Traceable Nanoscale Measurements of High Dielectric Constant by Scanning Microwave Microscopy

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Resume:

Most advanced processors made with the 2 nm transistors technology are being incorporated currently in electronic utilities such as laptops and smart phones all over the Globe. Future technologies will shortly go beyond this limit, thus raising high the bar for nanoscale electrical characterization techniques. Dielectric materials constitute a key element in transistors' fabrications. Their dielectric constants, loss tangent angle, especially at high frequencies, are paramount to guarantee highly preforming technological devices. Here we present a comprehensive metrological body of work done for the quantification of the dielectric permittivity of two commonly used high-k materials, namely lead zirconate titanate (PZT) and lead – magnesium niobate lead titanate (PMN-PT). Scanning microwave microscopy (SMM), fitted with a vector network analyzer (VNA – 6 GHz) is used to measure micro-capacitive structures prepared by the deposition of gold on polycrystalline rough dielectrics' surfaces. We demonstrate the traceability to the international system of units (SI) applying a modified short open-load (SOL) method for VNA calibration (range: 0.1 fF to 10 fF). We discuss in details all experimental factors dictating the control of low relative uncertainty levels (≤10%) in the measurement of high-k dielectric constants (from 400 to 800). Interfacial roughness, polycrystalline surfaces, dimensional measurements and parasitic capacitances constitute the main contributors to the overall uncertainty budget. Finite elements modelling of the micro-capacitance structures as well as the frequency dependence of the measured dielectric constants will be presented and discussed