Electrical Properties of Mg:Ag/tris-(8-hydroxyquinoline) Aluminum Heterointerface in Organic Light-emitting Devices

D. C. Choo, H. C. Im, D. U. Lee, and T. W. Kim
Advanced Semiconductor Research Center, Department of Electronics and Computer Engineering, Hanyang University, 17 Haengdang-dong, Seongdong-gu, Seoul 133-791, Korea
J. H. Han
Department of Electronic Engineering, Sejoing University, Seoul 143-747, Korea

Abstract

Organic molecular-beam deposition of Mg:Ag thin films with a low Mg concentration on tris (8-hydroxyquinolino) aluminum (Alq_3) layers at room temperature was performed to investigate the feasibility of using Mg:Ag thin films as cathode electrodes in organic light-emitting devices (OLEDs). The effective barrier height of the Mg:Ag/Alq_3 heterointerface, determined from current-voltage measurements, was as low as 0.23 eV. These results help improve understanding the electrical properties of the Mg:Ag/Alq_3 heterointerfaces in OLEDs.

1. Introduction

Organic light-emitting devices (OLEDs) are particularly attractive because of their promising application advantages, which offer a low driving voltage, a low power consumption, a high contrast, a wide viewing angle, a low cost, and a fast response time [1, 2]. Various device structures, consisting of carrier transfer layers, emitting layers, and electrodes, have been investigated to improve the efficiency of the OLEDs. Among the several layers of the OLEDs, the materials of the cathodes for electron injection are particularly important for enhancing device efficiency. The cathodes in the OLEDs with a low work function are formed to improve power efficiency by using metal alloys, which is necessary for highly efficient electron injection. Among the various kinds of cathodes, Mg:Ag alloy thin films with a high Mg concentration have been extensively used as cathodes because of their low tunneling barrier at the Mg:Ag/organic interface. Even though some works concerning the formation and the physical properties of the Mg:Ag thin films with a high Mg concentration grown on Alq_3 have been performed [3, 4], studies on the formation and the physical properties of the Mg:Ag with a low Mg concentration grown on the Alq_3 layer have not been carried out yet.

This paper reports the electrical properties of Mg:Ag alloy thin films with a relatively low Mg composition deposited on Alq_3 layers by using organic molecular-beam deposition (OMBD). Current-voltage (I-V) measurement was performed in order to determine the effective barrier of the Mg:Ag/Alq_3 heterointerface.

2. Experimental Details

The sample used in this study was grown on glass by using OMBD. As soon as the chemical cleaning process for the glass had been finished, the substrates were mounted onto a molybdenum susceptor in the OMBD system with a background

pressure of approximately 10^{-10} Torr. The sample used in this study was deposited on Al thin film, acting as anode electrodes, coated on glass substrates by using OMBD with effusion cells and shutters, and consisted of the following structures from the top side: a 100-nm Mg (5%)-doped Ag for a cathode electrode, a 100-nm Alq_3 layer for a emitting layer, and a 100-nm Al layer for an anode layer. The depositions of the layers were done at a room temperature and a system pressure of 10^{-6} Torr. The growth rate of the layers was 0.1 nm/s.

The as-grown Mg:Ag film prepared by using the OMBD technique had mirror-like surfaces, which was confirmed by using Normarski optical microscopy and scanning electron microscopy. The root mean square of the average surface roughness of the Mg:Ag thin film with a Mg composition of 0.5, as determined from the atomic force microscopy measurements, was 2 nm, and this result indicates that the surfaces of the Mg:Ag film grown on Alq_3 layer were relatively smooth.

3. Results and Discussion

Figure 1 shows the current as a function of the bias voltage was measured for the Mg:Ag/Alq_3/Al/glass structure. In the high voltage region, the current of the structure is well followed by the Fowler-Nordheim tunneling theory [5]. Assuming that the electric field is constant and the effective mass equals the free electron mass, the effective injection barrier of the Mg:Ag/Alq_3 heterointerface can be estimated. The ln[1/(electric field)^2] as a function of the 1/(electric field) for the structure, determined from Fig. 1, is shown in Fig. 2. The effective barrier of the Mg:Ag/Alq_3 heterointerface at high electric fields, determined from the slope of the straight line, is approximately 0.23 eV [6]. The effective barrier height of the Mg:Ag/Alq_3 heterointerface is much smaller than those reported in the literatures [7].

4 Summary and Conclusions

The electrical and electronic properties of Mg:Ag thin films with a low Mg concentration grown on Alq_3 layers by using OMBD were investigated. The effective barrier height of the Mg:Ag thin film with a Mg concentration of 5 %, determined from the (I-V) measurements, was as low as 0.23 eV. These results indicate that Mg:Ag thin films with a low Mg concentration grown on Alq_3 layers by using OMBD hold promise for potential applications as cathodes for OLEDs.

5. Figure Captions

Fig. 1. Current as a function of the bias voltage for the Mg:Ag/Alq_3/Al/glass structure.

Fig. 2. ln[1/(electric field)^2] as a function of 1/(electric field) for the Mg:Ag/Alq_3/Al/glass structure.

6. Acknowledgements

This work was supported by the Korea Research Foundation Grant. (KRF-2004-005-D00166).

7. References

[1] J. R. Sheats, H. Antoniadis, M. Hueschen, W. Leonard, J. Miller, R. Moon, D. Roitman, and A. Stocking, Science **273**, 884 (1996).

[2] V. Bulovic, G. Gu, P. E. Burrows, S. R. Forrest, and M. E. Thompson, Nature **380**, 29 (1996).

[3] S. A. Van Slyke, C. H. Chen, and C. W. Tang, Appl. Phys. Lett. **69**, 2160 (1996).

[4] H. Aziz, Z. Popovic, C. P. Tripp, N-X. Hu, A-M. Hor, and G. Xu, Appl. Phys. Lett. **72**, 2642 (1998).

[5] F. Brovelli, J. C. Bernede, S. Marsillac, F. R. Diaz, M. A. Del Valle, and C. Beaudouin, J. Appl. Poly. Sci. **86**, 1128 (2002).

[6] I. D. Parker, J. Appl. Phys. **75**, 1656 (1994).

[7] B. N. Limketkai and M. A. Baldo, Phys. Rev. B **71**, 085207 (2005).

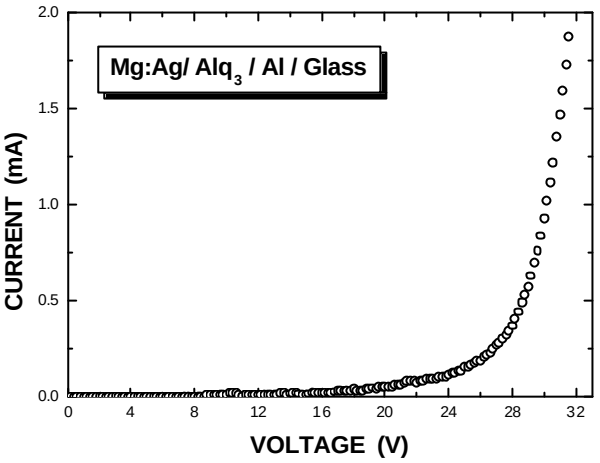

Fig. 1. Current as a function of the bias voltage for the Mg:Ag/Alq_3/Al/glass structure.

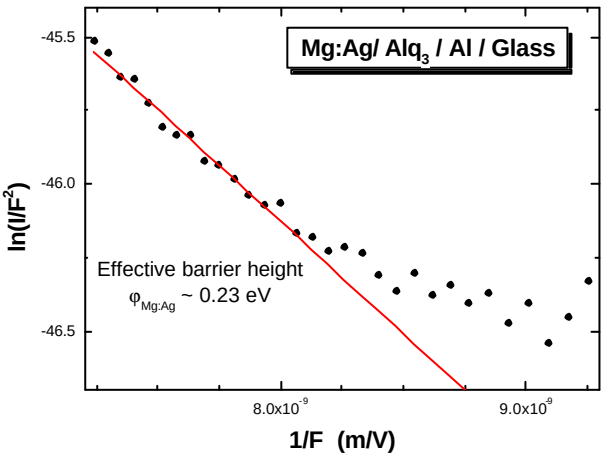

Fig. 2. ln[1/(electric field)^2] as a function of 1/(electric field) for the Mg:Ag/Alq_3/Al/glass structure.