A New Light Emitting Element Excited by Electron from PZT

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Experiments to observe anthracene radiation excited by hot electrons emitted from PZT ferroelectric substances by polarization inversion were performed with using 2.5 and 1.0 mm thick PZT disk type samples. The PZT electron source was fabricated with sandwiching a comb and a flat type electrode formed on the both sides of PZT plate. Then about 1 nm thick semi-conductive C-S-Au film was equipped on the comb type electrode side of PZT element. The anthracene layer was over coated on the C-S-Au film on the comb type electrode. When the polarization was inverted by an impulse voltage application, some radiation was observed on the comb type electrode side. It was difficult to distinguish the anthracene radiation from the surface discharge. In order to distinguish the anthracene radiation, additional experiments must be performing by optimizing the semi-conductive properties of C-S-Au film depending on the atomic composition and the thickness, the comb type electrode structure and the impulse voltage shape for the polarization inversion.

Keywords: PZT, Ferroelectric Substance, Polarization Inversion, Electron Emission, Anthracene, Radiation

1. Introduction

Electron emission from the ferroelectric substance is the phenomenon that the electrons are emitted from the compensated sites of polarized ferroelectric substance by rapid polarization inversion. The electron emission from the ferroelectric substance is interested as a new electron source, because the emission current of 7 A and the emitted electron energy of 3 keV were reported at CREN in 1988 [1-15]. Recently the emitted current was increased up to 200 A [16].

All above reports were concerned on the in-organic substances like as LiNbO_3 , PZT and others. It is known that PVDF (polyvinylidene fluoride) with β -type crystal structure shows ferroelectric nature. However there was no report on the electron emission from the organic ferroelectric substance like as PVDF. Then it was tried to observe the electron emission from the PVDF.

The PVDF sample was sandwiched by vacuum

evaporated Al films. One side of electrodes was processed to the comb-type electrode on $10 \times 10 \text{ mm}^2$ window area by a photo-lithography process. The polarization was reversed using an impulse voltage. However the electron emission from PVDF was not realized.

Then, the electric field distribution in the ferroelectric substance under the polarization was calculated. When the PVDF sample was polarized as the flat-type electrode was negative and the comb-type electrode was positive, the electric field was induced along the surface of PVDF between the each teeth electrode in the comb type electrode [17]. However, the evidence of electron flow on the surface to compensate the polarized positive charge was not observed. The reason will be referred to a high resistance of the PVDF surface.

To realize the current flow on the PVDF surface, the surface between the each teeth electrode were coated by semi-conductive layer. From several candidates, the C-S-Au film was selected as a

profitable semi-conductive film [18]. The electron emission could be observed by using this film [19, 20].

A new light-emitting device is proposed, which has a new structure using the ferroelectric electron emitter with the C-S-Au layer. The device structure is shown in Fig.1, where the electron will be emitted from the ferroelectric substance surface through the C-S-Au 1nm thick film by a polarization inversion method and the electrons are injected into the luminescence layer. If the electron energy is high enough to excite the luminescence substance, the light will be emitted.

Fig.1. A new light emitting device

2. Experimental methods and results

$\text{Pb}(\text{Zr,Ti})\text{O}_3$ (PZT) was used as a ferroelectric substance for the device. The PZT has the large dielectric constant of 1700 and the small coercive field of 0.7 MV/m (Table1). Therefore, the large emitting electron charge and the lower driving voltage are expected and compared to the PVDF case. The PZT used was a disk type.

Table 1. Physical constants of PZT and PVDF

	PZT	PVDF
dielectric constant	1700	6~13
Curie point [°C]	300	120
Spontaneous polarization [$\mu\text{C}/\text{cm}^2$]	28	5
Coercive field [MV/m]	0.7	50
Elastic modulus [N/m^2]	80	3

The comb-type electrode on the one side of the PZT disk was fabricated on the evaporated Al film by photo-lithography processes. The line and space width of teeth electrodes was 1 mm. The flat type

electrode was also evaporated Al film on the another side. The C-S-Au film, which is composed with Au atoms at about 10 atomic%, was coated on the PZT surface with the comb electrode by a cooperation process of plasma CVD and sputtering with using the plasma CVD reactor (Fig. 2). The deposited film thickness was about 1 nm after a few seconds discharge. The Au atom was dispersed uniformly without forming clusters in the film caused on chemical bond between Au and S atom.[21]

Fig. 2. Plasma CVD reactor

On the semi-conductive C-S-Au film, anthracene layer at about 500nm thick was evaporated as a luminous layer.

To emit the stored electron from the surface of polarized ferroelectric substance, the inverse polarity impulse voltage must be applied, which must induce a field larger than the coercive field of ferroelectric substance. The voltage required for polarization inversion was calculated to be a few thousand voltage using the value of coercive field and the disk thickness. The inversed voltage must be applied within the stored electron remaining during the process. The high voltage impulse generator as shown in Fig. 3 was constructed to induced a few nanosecond build up time. The impulse is formed by inducing the discharge in the space between the metal spheres in the impulse generating circuit as shown in Fig.3. The obtained impulse showed that the build up time was 1 ~ 10ns and the decay time was 10~100ms.

The flat electrode side of the sample element was glued on the copper plate electrode by using the silver paste and the comb electrode was connected to the isolated terminal by using a gold wire and the silver paste in order to form the power supply

circuit.

When the impulse voltage at 3000 V was applied on the sample element with 2.5 mm thick after the PZT polarization, some radiation was observed in the dark room.

Fig.3 Impulse generating circuit.

The radiation from the surface of comb-type electrode was recorded with using a digital camera in a movie mode. One picture of radiating surface is shown in Fig. 4. The radiating tree from the terminal electrode was extended to the whole area of comb electrode. In some case, the tree end extended along the lines of teeth electrodes as shown in the figure. Whereas it was expected the radiating tree extension was affected by the emitted electron from the PZT surface.

Fig. 4 Example 1 of surface discharge

This surface discharge radiation is not the luminous phenomenon that we expected. In addition, it is supposed that the observation of the anthracene radiation excited by the emitted electrons was obstructed by this surface discharge radiation.

In order to eliminate the surface discharge radiation, the PZT disk of 1 mm thick was

used to decrease the impulse voltage. The impulse voltage between 1000 V and 2000 V was applied to the device. The surface discharge could be controlled as the result. However, the expected radiation could not be observed.

The reason why the radiation could not be observed is not clear presently. However several reasons will be pointing out. The energy of emitting electron was not large enough to excite the anthracene radiation. For the purpose, the polarization inversion speed must be increased. Therefore, the impedance of power supply circuit was decreased as possible as by adopting Cu ring-shaped electrode and other methods. The C-S-Au film properties were also controlled by atomic composition and thickness. However, we could not observe the radiation from the anthracene layer.

3. Conclusion

A new radiation device was proposed, which used the electrons emitted from PZT plate by the polarity inversion through the semi-conductive C-S-Au film. In the experiments, the surface discharge radiation was observed on the surface of device. To eliminate the discharge, thin PZT element at 1 mm thick was used for the lower impulse voltage. However, the anthracene radiation was not observed yet. The reason has not been clarified, but it is supposed that the radiation will be realized by optimizing electronic energy for the anthracene excitation.

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