Fabrication and characterization of WSi$_2$ nanocrystals memory device with SiO$_2$ / HfO$_2$ / Al$_2$O$_3$ tunnel layer

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High-k dielectric materials such as HfO$_2$, ZrO$_2$ and Al$_2$O$_3$ increase gate capacitance and reduce gate leakage current in MOSFET structures. This behavior suggests that high-k materials will be promise candidates to substitute as a tunnel barrier. Furthermore, stack structure of low-k and high-k tunnel barrier named variable oxide thickness (VARIOT) is more efficient.[1] In this study, we fabricated the WSi$_2$ nanocrystals nonvolatile memory device with SiO$_2$/HfO$_2$/Al$_2$O$_3$ tunnel layer. The WSi$_2$ nano-floating gate capacitors were fabricated on p-type Si (100) wafers. After wafer cleaning, the phosphorus in-situ doped poly-Si layer with a thickness of 100 nm was deposited on isolated active region to confine source and drain. Then, on the gate region defined by using reactive ion etching, the barrier engineered multi-stack tunnel layers of SiO$_2$/HfO$_2$/Al$_2$O$_3$ (2 nm/1 nm/3 nm) were deposited the gate region on Si substrate by using atomic layer deposition. To fabricate WSi$_2$ nanocrystals, the ultrathin WSi$_2$ film with a thickness of 3-4 nm was deposited on the multi-stack tunnel layer by using direct current magnetron sputtering system [2]. Subsequently, the first post annealing process was carried out at 900°C for 1 min by using rapid thermal annealing system in nitrogen gas ambient. The 15-nm-thick SiO$_2$ control layer was deposited by using ultra-high vacuum magnetron sputtering. For SiO$_2$ layer density, the second post annealing process was carried out at 900°C for 30 seconds by using rapid thermal annealing system in nitrogen gas ambient. The aluminum gate electrodes of 200-nm thickness were formed by thermal evaporation. The electrical properties of devices were measured by using a HP 4156A precision semiconductor parameter analyzer with HP 41501A pulse generator, an Agilent 81104A 80MHz pulse/pattern generator and an Agilent E5250A low leakage switch mainframe. We will discuss the electrical properties for application next generation non-volatile memory device.


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