Deposition of hafnium/zirconium oxides solid solution by reactive magnetron sputtering for fast and low power ferroelectric devices

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IoT sensor node requires edge computing which means processing data at the source. These systems need highly energy efficient microprocessor units (MCU) using embedded non-volatile memories (eNVM). However eFLASH technology is limited by low write speed, high power and low endurance. Alternative fast, low power and high endurance eNVM could greatly enhance energy efficiency. FeRAM has the highest endurance of all emerging NVMs. However perovskite based eFeRAM is incompatible with Si CMOS, it does not easily scale and has manufacturability and cost issues. Recently discovered, doped HfO_2 [1] is a promising candidate to solve these problems. HfO_2 processes are already integrated in Si CMOS industry and its ferroelectric properties are adequate for using oxide layer thinner than 10nm. Nevertheless some of its properties should be improved for industrial applications.

As a consequence, the nucleation and stabilization of the ferroelectric phase (f-phase) has to be understood; the nucleation of the f-phase is attributed to the polar orthorhombic phase (o-III phase), but other phases are generally present inside the oxide after the growth due to stabilization issues [2]. Particularly, the formation of the monoclinic phase has to be avoided to enhance ferroelectricity. The presence of the f-phase has often been studied by Atomic Layer Deposition (ALD) [3].

However, the electrodes are most of the time made by sputtering, and industrial processes to separate Hf and Zr are usually expensive. It could be interesting to have only one process where the separation of Hf and Zr is not needed. Also, sputtering using only one target like Hf/Zr or HfO_2/ZrO_2 could ease co-sputtering for the realization of 1% La-doped $Hf_{0,5}Zr_{0,5}O_2$ as it shows a low annealing temperature and a very promising endurance and remanent polarization [4].

In 2015, Park et al. [3] wrote: “So far, it seems critical that the dielectric layer is deposited in the amorphous phase and crystallized in a later annealing step.” However, to our knowledge, there was no clear evidence of the phenomenon as films are generally grown amorphous by ALD. In this work, we grow ferroelectric $(Hf,Zr)O_2$ solid solutions made by reactive RF magnetron sputtering at room temperature and by using only one target. Changing the conditions in the sputtering chamber lead to crystalline or amorphous films at room temperature. We characterize the films by different technics such as X-rays Diffraction and Positive Up Negative Down (PUND) electrical characterization and we give details about the properties of our films and how one can improve their properties.

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