Development of Plasma Damage Free Sputtering Process for ITO Anode Formation Inverted Structure OLED

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Abstract

We developed the Hyper-thermal Neutral Beam (HNB) sputtering process as a plasma damage free process for ITO top anode deposition on inverted Top emission OLED (ITOLED). For examining the effect of the HNB sputtering system, Inverted Bottom emission OLEDs (IBOLED) with ITO top anode electrode were fabricated; the characteristics of IBOLED using HNB sputtering process shows significant suppression of plasma induced damage.

1. Introduction

For high efficiency OLED display with n-type transistor backplane as a-Si TFT, the Inverted Top emission OLED (ITOLED) is most suitable structure.[1-2] But, in ITOLED fabrication, ITO thin film deposition process for anode electrode caused critical damages to underlying organic layers. The generation of damage is supposed to be caused by high energy charged particles, UV radiation, and heating during the sputtering process. Therefore, to apply sputtering process to OLED, a damage free process should be needed. Recently, we are developing the Hyper-thermal Neutral Beam (HNB) sputtering system [6-8] as a new damage free sputtering process for deposition of ITO top electrode. In this study, for evaluating the capability of damage reduction of the HNB sputtering process on the organic layers, we tested two types of Inverted Bottom emission OLEDs (IBOLED) [9] with different anodes as Au single layer and ITO/Au double layers; ITO layer was deposited by HNB sputtering while Au layer was done by conventional thermal evaporation.

2. Experimental

Figure 1 is shows the configuration of Hyper-thermal Neutral Beam ITO sputtering system; the HNB system is composed of inductively coupled plasma (ICP) source, magnetron sputter gun, conductor reflector, and magnetic limiter. The magnetron sputter gun supplies ITO elements into the inductively coupled plasma in which some of sputtered elements can be ionized. All of ionized elements are accelerated in the plasma sheath between the plasma and the reflector, and neutralized mainly through the Auger neutralization. The plasma volumetric extension is limited by the magnetic limiter which has array of permanent magnets. The limiter suppresses charged particles from flowing down to the substrate.

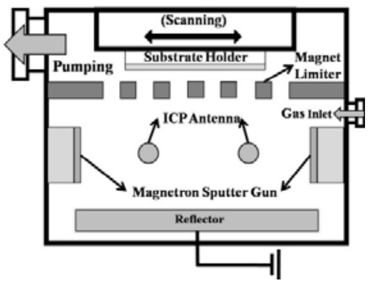

Figure 1. Configuration of HNB sputtering system

The test OLED devices consisted of ITO cathode / Organic Layers / various anodes as Au single layer and ITO/Au double layers.

The substrate were prepared by ITO-coated glass with high quality ITO thin film as thickness of 1500 Å and sheet resistance of 20 Ω/□ , respectively. After wet cleaning the ITO-coated glass substrates, transparent cathode layers (Al/Liq) and organic emitting layers, and WO_3 HIL were deposited by thermal evaporation with vacuum of 1 X 10^{-7} Torr. To prepare the evaluation samples for the HNB process, ITO thin film was directly sputtered on the HIL layer by HNB sputter with a vacuum of 5 X 10^{-7} Torr, followed by Au deposition by thermal evaporator. All of the process chambers are connected by load lock system without vacuum-breaking. The standard IBOLED device coded as 'Device A' has structure of ITO 1500Å/Al 30Å/Liq 9Å/Alq_3 600Å/NPB 600Å/WO_3 40Å/Au 1000Å, while the evaluation device for HNB system, coded as 'Device B' has same structure except double layered anode as HNB sputtered ITO 100Å/Au 1000Å. The current density–voltage–luminance (J–V–L) characteristics of the OLED cell were measured by the spectrophotometer (Photo Research PR650) and the computer-controlled programmable dc voltage source (Keithley 236)

3. Results and discussion

Fig. 2 presents performance comparison between test OLED devices. In previous reports [6-7], plasma damaged OLED devices have higher leakage current at reverse bias, but our test Device B processed by HNB sputter shows very low leakage current density at reverse bias and has very clean emission area as shown in Fig. 3, which is comparable to the standard sample as Device A. However, the turn on voltage of Device B is shifted to positive direction.

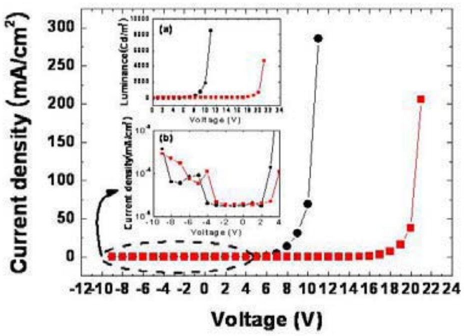

Figure 2. J-V and L-V (inset (a)) characteristics of the test OLED devices. The circle plot is 'Device A' and square plot is 'Device B'. Inset (b) is characteristics of leakage current at reverse bias.

In order to survey the reason of turn-on voltage shift in Device B, we observed the interface of WO_3 hole injection layer after HNB process by the Auger Electron Spectroscopy, and found very thin Fe impurity layer on WO_3 surface. During this experiments, our HNB sputter used stainless steel reflector for neutralizing sputtered elements. But while neutralization by ion-metal collision, some of Ar ions can sputter out Fe ions from the reflector; the Fe impurities on WO_3 surface can make work-function mismatch between WO_3 and ITO layers. Therefore, turn on voltage shift of 'Device B' may not caused by plasma process damages. Currently, problems of Fe impurity contamination could be solving by new reflector materials.

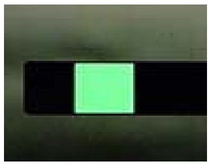

Figure 3. Picture of emitted IBOLED using HNB sputtering process.

4. Summary

The HNB ITO sputtering system was verified to affect no damages on the underlying organic layers by investigating characteristics of tested IBOLED devices. But, the turn-on voltage of the IBOLED with ITO anode deposited by HNB sputter observed is shifted. This shift is caused by Fe impurities from stainless steel reflector, not plasma damages. ITO deposition process by the HNB sputtering system does not cause plasma damages on the underlying organic layer and can be used in top anode ITO formation for ITOLED fabrication process.

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