Investigation of the ZnO based TFT interface properties with synchrotron radiation analysis

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Abstract

The interface between SiNx and ZnO was investigated with Near Edge X-ray Absorption Fine Structure (NEXAFS) for ZnO based thin film transistor (TFT) applications. Impurity species were interstitial N_2 molecules at the SiNx / ZnO interface. The evolution of N_2 is decreased with increasing of anneal temperature.

1. Introduction

Transparent electronic devices are nowadays one of crucial technologies for the next generation of optoelectronic devices. Oxide based channel materials have recently been proposed as thin film transistors (TFTs). Transparent thin film transistors (TTFTs) using transparent oxide semiconductors (TOSs) as the channel layer have several merits compared with conventional Si-TFTs when applied to flat panel displays. These include the efficient use of backlight in LCDs or emitted light in OLEDs and insensitivity of device performance to visible light illumination. In addition, oxide TFTs have potential advantages over semiconductor-based TFTs in terms of their high voltage, temperature, and radiation tolerances.

Recently, the application of ZnO as an active channel layer of TTFT has attracted great interest since ZnO can be prepared at low deposition temperature with relatively high field effect mobility (0.3–70 cm^2/V s), good on–off ratio of about 10^5–10^7, and transparency within visible range wave length. [1-6] ZnO is presently attracting much attention due to its possibilities for replacing amorphous Si that has been widely used as the channel layer in conventional TFTs. Unlike Si based TFTs, it is expected that the characteristics of ZnO based TFTs would not degrade on exposure to visible light due to the wide band gap of its active channel layer. In this study, we investigated ZnO based TFT interface from synchrotron radiation analysis. A silicon nitrides (SiNx) is used for gate insulator. ZnO thin films of 5 nm thick on SiNx were specially designed to study chemical species by interface reaction because it is impossible to investigate the interface non-destructively with thick layer by photo emission spectroscopy. This is the direct observation of interstitial N_2 molecules in the interface between SiNx and ZnO. The thermal behavior of impurities at the interface also will be discussed.

2. Experimental

The samples were prepared with Si / Mo (100 nm) / SiNx (30 nm) / ZnO (5 nm) structure. The Mo layer on the Si substrate was deposited with DC magnetron sputter to solve the charging effects from the insulating layer during photoemission experiments. We deposited optimized ZnO layer with RF magnetron sputtering and SiNx with PECVD at room temperature. After the deposition, samples were annealed at 300 ℃, 400 ℃, and 600℃ for 10 minutes in vacuum chamber. Interface analysis for the samples was performed using synchrotron radiation source. Near edge x-ray absorption fine structure (NEXAFS) experiment can be conducted at the 8A1 (U7) beam line in Pohang Advanced Laboratory (PAL). The spectra were obtained by recording the sample current in total electron yield (TEY) mode as a function of energy. The absolute photon energy scale was referred to the value of 401.10 eV which position is the π^* resonance peak for a gas phase N_2.

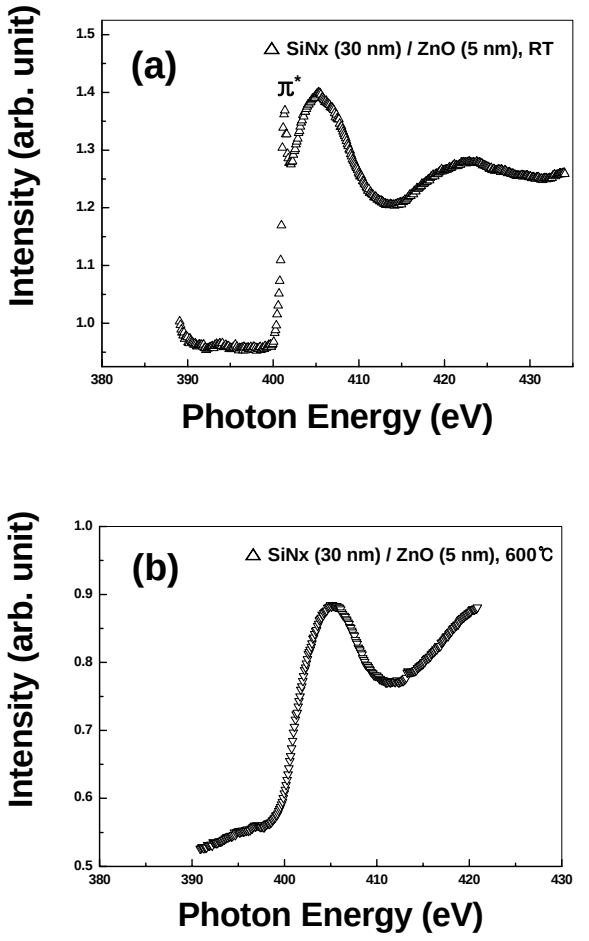

Fig. 1. (a) N K-edge absorption spectra for SiNx (30 nm) / ZnO (5 nm) (a) as-deposited and (b) annealed at 600 ℃ for 10 minutes (energy step = 0.1 eV).

3. Results and discussion

NEXAFS technique is useful to examine the interface reaction non-destructively unlike XPS, SIMS and AES analysis. Figure 1 shows a N K-edge absorption spectrum for the SiNx / ZnO films. The chemical species of the sharp peak in figure 1 (a) was interstitial molecular N2 reported by Y. Chung et al [7]. After anneal at 600 ℃ in vacuum chamber, interstitial N2 peak disappeared in figure 1 (b). To discuss more detail results, we obtained a fine spectrum of the 400 ~ 403 eV range (figure 2) with different anneal conditions.

Figure 2 shows the characteristic vibrational structures indicating the presence of N2 molecules and the change of N K-edge fine structure with the anneal temperatures. The intensity of π * resonance peak was decreased with increasing anneal temperature for each structure and finally disappeared above 600 ℃ as seen in figure 1 (b). The decrease of π * peak intensity mainly can be attributed to out-diffusion of N2 molecule [7].

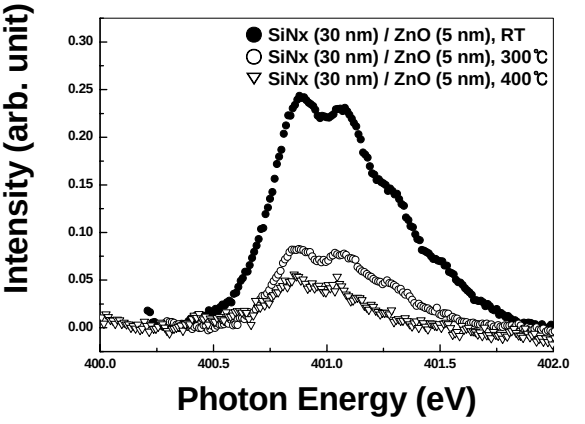

Fig. 2. High resolution (energy step = 0.01 eV) N K-edge spectra of SiNx (30 nm) / ZnO (5 nm).

4. Summary

In recent years, ZnO has received much attention as the potential material for a wide variety of electronic devices. In the low temperature TFT process, the device properties are severely limited by the large impurity evolution in ZnO and SiNx, which are used for active channel layer and gate insulator respectively. Our results have shown that impurity species were interstitial N2 molecule by NEXAFS. The NEXAFS technique has a merit in observing the interface non-destructively. It was directly observed in the vibrationally resolved N K-edge absorption spectra at the contact interface. The evolution of N2 is decreased with increasing of anneal temperature. However, it is still controversial that π * resonance peak of N K-edge originated from SiNx layer or SiNx / ZnO interface. We will discuss the origin of interstitial N2 using only SiNx layer for a reference. We will also show the electrical properties for ZnO based TFT with above anneal condition.

5. References

1. S. Masuda, K. Kitamura, Y. Okumura, S. Miyatake, H. Tabata, T. Kawai, J. Appl. Phys. 93 (2003) 1624
2. R.L. Hoffman, B.J. Norris, J.F. Wager, Appl. Phyis. Lett. 82 (2003) 733
3. P.F. Carcia, R.S. McLean, M.H. Reilly, G. Nunes Jr., Appl. Phys. Lett. 82 (2003) 1117
4. J. Nishii, F.M. Hossain, S. Takagi, T. Aita, K. Saikusa, Y. Ohmaki, I. Ohkubo, A. Ohtomo, T. Fukumura, F. Matsukura, Y. Ohno, H. Koinuma, H. Ohno, M. Kawasaki, Jpn. J. Appl. Phys. 42 (2003) L347
5. E. Fortunato, P. Barquinha, A. Pimentel, A. Goncalves, A. Marques, R. Martins, L. Pereira, Appl. Phys. Lett. 85 (2004) 2541
6. E. Fortunato, A. Pimentel, L. Pereira, A. Goncalves, G. Lavareda, H. Aguas, I. Ferreira, C.N. Carvalho, R. Martins J. Non-Cryst. Solids 338–340 (2004) 806–809
7. Y. Chung, J.C. Lee, H.J. Shin Appl. Phys. Lett. 86 (2005) 022901