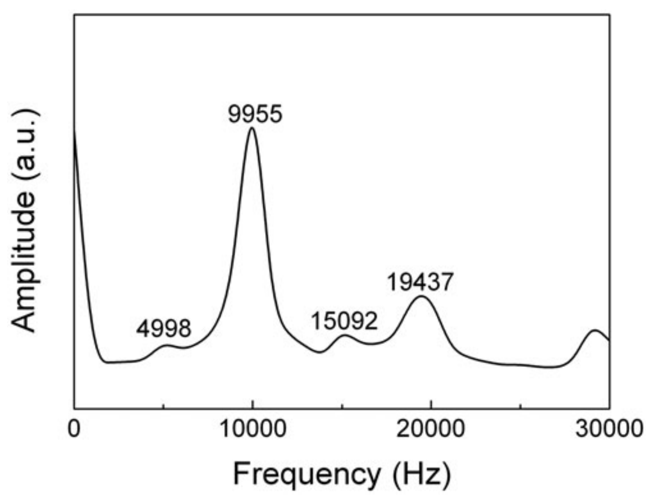

Figure 4. Fast Fourier transform (FFT) of applied voltage with square waveform (applied voltage: 300 V).

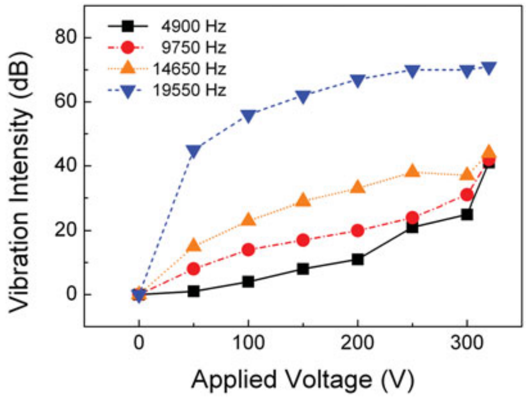

Figure 5. The variation of vibration intensities at the frequency of 4900 (square), 9800 (circle), 14600 (triangle), and 19800 (reverse triangle) Hz as a function of applied voltage.

Figure 6 shows the vibration spectra of a noisy panel (noise level: 29 dB at 300 V) at different applied voltage. The vibration spectrum at applied voltage of 300 V exhibited additional vibration peaks beside the specific peaks on normal panel. Depending on the applied voltage, the noise level of normal panels was slightly changed around 25 dB, otherwise the noise level also increased from 25 to 29 dB with rising applied voltage, and the reason for the increase of noise level was thought to be from some structural defects in noisy panels. The standard sound level measurement has been carried out in an anechoic room, because the external acoustic sounds did not easily block. Otherwise, the vibration measurement was relatively simple and easy compared to the sound level measurement and did not need specially designed room. Therefore, the additional vibration peaks beside the specific peaks due to driving signal was found to be good indicators to distinguish the noise

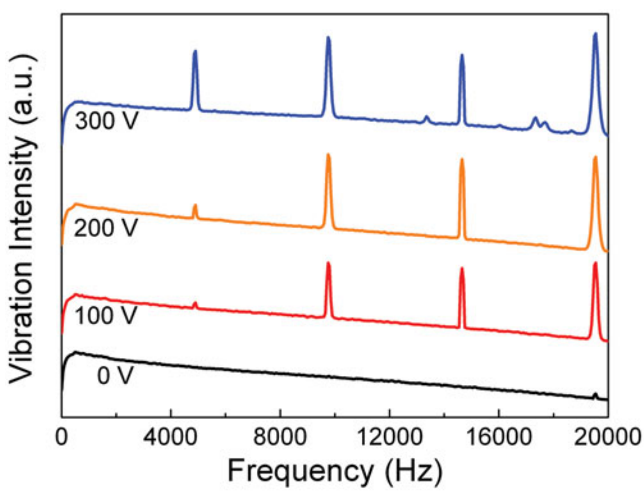

Figure 6. Vibration spectra of AC-PDPs according to applied voltage (panel noise level: 29 dB at the applied voltage of 300 V).

level of AC-PDPs, and this implied that noisy panels could be filtered in a production line using simple vibration measurement.

Conclusions

In this study, the origin of vibrations in AC-PDPs was investigated, and the relationship between sound level and vibration was studied in depth. The vibration peaks in AC-PDPs were observed at 4900, 9750, 14650, and 19550 Hz, and the oscillation frequencies for the applied voltage were located at 4998, 9955, 15092, and 19437 Hz. In addition, the vibration intensity had a linear relationship whether the discharge was on or off and this implied the displacement current played a crucial role in the vibration of AC-PDPs. From these results, the electric field due to displacement current played an important role to yield vibration in AC-PDPs and the electrical oscillation in applied power was equivalent to mechanical vibration. In addition, the vibration spectrum on noisy panel exhibited additional vibration peaks besides the specific peaks on normal panel (25 dB)., The noise level of normal panels was slightly changed around 25 dB depending on the applied voltage, otherwise the noise level of noisy panel increased from 25 to 29 dB with rising applied voltage. This reason for increase of noise level was considered as the existence of structural defects in noisy panels. This meant that additional vibration peaks beside the specific peaks due to applied power can be used as good indicators to distinguish the noise level of AC-PDPs and we believed the vibration measurement of AC-PDPs was a powerful method to filter the noisy panels in production lines.

Acknowledgments

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