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Effects of performance improvement on InGaZnO thin film using by micro-wave irradiation for both ReRAM and TFT applications

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Abstract

For the first time, a micro-wave irradiation method was employed to enhance both memory properties of resistive switching and TFT performance for the InGaZnO (IGZO) thin film. Compared with the on/off ratio (10^1) resistive switching using by conventional thermal annealing (CTA) treatment, the micro-wave irradiation method dramatically increased to be 10^2 at the as-deposed state of 4x. Also, the S-swing and field-effect mobility characteristics of TFT were improved as 417 mV/decade and 10.43 cm^2/Vs, respectively. In addition, instability of transfer performance of TFT was improved. The threshold voltage shift (Vth) was reduced from 14.95 V to 4.33 V on positive bias stress. This result was comparable with the result of CTA as 4.54 V shift. Therefore, the incorporation of micro-wave irradiation on the IGZO thin film-based devices could be considered one of the very promising approaches to improving the performance of both ReRAM and TFT.

1. Introduction

Among several resistive switching materials, InGaZnO (IGZO) has attracted increasing attention in recent years as integrated thin film transistor (TFT) periphery circuits for system-on-panel (SoP) applications.

For IGZO based SoP applications, the resistive switching layer should be undergone on the same process of TFT's active channel layer in the front-end-of-line[1]. This specific fabrication is contrasted to CMOS friendly resistive switching materials, such as HfO_x, AlO_x, ZrO_x, WO_x, etc, formed on the via or plug structure in the back-end-of-line[2]. However, it is well known that the IGZO TFTs required the thermal annealing treatment because of instability characteristics and it impacts integrated devices, such as resistive random access memory (ReRAM), and limits processes of fabrication[3].

Recently, it is reported that micro-wave irradiation treatment improved electrical performance of IGZO TFT.[4] From the paper, device received irradiation energy transfer directly by absorption throughout the volume of material. The novel irradiation can reduce the instability of IGZO TFT, especially V_{th} shift, and is considered to be a promising treatment in terms of thermal uniformity, rapid, shortened manufacturing period, selectivity of target material in device structure. In this work, we investigated the effects of micro-wave irradiation on electrical performance and reliability of IGZO ReRAM with TFT. Particular, the treatment reduced reset current dramatically on ReRAM device while transfer characteristics of TFT improved. Furthermore, the fast treatment is a low temperature process; the maximum temperature in this work is 60 ^{o}C during process at 600 watts for 5 min. Therefore, the micro-wave irradiation can contribute to realize future SoP application, especially fully transparent and flexible electronics.

2. Experimental

The p-type Si with a 300-nm thick thermal oxide were used as a starting material. A 100-nm-thick Pt was deposited with a 10-nm-thick Ti as adhesion layer. And then, in order to fabricate ReRAM and TFT devices, a 70-nm-thick resistive switching layer and active channel layer were formed by RF sputtering system at a power of 100 W. Next, we deposited a 100-nm-thick Ti while pseudo-MOS structure was used for IGZO TFT. A square pattern of 110 x 180 um^2 is used for ReRAM. Finally, in order to compare the annealing effect for fabricated IGZO-based ReRAM and TFT devices, thermal and micro-wave treatments were performed in O_2 ambient at 400^{o}C for 30 min and at 2.45 GHz and a 600 W for 5 minutes, respectively

3. Results and discussions

Fig.1 shows typically resistive switching characteristics of IGZO ReRAM with treatments. The bipolar switching behavior is observed. As compared with thermal annealing, the micro-wave irradiation treatment reduced reset current significantly, and it improved memory window of ReRAM. The inset of Fig.1. shows retention characteristics of micro-wave irradiation treated device at room temperature and 85 °C. It shows that 10 years data retention is guaranteed.

Also, we manufactured TFT devices with thermal annealing and micro-wave irradiation treatments. Fig.2 shows that the micro-wave irradiation improved memory performance of IGZO-ReRAM as well as changed dramatically electrical properties of IGZO-TFT. After the irradiation treatment, the subthreshold swing (S.S.) was 417 mV/decade and field effect mobility was 10.43 cm/V·s. A notable fact in the inset of Fig.2. is that the threshold voltage shift was reduced by using micro-wave irradiation as compared with thermal annealing after bias stress induced.

4. Conclusion

The effects of the micro-wave irradiation treatment on electrical performance of IGZO ReRAM device with TFT device were demonstrated. Compared with the thermal annealing, the sample treated micro-wave irradiation showed lower reset current, outstanding memory window, and superior reliability. In addition, the treatment improved transfer characteristics of IGZO TFT dramatically. Therefore, this study suggested that the novel treatment has feasibility in transparent and flexible SoP applications.

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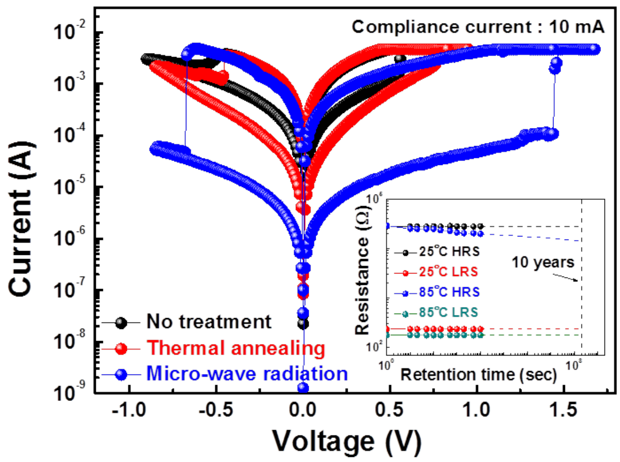

Fig. 1. The typical resistive switching characteristics measured from no treatment, thermal annealing, and micro-wave irradiation of ReRAM devices. Inset : The retention characteristics of device with micro-wave irradiation at 25 and 85 °C.

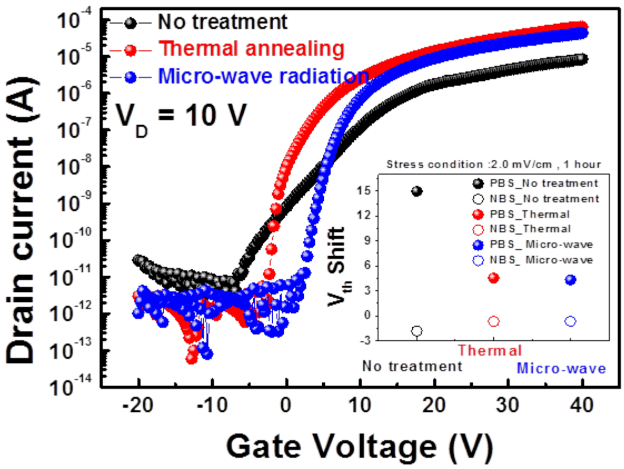

Fig. 2. The transfer characteristics of the thin film transistor devices with no treatment, thermal annealing, and micro-wave irradiation. Inset : Threshold voltage shifts with the treatments after positive and negative bias stress induced.