High-k Challenges for a New Horizon in Functional Smart Electronics

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Abstract:

The dielectric insulator is a key component in microelectronic devices such as the central processing unit (CPU), dynamic random-access memory (DRAM) and flash memory. The basic function of the dielectric material is to enhance the capacitive coupling between adjacent metals and semiconductors, although it should also suppress the leakage current between electrodes, which undermines the energy consumption (in CPU and DRAM) or long-term reliability (in flash memory). In past decades, silicon dioxide (SiO_2) has been used as a key dielectric material because it allows for defect-free, high-quality thin-film growth. As the integration level of microelectronic devices is currently exponentially increasing, the thickness of SiO_2 has decreased to maintain the device performance. However, SiO_2 has already been replaced by Al_2O_3 (DRAMs), Ta_2O_5 (filters) and Si_2N_2O (transistor), HfO_2 (gate dielectric in CPU),[1] ZrO_2 (capacitor in DRAM) and other metal oxides (e.g. La_2O_3, Pr_6O_{11}) as well because of the leakage current with nanoscale thickness due to the quantum tunneling effect,[2] which causes serious problems in power consumption and device performance. With high-k dielectrics, the dielectric thickness can be increased at the same capacitance, thereby suppressing the leakage current and a lot of demand from semiconductor industries for the new challenging of high-k materials has been emerged. [3] This presentation explores and addresses the challenges of high-k dielectric materials, one of the major concerns in the evolving semiconductor industry and the International Technology Roadmap for Semiconductors (ITRS). The application of high-k dielectric materials is a promising strategy that allows further miniaturization of microelectronic components and various applications. It will be a brief and broad review of some metal oxide materials, including a brief historical note of Moore's law, followed by my research overview based on the various technologies behind functional materials and applications. It goes on to discuss the selection of high-k materials with Atomic Layer Deposition (ALD) techniques which probably the best choice of technology for enabling novel devices and achieving the strictest production requirements of different high-k thin films. [4] Fundamental growth conditions, structural and electrical properties of various metal oxide and composite materials would be introduced as a candidate for future solid state electronics.[5]

References

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