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Ge-doped hafnia-based dielectrics for non-volatile memory applications

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Hafnium-based dielectrics are promising high-k dielectrics to replace SiO_2 gate oxide in CMOS devices. However, in ultrathin film approach, the structure and the properties of these materials depend strongly on the deposition conditions and the post deposition treatment. It was predicted from the first principles that dielectric constant of hafnia can be significantly increased when this latter is doped by silicon and/or germanium[1].

We demonstrated recently that silicon plays the most important role to improve the thermal stability of ultrathin films at high temperature annealing and, thus, Si-doped hafnia can be successfully used for nanomemory applications[2,3]. In this work, we will present the effect of germanium doping on the properties of hafnium-based dielectrics and compare with those observed for Si-doped hafnia.

The films investigated were fabricated by RF magnetron sputtering approach from HfO_2 target topped by either Si or Ge chips. The films were studied by means of XRD, TEM, FTIR and photoluminescence (PL) methods versus an annealing treatment. It was observed that Ge-doped films demonstrate phase separation at lower thermal treatment than their Si-doped counterparts. This phase separation occurs at 400-700°C and it is accompanied by the formation of Ge-nanoclusters and tetragonal HfO_2 phase. The stability of Si-doped films upon this annealing treatment was confirmed. Note that phase separation process for Si-doped hafnia starts from 1000°C.

The MOS capacitors were fabricated on the basis of HfO_2/HfGeO/HfO_2 and HfSiO/HfGeO/HfSiO stacks and their electrical properties were studied. The memory effect was observed in both types of MOS capacitors and the optimal annealing treatment was found to be at 600°C for 15 minutes. A memory window of ~7 V at a sweeping voltage of ± 14 V has been achieved.

The obtained results demonstrate that the RF magnetron sputtering is a promising technique for the production of different nonvolatile memory devices fully based on high-k dielectrics.

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