Conducting atomic-force microscopy as a tool for modification and characterisation of thin silicon gate oxides

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The constant trend towards miniaturization in semiconductor industries leads to tremendously increasing efforts on the investigation of structure formation in the nanometer regime. Our contribution to these efforts is the investigation of oxide nanostructure growth on silicon gate oxides using Conducting Atomic-Force Microscopy (C-AFM). The experiments shall increase the understanding of electrically induced oxide formation. C-AFM measurements are performed by applying voltage pulses between a highly boron doped diamond coated AFM tip and silicon gate oxide samples. Under ambient conditions, surface modifications with lateral dimensions of about 100 nm are achieved due to local oxidation. The process of structure formation is studied in dependence of the applied voltage, the pulse duration, and the voltage polarity. The threshold electric field (E_{th}), necessary for protrusion growth is calculated from the applied sample voltage divided by the oxide thickness. It shows an almost constant value for different thermal oxide thickness (d_{ox}) when positive sample voltages are applied. However, a strong decrease of E_{th} is observed with increasing d_{ox} for negative sample bias. Further, the quality of the initial gate oxides and the produced oxide structures are compared by applying a voltage ramp to the sample and measuring the tunnelling current. From a Fowler-Nordheim fit we can draw conclusions about the oxide quality before and after the electrically induced oxidation process.