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Impact of oxidization, nitridation, and process temperature on materials for ReRAM

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Recent intensive research and development activities on resistive random access memory (ReRAM) technology improve its operating performance and several prototypes of the integrated memory array have been demonstrated successfully. As the miniaturization of the memory element progress, the volume of the materials constituting the memory element decreases and some extraneous effects will become a concern. For instance, the interface reaction between the oxide and electrode materials inside the memory element should be clarified especially when the thickness of the oxide layer is quite small. The reaction between the process gas species and the electrode materials can also be an unfavorable factor which influences the operating performance of ReRAM. In the present contribution, the impact of the process gas and process temperature on materials in the memory element is discussed.

In order to investigate the reaction between the process gas and the electrode materials, we prepared the Pt/Ta(5nm)/TaN/Pt structure without oxide layer by sputtering and devices fabrication in analogy with the ReRAM element was carried out. The interlayer insulator was 20 nm thick SiO_2 film deposited by plasma enhanced chemical vapor deposition (PECVD). The post annealing process in the oxygen ambient at 400 °C was conducted after the device fabrication process was completed. Despite the existence of the interlayer insulator, the increase of the resistance was observed. Moreover, the resistance switching characteristics was also observed. The intrusion of the oxygen-isotope ^{18}O was confirmed by secondary ion mass spectroscopy (SIMS). The profile of oxygen intruding into the Ta film was clearly changed and the amount of oxygen in Ta decreased when the annealing in the nitrogen ambient was performed a prior to the oxidization process. The oxygen diffusion barrier protecting the reactive elements in ReRAM from extraneous oxygen gas is thought to be essential.

The impact of the process temperature on the operating performance was investigated using the TiN/Ti/HfO_2/TiN structure. In-situ electron energy loss spectroscopy (EELS) measurement at the elevated temperature up to 500 °C was conducted. The diffusion of oxygen from HfO_2 to Ti was observed. The resistance switching characteristics of the control device was also influenced by this annealing process, depending on the annealing temperature and the thickness of Ti.

Above results strongly indicate the importance of ReRAM memory element and device fabrication process designs focusing on the chemical reactions among oxide and electrode materials in ReRAM and process gas.

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