The charge transport mechanism and the nature of traps in charge trap flash, ReRAM and FeRAM devices

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High-κ dielectrics HfO_x, ZrO_x, $Hf_{0.5}Zr_{0.5}O_2$, AlO_x, SiO_x, SiN_x are used now in charge trap flash (TANOS), ReRAM and FeRAM devises. In Si_3N_4 of TANOS the charge transport limited by multiphonon trap ionization [1]. It is proved that the traps responsible for memory effect is the Si-Si bonds [2]. Alumina is used in TANOS charge trap flash devices as blocking dielectric [1]. Electron transport in amorphous Al_2O_3 is limited by multiphonon trap ionization [3]. The luminescence band 3.0 eV in amorphous Al_2O_3 has excitation energy 6.0 eV [4]. The photoluminescence Stokes shift (6.0-3.0)/2=1.5 eV is equal to the thermal trap energy 1.5 eV. Quantum-chemical simulation shows that oxygen vacancy in alumina is electron trap.

The charge transport in high-κ dielectrics is determined by electron and hole traps. The charge transport in ReRAM based on HfO_2 is controlled by trap assisted tunneling between traps [5,6]. Thermal trap energy in HfO_2 is equal to 1.25 eV [6,7]. The trap nature in HfO_2 was studied with luminescence experiments. The blue luminescence band 2.7 eV has excitation energy 5.2 eV. The same energy has absorption peak of oxygen vacancy in HfO_2. Hence, the 5.2 eV excitation peak and 2.7 eV luminescence band are related to oxygen vacancies [6]. The photoluminescence Stokes shift (5.2-2.7)/2=1.25 eV is equal to thermal trap energy. Hence, the oxygen vacancy in HfO_2 is electron trap [7,8]. Similar results were obtained for ZrO_2. It was concluded that the oxygen vacancies in ZrO_2 are electron and hole traps.

$Hf_{0.5}Zr_{0.5}O_2$ is used as memory node in ferroelectric memory FeRAM. The charge transport in $Hf_{0.5}Zr_{0.5}O_2$ is limited by trap assisted tunneling between traps [9]. With photoluminescence experiments and quantum-chemical simulation it was found that oxygen vacancy in $Hf_{0.5}Zr_{0.5}O_2$ is electron trap.

[1] V.A. Gritsenko, Silicon Nitride on Si: Electronic Structure for Flash Memory Devices, chapter in book “Thin Films on Si: Electronic and Photonic Applications” p.273-322 ’’World Scientific Press”, 2016
[2] V.A. Gritsenko, N.V. Perevalov, at al, Applied Physics Letteres, v. 109, p. 06294, 2016
[3] N. Novikov, V.A. Gritsenko, K.A. Nasyrov, Appl. Phys. Lett. v. 94, p. 222904, 2009
[4] T.V. Perevalov, O.E. Tereshenko, V.A. Gritsenko, at al, J. Appl. Phys. v.108, p.013501, 2010
[5] D. R. Islamov, V. A. Gritsenko, at al Applied Physics Letteres. v. 105, p. 222901, 2014
[6] V. A. Gritsenko, T. V. Perevalov, D. R. Islamov, Physics Reports, v. 613, p.1, 2016
[7] T.V. Perevalov, V.Sh. Aliev, Applied. Physics Letters, v.104, p. 071904, 2014
[8] V. Gritsenko; D. Islamov, T. V. Perevalov, at al, , J. Phys. Chem. C, v. 120, p 19980, 2016
[9] D. R.Islamov, T. V.Perevalov, at al, Appl. Phys. Lett. v. 106, p. 102906, 2015

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