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Rare earth oxides by atomic layer deposition on Si and Ge: evaluation and perspectives

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Summary

This presentation will start offering a synthetic view on the general issues related to scaling devices in microelectronics. The gate length needs to be reduced, and, consequently, gate leakage phenomena must be significantly limited. Alternative design for complementary metal-oxide-semiconductor (CMOS) devices were considered to solve the problem, however recently other possible solutions are examined: e.g. the implementation of high-mobility semiconductor, or of high dielectric constant (κ) oxides. Advantages and limitations of high-mobility semiconductors (e.g. Ge), and of high-κ oxides (including rare earth – RE – oxides) in future CMOS devices will be discussed. Next, the general features of atomic layer deposition (ALD) as oxide deposition technique for advanced oxides will be considered, illustrating briefly the growth mechanism, and the advantages of the self-limiting process. As a next step, RE oxides as high-κ dielectric candidates for novel ultra-scaled microelectronic devices will be considered, with special attention on the effects of the decreasing ionic radius with increasing atomic number of the RE cation (*lanthanide contraction*), and of the varying filling level of the *f* shell throughout the RE element series. The former effect affects seriously the sensitivity of RE oxides to moisture and to silicon diffusion from the Si(100) substrate to the RE oxide upon annealing. Experimental evidences of these phenomena will be given. On the other hand, the varying filling level of the *f* shell throughout the RE element series affects the electronic properties of the RE oxides (e.g. their band gap). The consequences on the band alignment of the RE oxides on Si(100) and possibly also on Ge(100) substrates will be discussed. Next, experimental results will be reported on those RE oxides which recently received most of the attention as possible high-κ dielectric candidates for novel ultra-scaled microelectronic devices: La_2O_3 (interesting because of the expected high-κ value of the hexagonal sesquioxide $P32/m$ phase), Pr_2O_3 (intensely studied because of its high-κ value, and already successfully integrated), Gd_2O_3 (which was found to successfully passivate the GaAs surface), Lu_2O_3 and Yb_2O_3 (these oxides are structurally stable both in air and upon annealing on Si(100), exhibit good electric properties on Ge(100), especially when O_3 is used as oxygen source during deposition). Finally, advantages of ternary oxides, including aluminates and silicates, will be discussed.