Fabrication of Au/ZnO/Au heterostructure with resistive switching properties

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Abstract

Resistive random access memory (R-RAM) is a kind of non-volatile memory that can keep its information even power is turned off. The resistance states can be switched by electric field and can be operated at low voltage. Therefore, we try to find a suitable fabrication condition to deposite a Au/ZnO/Au trilayer RRAM device using sputtering. A bipolar resistive-switching behavior with high set/reset ratio can be achieved in our work.

Keywords: memory device, non-volatile memory (NVM), oxygen vancancy, solid state

1. Introduction

The memory device is one of the most important electronic devices for computer or smart phone. The devices that we need nowadays require having a high-density, high-speed and non-volatile memory (NVM). There exist as various kinds, but the ones we know well are dynamic random-access memory (D-RAM)) and static random-access memory (S-RAM). D-RAM is very fast and can be connected with central processing unit. However, it has many disadvantages because D-RAM is volatile memory. The S-RAM is a high-speed device but more expensive and less density than D-RAM and is therefore not used for high-capacity [1].

Resistive random access memory (R-RAM) has been considered as a candidate for future RAM beyond D-RAM because R-RAM is a nonvolatile storage technology. R-RAM is a new technology made from oxide materials and cheaper than D-RAM and S-RAM. The most of the RRAM cells have a simple capacitor-like 'Metal/Insulator/Metal (MIM)' structure. It works by changing the resistance across a dielectric solid-state material [2].

R-RAM based on the resistive switching (RS). It has two states which are high resistance state (HRS) and low resistance state (LRS), respectively. The two states can be switched from one to the other by an appropriate electric field. Normally, the operation which changes the resistance of the device from HRS to LRS is called a 'SET' process, while the resistance of the device from LRS to HRS is called a 'RESET'. In addition, it can be read at the low voltage and also store data even if electric stress is cancelled [3].

In this work, we fabricate the R-RAM using ZnO and Au to investigate the property of R-RAM. ZnO and Au were deposited by radio frequency sputtering under pressure 3×10^{-6} Torr and measured by Source meter.

2. Experimental

The resistive switching (RS) memory devices were prepared through the following processes as shown in Figure 1. The Au(~60nm)/ZnO(~x nm)/Au(~60nm) heterostructures were fabricated as conventional crossbar metal/insulator/metal structures with an electrode area of 200 mm × 200 mm and a metal shadow mask on SiO_2/Si substrates. The substrates (2 cm × 2 cm) that were cut by diamond pen from 2 inch SiO_2/Si wafer and were cleaned by Ultrasonic cleaner for 3 cycles (1 time/3 min) using acetone, and alcohol step by step. After that wiped by delicate task wipers, samples were blowed by N_2 gas again. The mask was sticked to SiO_2 wafer by Heat resistant tape and use spring for seize between sample and disk during sputtering. The next step is putting target and disk into Sputtering machine. The base pressure of the sputtering chamber was pumped below 3×10^{-6} Torr using a turbomolecular pump. Au and ZnO thin films were deposited at room temperature using Au and ceramic ZnO target under a working pressure of 2×10^{-2} Torr with a mixure of different Ar/O_2 ratio with different power. The desired thicknesses of ZnO are controlled by use of quartz crystal monitoring. After deposition, the next step is to get samples out from the chamber and got the tape on samples out by Tweezers. Then, we used silver glue to stick Cu wire on samples and waited for 4 hr for drying.

After that the samples were measured by Source meter and applied DC current voltage for considering the Resistance switching.

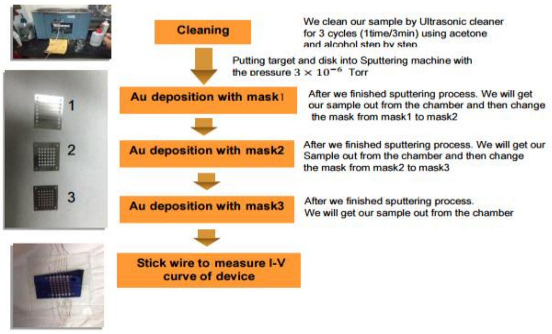

Figure 1. The procedure of our fabrication process

3. Results and Discussion

We have tried different fabrication parameters (or conditions) to achieve a RS Au/ZnO/Au heterostrucutres. The I-V curve of the first condition is shown in Figure 2. RS properties cannot be observed because the resistance is too low for HRS. The result of the second condition is shown in Figure 3. The sputtering power is the same as the first condition. But in this condition we add some oxygen inside the chamber when we deposited ZnO. However, the result of R-RAM is still low resistance. The result of third conditions is shown in Figure 4. We increase the thickness of ZnO from 70 nm to 140 nm. The third conditions also do not show the RS properties. Because the 140 nm ZnO should be thick enough to have HRS, therefore, we suppose the sputtering power of Au for top electrode is too large and will cause the diffusion problem, hence, resulting in a low resistance of device. The result of the fourth conditions is displayed in Figure 5. This time we have lowered the sputtering power of the top electrode Au but still do not show the RS behavior. We suppose maybe the bottom Au is too rough. We will change the sputtering power of bottom Au in the next run. The result of the fifth conditions is revealed in Figure 6. The resistance of the device is very high in this condition but still do not show RS behavior. We find the resistance of bottom Au is too large compared with other metallic electrode [3]. We should find a suitable sputtering power to control our bottom Au electrode before we deposit the ZnO layer. The result of the sixth condition is shown in Figure 7. Although the results of sixth conditions show the RS-like behavior, the resistance of top Au electrode is still too high. We will try to change the shape pattern of top electrode.

In the Figure 8, we just consider we should measure the SET (HRS to LRS) and RESET (LRS to HRS) in different ways. Because in the past we measure our sample without setting up the current limitation, it will made our device easy to be broken. So we have to set up a limitation of SET. But during RESET measurement, we don't need to set up the limitation for switch the resistance back to HRS.

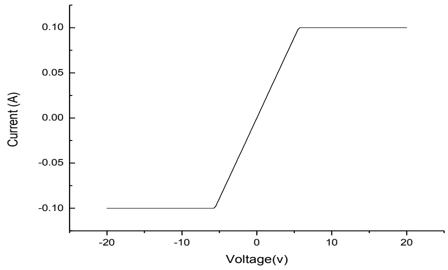

Figure 2. I-V curves of the first condition.

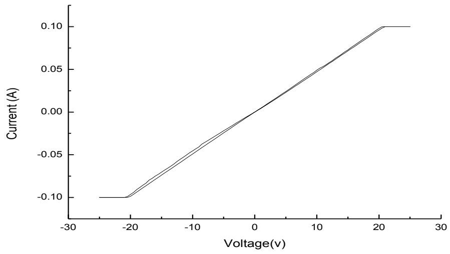

Figure 3. I-V curves of the second condition.

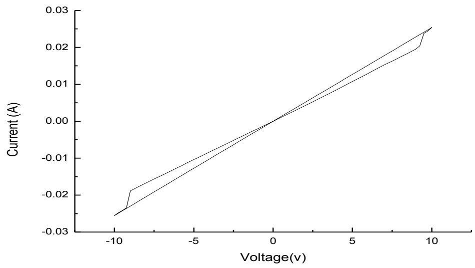

Figure 4. I-V curves of the third condition.

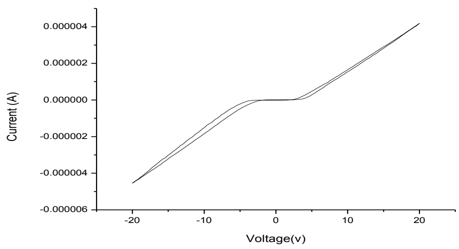

Figure 5. I-V curves of the fourth condition.

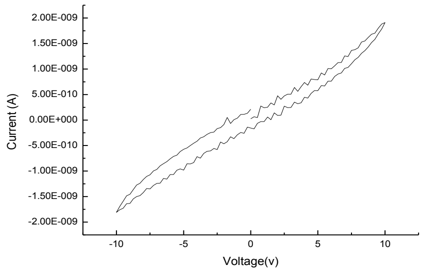

Figure 6. I-V curves of the fifth condition.

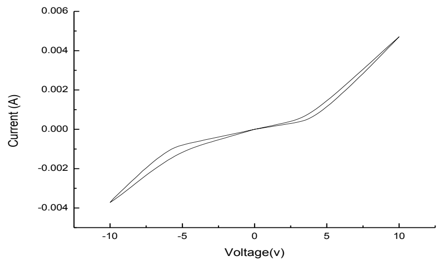

Figure 7. I-V curves of the sixth condition.

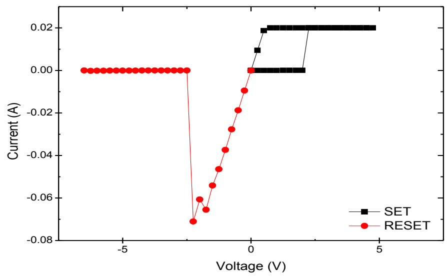

Figure 8. I-V curves of the sixth condition (new sample).

Figure 9 shows the x-ray diffraction (XRD) patterns of the Au film deposited on SiO_2/Si wafer. XRD pattern of Au index (220) shows a f.c.c structure of Au. Figure 9 shows the XRD patterns of the Au/ZnO film, the apparent Au (220) and ZnO (002) peaks reveal our sixth condition can grow Au/ZnO/Au heterostructures with good crystalline structures, therefore, can reveal the RS behavior.

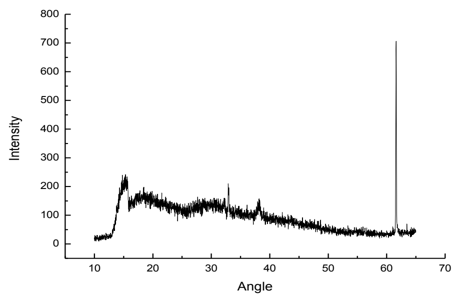

Figure 9. XRD pattern of Au films deposited on SiO_2 /Si wafer surface of the sixth condition (new sample).

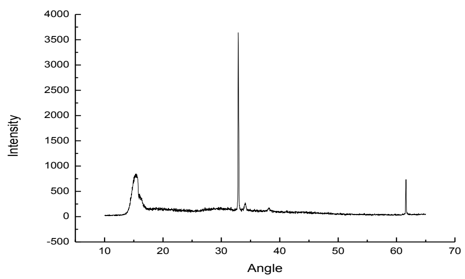

Figure 10. XRD pattern of Au/ZnO film of the sixth condition (new sample).

4. Conclusion

This work investigated how to deposit Au/ZnO/Au devices with RS properties using sputtering. When the applying electric power/thickness is 100 W/140 nm during ZnO sputtering and 25 W/ 60nm during Au sputtering, a Au/ZnO/Au can show a successful bipolar RS ("SET" and "RESET") behavior and showed good memory performance.

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