論文の内容の要旨

論文題目　Control of Ultra-thin Amorphous High-*k*/Ge Interface for Ge-CMOS Devices
(Ge-CMOSデバイスのための極薄アモルファスHigh-*k*/Ge界面の制御の研究)

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In the recent CMOS technology, device-size scaling and high-mobility channel are very important to achieve high-performance MOSFETs. To suppress short-channel effects in scaled MOSFETs, the equivalent SiO_2 thickness (*EOT*) of gate dielectrics should be scaled down to below 1 nm (subnanometer scale), in addition to suppression of interface states density (D_{it}).

A high-*k*/Ge gate stack is one of the most promising candidates for use in future CMOS devices. To achieve a high-*k*/Ge with both subnanometer-scale *EOT* and low D_{it}, thermal stability and atomic diffusion at the interface are vital. Furthermore, amorphous high-*k* gate dielectrics are also needed to suppress fatal gate-leakage currents. In this thesis, three types of amorphous high-*k*/Ge interfaces are proposed, namely, (i) a reactive interface ($LaLuO_3$/Ge), (ii) a less reactive interface (Al_2O_3/Ge), and (iii) a nonreactive interface (AlN/Ge). They are investigated at the desirable Ge-processing temperature of around 600°C, which is required to activate dopants in source and drain regions. Conventional thermal-equilibrium post-deposition treatments are also used to clarify the important factors that fundamentally determine the high-*k*/Ge interface properties.

On the basis of these investigations, the guiding principles of *EOT* scaling and interface stabilization (low D_{it}) in amorphous high-*k*/Ge gate stacks are elucidated. First, an extreme suppression of GeO_2 interface layer formation is proved to be of primary importance to achieve subnanometer-scale *EOT*. Second, the stabilization of a GeO_2/Ge stack (suppression of GeO desorption) with the use of rare-earth metal, Al, and N atoms is determined to be pivotal to achieve a low D_{it}. In the process, some new findings on high-k/Ge gate stack processing are also discussed. Finally, a high-k/Ge gate stack with an *EOT* of ~0.88 nm and a D_{it} of ~10^{11} $eV^{-1}cm^{-2}$ is successfully demonstrated.

以上