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Fabrication of Tris(8-Hydroxyquinoline) Aluminum (Alq3)/Poly(N-Vinylcarbazole)(PVK) Superlattices Structure and Its Use for Electroluminescent Device

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1. Introduction

Inorganic semiconductor quantum wells (QWs) and superlattices (SLs) structures have been a subject of intense study in the past twenty years due to their interesting optical and electronic properties which have many promising applications in optoelectronic device technology. Many new physical phenomena have been discovered, and many novel device concepts have been developed based on these ultrathin layer structures of inorganic semiconductor materials. In order to grow defect-free superlattices structures, the material used should be lattice matched. Lattice mismatch can induce strain which generates crystal defects such as dislocations when the layer thickness exceeds a certain critical value. Organic materials, in contrast, are bonded by the relatively weak van der waals force, Therefore, it is possible to grow high quality heterostructures and superlattices structures without inducing large strains using a variety of organic materials [1 ~ 6].

Another reason for this growing interest is the fact that optical and electronic processes in organic semiconductors are fundamentally different from those in conventional inorganic semiconductors, giving them unique optical and electronic properties. And the possibility of tailoring these properties through layering is quite intriguing. Further investigation into the linear as well as nonlinear optical and electronic properties of organic layered structures may lead to new optoelectronic device applications.

In this paper, we report fabrication of the superlattices structures of tris(8-hydroxyquinoline)aluminum (Alq_3) and Poly(N-vinylcarbazole) (PVK) by a multisource-type high-vacuum organic molecular deposition. The characteristics of superlattices structures are determined by the small-angle x-ray diffraction, The electroluminescent devices (ELs) with the superlattices structure have also been fabricated and the emission characteristics are discussed.

2. Experimental Details

Commercially available powders of Alq_3 and PVK were used in this study. Fig.1 shows the molecular structures, Superlattices with artificial multilayers were fabricated using a multisource-type high-vacuum organic molecular deposition system. Alq_3 and PVK were loaded into two adjacent quartz crucibles with a nozzle. Each crucible was heated to maintain a deposition rate of 0.1 ~ 0.2nm/s., which was monitored by a quartz oscillating thickness monitor (IL-400). The alternating layered structure were fabricated onto three kinds of substrates, the Si (100) substrate was used for small-angle x-ray diffraction measurement, the quartz substrate was used for optical measurement and the indium-tin-oxide(ITO) coated glass substrate for the ELs. The thickness of the Alq_3 and PVK layers were designed to be 3.0nm, The number of layer pairs in the superlattices was designed to be 20. During deposition, the substrates were maintained at room temperature using shutters. The base pressure of the deposition system was 2 × 10^{-7}Torr., and the pressure during the deposition was 6 × 10^{-7}Torr..

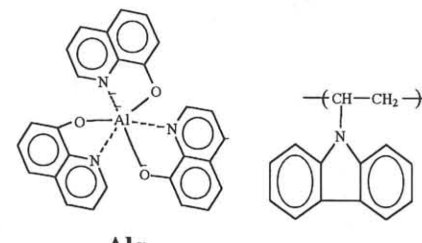

Fig.1 Molecular structures of organic/polymeric materials used in this study,

3. Results and Discussion

Small-angle x-ray diffraction is an effective method to check whether a layered structure exists in an alternately deposited film or not. Fig.2 shows the small-angle x-ray diffraction patterns of the Alq_3/PVK superlattices with 20 periods on Si(100) wafers. In the diffraction patterns, significant diffraction peaks are observed at small angles, These peaks correspond to the first, second and higher-order Bragg diffraction satellite peaks from the artificial multilayer superlattice structure. This indicates that these superlattices have a periodically layered structure through the entire stack. The observed period is 6.2nm; Compared with the designed one, 6.0nm. The designed period is the sum of single Alq_3 and single PVK layer thicknesses determined from the thickness monitors. It is easily confirmed that the observed period estimated from the first-order Bragg diffraction peak [equation (1)] is almost in agreement with the designed period.

$$2d\sin\theta = n\lambda \tag{1}$$

where d is superlattices period; λ is CuK_α wavelength; and θ is diffraction angle.

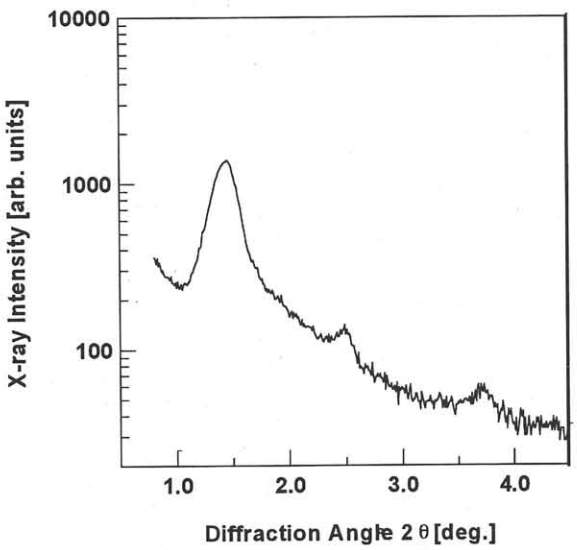

Fig.2 Small-angle x-ray diffraction patterns of Alq_3/PVK superlattices

Electroluminescent devices (ELs) have also been fabricated using the superlattices structure. The ELs consists of the superlattices structure sandwiched by indium-tin-oxide(ITO) coated transparent electrode as positive bias side and the aluminium(Al) electrode as negative bias side. The Alq_3 layer contacts to the Al electrode and the PVK layer to the ITO electrode. The emission area is 2 × $2mm^2$, There are twelve ELs on the same substrute. The emission spectrum is shown in Fig.3 for the ELs of the superlattices structure (20 periode of 3.0nm-thick Alq_3 and 3.0nm-thick PVK) in comparison with that of photoluminescent (PL) spectrum at room temperature. In Fig.3 the peak emission intensities of the spectrum are normalized. The emission peak of the ELs spectrum was observed at 512nm (dash line) and 526nm for the PL spectrum (solid line), the emission from PVK is not observed and the spectrum does not changed with the injection current. That is, only emission from Alq_3 layer was observed for the superlattices structure . From these results, it should be noted that the excitons are confined in the Alq_3 layer in the case of superlattices structure ,and the excitons generated in the PVK layer are transferred into the Alq_3 layer efficiently and result in the emission in the Alq_3 layer.

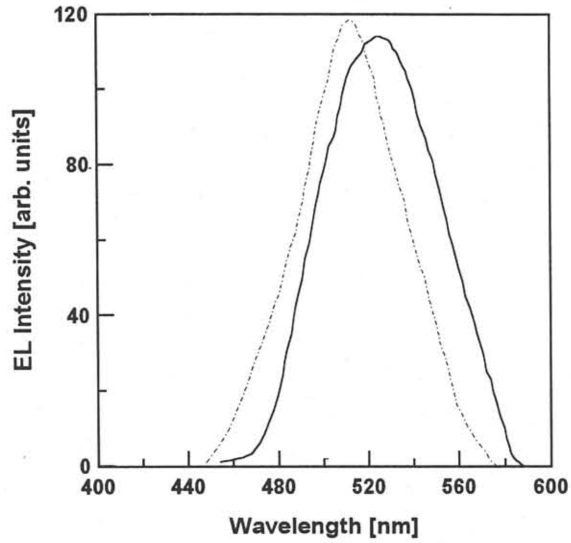

Fig.3 Photoluminescence (solid line) and electroluminescence (dashed line) spectrum of Alq_3/PVK superlattices structure

4. Conclusion

Organic/polymeric superlattices structures of Alq_3 and PVK have been successfully fabricated using a multisource-type high-vacvum organic molecular deposition system. The small-angle x-ray diffraction patterns show that the superlattices have a periodically layer structure through the entire stack. The electroluminescent devices with the superlattices structure have also been fabricated and the emission characteristics are diacussed.

Acknowledgements

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