Ferromagnetic HfO_2/Si/GaAs interface for spin-polarimetry applications

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In this letter, we present electrical and magnetic characteristics of HfO_2-based metal-oxide-semiconductor capacitors (MOSCAPs), along with the effect of pseudomorphic Si as a passivating interlayer on GaAs(001) grown by molecular beam epitaxy. Ultrathin HfO_2 high-k gate dielectric films (3–15 nm) have been grown on Si/GaAs(001) structures through evaporation of a Hf/HfO_2 target in NO_2 gas. The lowest interface states density D_{it} at Au/HfO_2/Si/GaAs(001) MOS-structures were obtained in the range of $(6-13)\times10^{11}$ $eV^{-1}cm^{-2}$ after annealing in the 400–500 °C temperature range as a result of HfO_2 crystallization and the Si layer preservation in non-oxidized state on GaAs. HfO_2-based MOSCAPs demonstrated the ferromagnetic properties which were attributed to the presence of both cation and anion vacancies according to the first-principle calculations. Room-temperature ferromagnetism in HfO_2 films allowed us to propose a structure for the ferromagnetic MOS spin-detector. © *2015 AIP Publishing LLC*.
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The creation of metal-insulator-semiconductor (MIS) structures in which both insulator and metal layers are ferromagnetic could be very promising for spin polarimetry applications based on the optical detection of spin-filter effect[1,2] and spin-dependent transistors.[3,4] Injection of spin-polarized electrons into semiconductors is the first step towards the realization of semiconductor-based spintronic devices which utilize the spin degree of freedom of electrons. Herewith, the insulator layers (tunneling barriers) and interfaces play the crucial role in the scattering mechanisms of charge and spin that require the control of electrical and ferromagnetic (FM) properties of MIS junctions to achieve efficient spin-injection and spin detection in spintronic devices.[2]

Thin insulating films on semiconductors are of current interest regarding the applications using electron tunneling between ferromagnetic films and semiconductors. Hafnium oxide (HfO_2) has been extensively studied during the last years due to its relatively high dielectric constant, high melting point, and chemical stability. It is found suitable as a high-k material to replace the gate dielectrics in field effect transistors and dynamic random access memories.[5] HfO_2 is particularly interesting because it can be grown on Si surfaces with a low density of interface states, while Si itself can be grown pseudomorphic on a GaAs surface forming the so-called interface control layer (ICL).[6–8] Moreover, HfO_2 demonstrated the room temperature ferromagnetism.[9] The observation of ferromagnetism in un-doped HfO_2 has opened up a possibility to use this compound in magneto-optic and magneto-electronic applications. The modulation of pure spin currents with a ferromagnetic insulator has been recently demonstrated.[10] In this respect, a three layer system of FM metal/FM insulator/semiconductor (FMM/FMI/S) could be used as a spin selective filter with self-calibrated properties.[11] Schematically, the proposed GaAs-based FM MIS structure is shown in Fig. 1. The proposed structure should allow to measure all three spin components: two in-plane components, by measuring cathodoluminescence intensity,[1] and out of plane component by measuring the cathodoluminescence polarization.[12]

The present research work reports experimental data on the epitaxial growth, composition, electrical and magnetic properties of thin HfO_2 films deposited by electron beam evaporation of the Hf/HfO_2 target in an NO_2 flux. The reactions between HfO_2 and Si/GaAs during deposition and

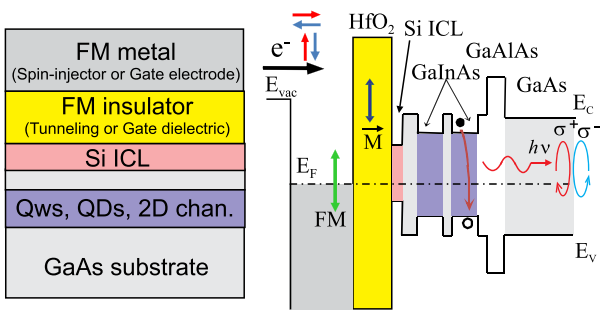

FIG. 1. The proposed MOS-structure (left) and a band diagram of Si ICL passivated GaAs-based structure with both FM base (gate) electrode and FM tunneling insulator layer (right).

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