Ultrathin dielectric oxides for microelectronics: Electrical characteristics and defects

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The fundamentals of traditional gate oxides (SiO_2) and novel high-permittivity oxides ('high-k', e.g. HfO_2) for metal-oxide-semiconductor field-effect transistors (MOSFETs) will be reviewed, with a focus on basic electrical characterization. Based on the principles of MOSFET operation, I will first rationalize past and future gate oxide trends for high-performance and low-power logic processor scaling. Then, I will introduce the MOS capacitor as a simple system to test oxide quality. Similarities to oxide-supported metal clusters in catalysis will be pointed out. Next, I will review electrical characteristics of such capacitors, relating observed trends to fundamental gate oxide properties, e.g. thickness, dielectric constant, transport of electrons or ions, and the presence of charged defects. I will conclude with a selection of case studies. Aside from the historic example of mobile Na ions in SiO_2, I will concentrate on phenomena relevant to Hf-based high-k gate oxides, such as oxide morphology, fixed charges due to N or Al, and O vacancies in the high-k bulk and at the gate electrode interface.