새로운 방식의 유기박막트랜지스터 패시베이션 기술

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The novel encapsulation method for organic thin-film transistor

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Abstract

In this study, we report a novel encapsulation method for longevity of an organic thin-film transistor (OTFT) using pentaceneby means of an adhesive multiplayerincluded Al film. For encapsulation of OTFTs, the Al film adhered onto the OTFT in a dry nitrogen atmosphere using a proper adhesive. A lifetime, which was defined as the time necessary to reduce mobility to 2% of initial mobility value, was observed from the typical I_{D}-V_{D} characteristics of the field-effect transistor (FET). The initial field effect mobility μ was measured to be 2.0x10^{-1} cm^2/Vs. The characterization was maintained for long times in air. No substantial degeneration occurred. The performance and the stability are probably due to the encapsulation effect.

Key Words : Organic thin-film transistor, organic semiconductor, passivation, life-time, encapsulation

1. Introduction

Organic thin-film transistors (OTFTs) have received increasing attention recently in place of conventional inorganic electronics because of advantages in their lower cost[1] and simpler packaging, relative to conventional inorganic electronics, and their compatibility with flexible substrates. Owing to these excellent properties which are obviously advantageous for display operation, identification tags[2] and sensors.[3] For the commercial value of many applications based on organic devices, stability and performance of organic materials are important. Pentacene which has been demonstrated in high-mobility field effect transistors[4,5] among organic materials used to form active layers of OTFTs are susceptible to water, oxygen and other environmentalelements present in ambient conditions. As a result, conventional OTFTs with pentacene as an active layer exhibit a relatively short lifetime (in this study, defined as the time necessary to maintain the initial mobility value). However, development of encapsulation method for OTFTs has hardly been performed to construct the long-lived OTFTs.

To maintainthe electric characteristics of OTFTs for a long time, a few studies have been reported to construct the encapsulated OTFTs.[6,7] We have already performed the passivation layer using polyvinyl alcohol (PVA) formed by mean of wet process.[8] But our workshave experienced degradation about one order lower than before wet process. This result may mainly be by change of sheer stress after drying and/or migration of PVA solution through pentacene.

2. Experimental

The device was fabricated by conventional process. The source and drain electrodes were fabricated by the photolithographic lift-off process. The source and drain electrodes, which consisted of a 20-nm-thick Cr layer and an 80-nm-thick Au layer, were deposited onto the on thermal silicon dioxide (SiO_2) surface by using sputter. The channel length, L, was 10 μm and width, W, was 50 μm. Pentacene pre-purified using the train-sublimation was used as an active layer material. During the pentacene deposition, the substrate temperature was held at 90 ℃. The total thickness of the pentacene film is 1000 Å with a deposition rate of 1 Å/s. The working pressure was held below 5 x 10^{-6} mbar during the active layer deposition.

We report a novel encapsulation method by mean of an adhesive multilayer formed by a conventional lamination process. For encapsulation of OTFTs, the Al film adhered onto the OTFT in a dry nitrogen atmosphere using a proper adhesive. The adhesive multilayer consists of polyacrylate based adhesive (thickness, 15 ㎛) and Al (thickness, 185 ㎛), which exhibits water vapor transmission rate below the limit (5 x 10^{-3} g/㎡[day]) of MOCON detection instruments (permatranw® 3/31 MA).

The OTFT was stored at room temperature in air. Electrical measurements were performed at room temperature in air, using a parameter analyzer (HP4145, Hewlett Packard).

3. Results and discussion

A schematic diagram of the co-planar structure OTFT used in this study is shown in Fig. 1. In general, it was difficult that coating of some layer onto pentacene film without degradation and damage. We have used PVA among of the reported materials, which could be coated without degradation. But our works have experienced degradation with difference from other report. Figure 2 shows the electrical characteristics of OTFT encapsulated by the PVA coating method. Plot of drain current, I_D, vs. drain voltage, VD, at various gate voltage, VG. The field effect mobility μ was measured to be 1.5 x 10^{-2} cm^2/Vs before coating PVA [Fig. 2 (a)]. The mobility was immediately measured to be 2.2 x 10^{-3} cm^2/Vs after coating PVA [Fig. 2 (b)]. The degradation of electrical characteristics was observed. It is supposed, the reason is sheer stress by the viscosity of PVA when it was coated and dried. Because of the reason, we developed a novel encapsulation method for OTFTs. OTFTs were packaged by novel encapsulation method; the Al film adhered onto the pentacene active layer in a dry nitrogen atmosphere using a proper adhesive. Using this method, we observed no degradation. Figure 3 (a) shows the initial field effect mobility μ was measured to be 2.0 x 10^{-1} cm^2/Vs. The characterization was maintained for long times in air [fig. 3 (b)]. No substantial degeneration occurred. The initial mobility of no passivation device was measured to be 1.3 x 10^{-1} cm^2/Vs. But the characterization was degraded to be 1.0 x 10^{-3} cm^2/Vs after long terms. Their mobility is reduced to 2 % of initial mobility value. In this study, a lifetime was defined as the time necessary to reduce mobility to 2% of initial mobility value.

Through this result, the performance and the stability were observed by the novel encapsulation effect.

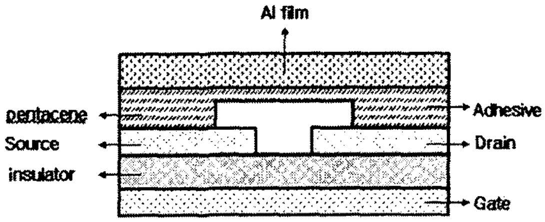

Fig. 1. A schematic diagram of OTFT fabricated by using novel encapsulation method.

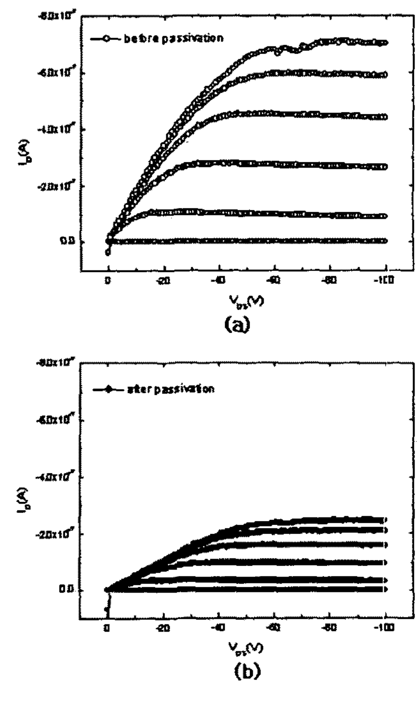

Fig. 2. The electrical characteristics of OTFT encapsulated by the PVA coating method. Plot of drain current, I_D, vs. drain voltage, V_D, at various gate voltage, VG. (a) The field effect mobility μ was measured to be 1.5 x 10^{-2} cm^2/Vs before passivation. (b) The mobility was immediately measured to be 2 x 10^{-3} cm^2/Vs after passivation.

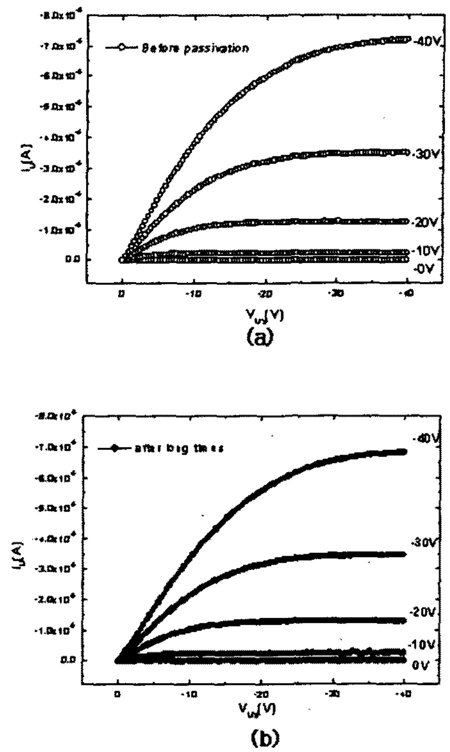

Fig. 3. The electrical characteristics of OTFT encapsulated by multilayer method. These measurements were carried out at room temperature. The drain bias was swept from 0 to 40 V and gate biases between 0 and 40 V in steps of 10 V. (a) A initial mobility with passivation layer. (b) A mobility of the device with passivation layer after long term.

4. Conclusion

In summary, we found that the adhesive multilayer could effectively protect the organic device by using the conventional lamination method. Its encapsulation method, which is very simple and convenient to perform, did not influence the characteristics of OTFTs. The passivated device showed the maintenance of initial mobility (2.0 x 10^{-1} cm^2/Vs) for long times and its longevity was affected by the structure of the adhesive multilayer.

Lamination process encapsulation by mean of the adhesive multi layer is a novel encapsulation of OTFT devices, which may be applied to flexible and light-weight encapsulation for flexible OTFT devices.

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References

[1] C. D. Dimitrakopoulos and D. J. Mascaro, IBM J. Res. Dev. 45, 1, 2001.
[2] Ziernelis K. Nature, 393, 619, 1998.
[3] Torsi L, Dodabalapur A, Sabbatini L, Zambonin PG, Sens Actuators B, 67, 312, 2000.
[4] C. D. Dimitrakopoulos and P. R. L. Malenfant, Adv. Mater. 14, 99, 2002.
[5] H. E. Katz and Z. Bao, J. Phys. Chem. B 104, 671, 2000.
[6] C. D. Sheraw, L. Zhou, J. R. Huang, D. J. Gundlach, T. N. Jackson, M. G. Kane, I. G. Hill, M. S. Hammond, J. Campi, B. K. Greening, J. Francl, and J. West, Appl. Phys. Lett. 80, 6, 2002.
[7] W. Fix, A. Ullmann, J. Ficker, and W. Clemens, Appl. Phys. Lett. 81, 9, 2002.
[8] Jung Hun Lee, S. H. Kim, G. H. Kim, J. Lee, Y. S. Yang, H. Y. Chu, J. Oh, L. Do, and T. Zyung, J. of the Korean Phys. Society, 42, S614, 2003