Wetting Characterization of High Aspect Ratio Nanostructures by Gigahertz Acoustic Reflectometry

Authors : C. Virgilio, J. Carlier, P. Campistron, M. Toubal, P. Garnier, L. Broussous, V. Thomy, B. Nongaillard

Abstract : Wetting efficiency of microstructures or nanostructures patterned on Si wafers is a real challenge in integrated circuits manufacturing. In fact, bad or non-uniform wetting during wet processes limits chemical reactions and can lead to non-complete etching or cleaning inside the patterns and device defectivity. This issue is more and more important with the transistors size shrinkage and concerns mainly high aspect ratio structures. Deep Trench Isolation (DTI) structures enabling pixels' isolation in imaging devices are subject to this phenomenon. While low-frequency acoustic reflectometry principle is a well-known method for Non Destructive Test applications, we have recently shown that it is also well suited for nanostructures wetting characterization in a higher frequency range. In this paper, we present a high-frequency acoustic reflectometry characterization of DTI wetting through a confrontation of both experimental and modeling results. The acoustic method proposed is based on the evaluation of the reflection of a longitudinal acoustic wave generated by a 100 µm diameter ZnO piezoelectric transducer sputtered on the silicon wafer backside using MEMS technologies. The transducers have been fabricated to work at 5 GHz corresponding to a wavelength of 1.7 µm in silicon. The DTI studied structures, manufactured on the wafer frontside, are crossing trenches of 200 nm wide and 4 µm deep (aspect ratio of 20) etched into a Si wafer frontside. In that case, the acoustic signal reflection occurs at the bottom and at the top of the DTI enabling its characterization by monitoring the electrical reflection coefficient of the transducer. A Finite Difference Time Domain (FDTD) model has been developed to predict the behavior of the emitted wave. The model shows that the separation of the reflected echoes (top and bottom of the DTI) from different acoustic modes is possible at 5 Ghz. A good correspondence between experimental and theoretical signals is observed. The model enables the identification of the different acoustic modes. The evaluation of DTI wetting is then performed by focusing on the first reflected echo obtained through the reflection at Si bottom interface, where wetting efficiency is crucial. The reflection coefficient is measured with different water / ethanol mixtures (tunable surface tension) deposited on the wafer frontside. Two cases are studied: with and without PFTS hydrophobic treatment. In the untreated surface case, acoustic reflection coefficient values with water show that liquid imbibition is partial. In the treated surface case, the acoustic reflection is total with water (no liquid in DTI). The impalement of the liquid occurs for a specific surface tension but it is still partial for pure ethanol. DTI bottom shape and local pattern collapse of the trenches can explain these incomplete wetting phenomena. This high-frequency acoustic method sensitivity coupled with a FDTD propagative model thus enables the local determination of the wetting state of a liquid on real structures. Partial wetting states for non-hydrophobic surfaces or low surface tension liquids are then detectable with this method.

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