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High Performance Electroluminescent Display Device with AlON-TiON Insulator

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Abstract

For the insulator of inorganic thin film electroluminescent (TFEL), devices AlON combined with TiON was used and it exhibits higher luminance than AlON as well as Al_2O_3 insulator. Furthermore, using AlON with TiON film show better stability and higher luminance than that with TiO_2 grown by conventional atomic layer deposition (ALD) for the application of the insulator of ZnS:Mn TFEL device.

1. Introduction

It is very important to choose insulators with high dielectric constant to satisfy high stability for electric breakdown in fabrication of thin film electroluminescent (TFEL) device. However, it seems difficult to satisfy both conditions simultaneously, because insulators with high dielectric constant unfortunately tend to exhibit a low breakdown field.

Although SiO_2 film shows high breakdown fields of 6-7 MV/cm, dielectric constant of that is as low as 4, whereas insulators such as TiO_2 with high dielectric constant exhibit breakdown field of 0.2 MV/cm.[1] In order to overcome weak breakdown strength, Ce doped TiO_2 was prepared.[2] However, the improvement of breakdown strength could not exceed 0.2 MV/cm. In particular in the application of the insulating layer of ELD, in order to characterize dielectric materials for insulating layers, a figure merit is introduced defined as $\varepsilon_0 \varepsilon E_{BD}$ where $\varepsilon_0 \varepsilon$ is dielectric constant and E_{BD} breakdown electric field.[1] In general, it is desirable that the figure of merit corresponds to 4-6 $\mu C/cm^2$.

Y_2O_3 and Ta_2O_5 layers were also considered to be alternative, however SiON and Si_3N_4 layers should be accompanied to prevent ion and moisture penetration.[3-4] Therefore, Al_2O_3 film has been used to meet halfway, and Al_2O_3 combined with TiO_2 film was also used. However, it is insufficient to satisfy both conditions mentioned above.

In this article, using plasma enhanced atomic layer deposition (PEALD) with oxygen and nitrogen plasma, AlON combined with TiON (ATON) was used as the insulator of TFEL device. The film deposited by PEALD has shown lower leakage current and high dielectric constant for dielectric films than that by conventional ALD.[5] In particular, AlON film has shown much higher dielectric breakdown fields when it is used as insulators of TFEL device.[6] ZnS:Mn TFEL device with the insulator of ATON insulator grown by our method has exhibited higher luminance than that of conventional Al_2O_3 grown by ALD and AlON. At the same time, reasonable stability for dielectric breakdown was confirmed.

2. Experimental

AlON and TiON films were grown at 250 °C with oxygen and nitrogen gas by PEALD. TiO_2 film was grown at 250 °C with TTIP and H_2O by ALD. In these experiments, working pressure was 3.0 torr and plasma power was 300 W. In investigating dielectric breakdown fields of AlON and ALD grown TiO_2 multi-layer, thickness ratios of both layers were varied with 1:2, 1:1 and 2:1. Total thickness of each sample was 70 nm. For confirming characteristics of the insulator in ELD, ZnS:Mn phosphor of 600 nm was used. The structure of ELD is depicted in Fig. 1, which is composed of ZnS:Mn phosphor layer grown by rf-sputtering, Al electrode by e-beam evaporation and insulators by ALD. In ELD, bottom insulating layers were fixed with 165nm thick-AlON films, while thickness of top insulating layers were ranged 140nm to 150 nm with various materials.

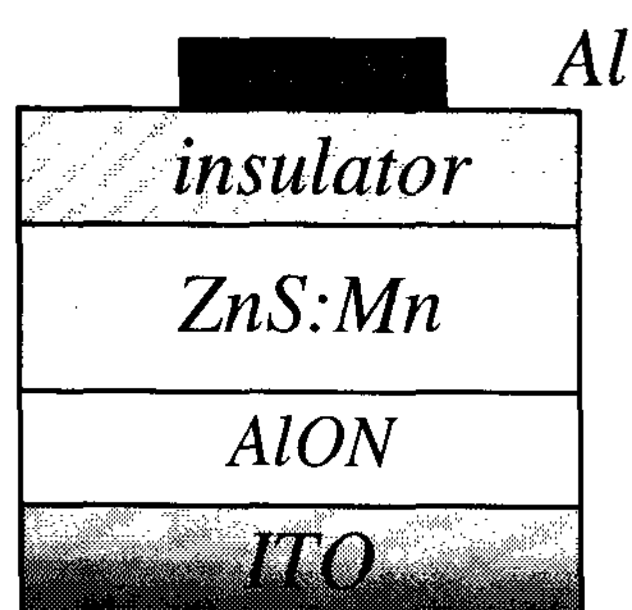

Figure 1 Structures of EL devices with various top insulators.

3. Results and discussion

In case of ALD grown TiO_2 layer, breakdown fields were below 0.2 MV/cm and current levels were relatively high. Hence, it is difficult to use those layers as the insulators of ELD. It has been required that multi-layers combined with AlON and TiO_2 or TiON layer should be used as the insulators of ELD. For the purpose of investigating the property of breakdown strength, 70 nm thick-insulators combined with AlON and TiO_2 layers were deposited on ITO/Glass followed by covering Al electrode. Figure 2 shows breakdown fields of insulators of three conditions. As the thickness of AlON film increases, breakdown fields considerably increase. In case of thickness ratio of AlON and TiO_2 is 2:1, 6 MV/cm was obtained.

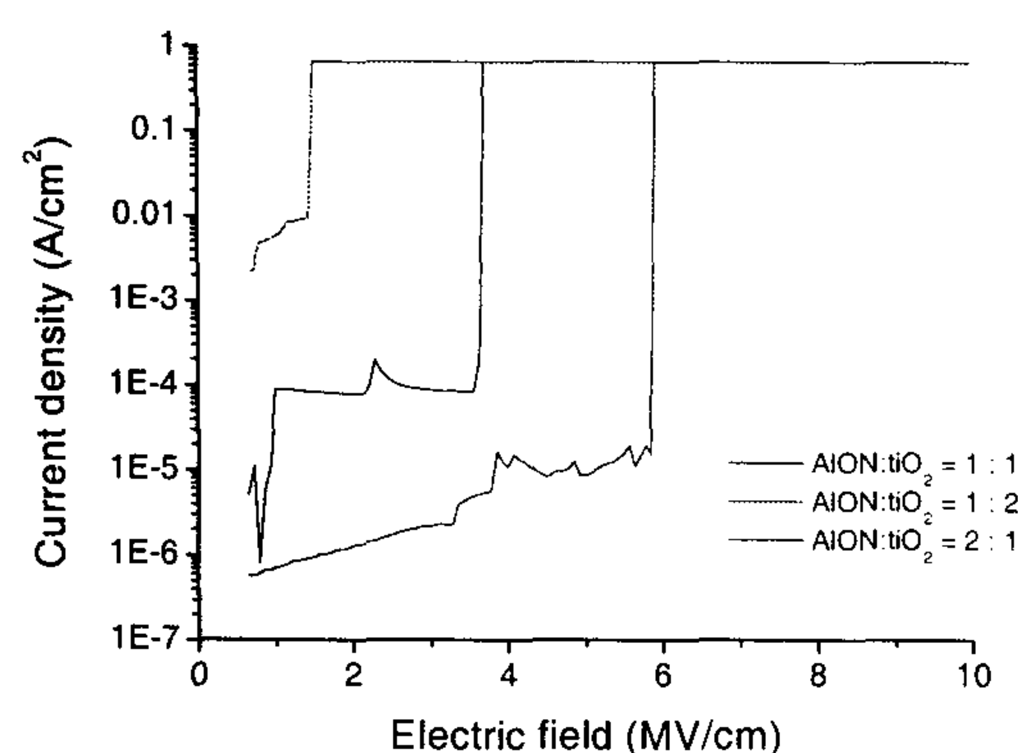

Figure 2 Plots of current density versus electric field of three insulators.

To compare the effects of insulators on Luminance-Voltage (L-V) curves, four kinds of insulators were used as top insulators in 0.6 μ m thick ZnS:Mn TFEL device. AlON films were used as bottom insulators. L-V curves of these four conditions are depicted in Fig. 3. For L-V measurements, 60 Hz square wave was used in applying voltages to EL devices.

The EL device using AlON as top insulator is most stable among four devices due to its high dielectric breakdown strength. For EL device of ATO (1:1), luminance is enhanced by 30% compared to that of Al_2O_3 grown by ALD at 30 V above threshold voltages. Moreover, the stability of EL device with ATO insulator is comparable to that with ALD grown Al_2O_3. However, it is insufficient to be effective insulator for accomplishing device with high luminance.

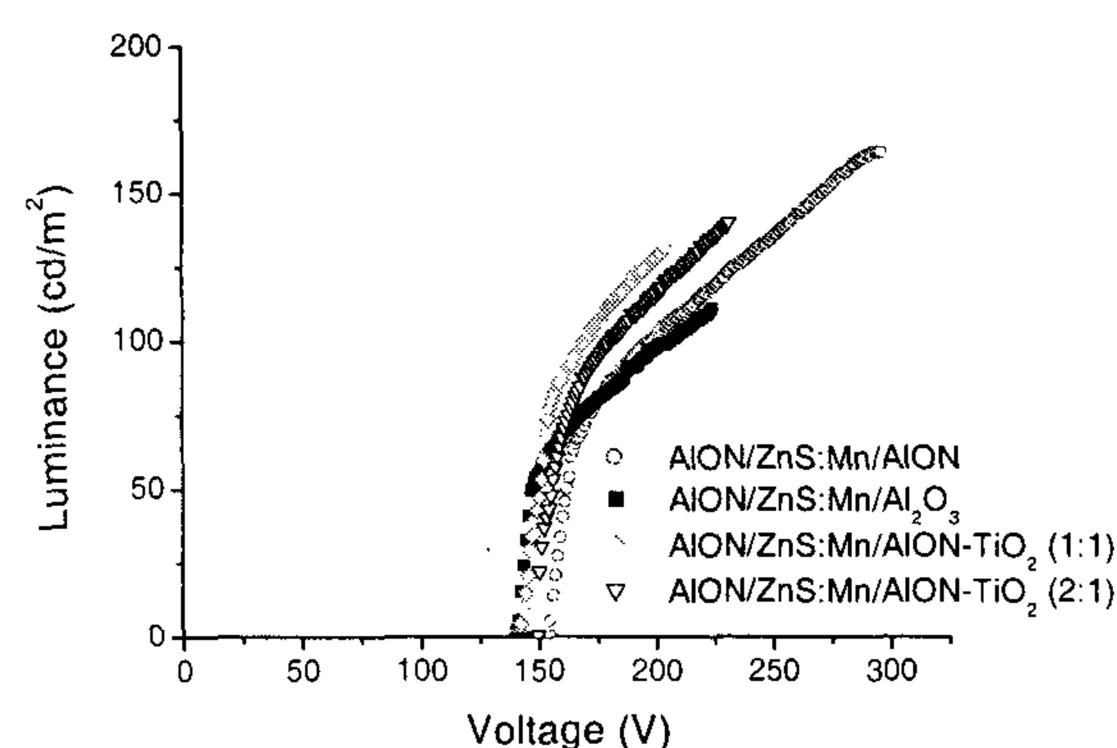

Figure 3 L-V curves of ZnS:Mn TFEL devices with various top insulators.

In case of TiON layer grown by PEALD was used instead of TiO_2 layer, the breakdown fields are improved as high as 8 MV/cm and 6 MV/cm in case of the thickness ratio of AlON and TiON is 1 and 2, respectively. Therefore, one can easily find that TiON is more stable than TiO_2 grown by ALD and TiON insulators combined with AlON should be adopted. Although the breakdown field of TiON is higher than TiO_2, it is unstable to adopt TiON of single layer to the insulator of ELD. TiON combined with AlON should be applied to the insulating layer of ELD.

For the purpose of investigating the properties of AlON-TiON (ATON) insulators film in ELD, insulating layer with unity thickness ratio of AlON

and TiON was prepared and then compared with Al_2O_3 grown by ALD.

Figure 4 exhibits L-V curves of ZnS:Mn TFEL devices with different top insulators, 180nm thick-ATON grown by PEALD and 180nm thick-Al_2O_3 grown by ALD obtained by applying voltages of 500 Hz square wave. Although threshold voltages of both ELDs are similar, slope and luminance of both samples are considerably different each other. TFEL device with ATON shows high luminance dramatically enhanced by 150 % compared to that with Al_2O_3 insulator at L_{30}.

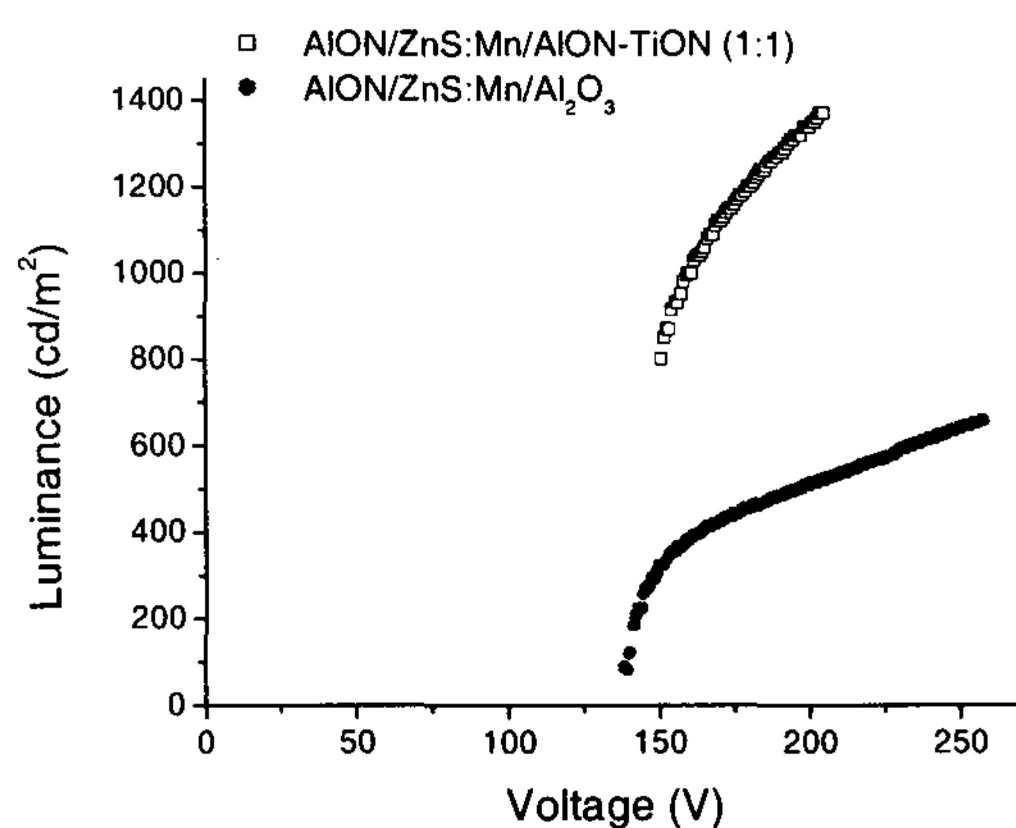

Figure 4 L-V curves of various ZnS:Mn TFEL devices with ATON and Al_2O_3 grown by ALD as top insulators

From the slope of Q-V curve, it can be estimated that dielectric constant of ATON top insulating layers is 16. Hence, the figure of merit of ATON insulator is 11 $\mu C/cm^2$, which is much higher than others even that of ALD grown Al_2O_3 film of 6 $\mu C/cm^2$.[1] It indicates that ATON is most effective insulator among thin film insulators for EL devices.

4. Conclusion

In case of using TiON films for the insulator of TFEL device, it is effective to increase luminance dramatically whereas TiO_2 films grown by ALD have little effect on the enhancement of luminance. In addition, breakdown voltages of TiON film is higher than that of TiO_2 film, therefore it is better to adop, TiON film for the insulator of TFEL device in view of the stability under high driving voltage. In practice, TiON films should be combined with AlON film to improve breakdown strength, which gives high stability of ELD let alone high luminance.

5. References

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