High Resolution SubSurface Probe Microscopy for node5 applications

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INTRODUCTION

Imaging of nanoscale structures buried in a covering material is an extremely challenging task, but is also considered extremely important. From fundamental research into living cells structures, to process control in semiconductor manufacturing, many fields would benefit from the capability to image nanoscale structures through arbitrary (opaque) covering layers. We have shown that combining Atomic Force Microscopy with ultrasound in a technology called Scanning Subsurface Probe Microscopy (SSPM) is a promising technology to enable such imaging.

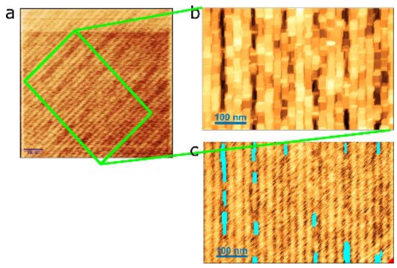

Figure 1 *– (a) Six nanometer wide Si fins in* SiO_2 *buried under 40nm pSi from an early production wafer showing many defective fins. (b,c) Direct, high resolution imaging allows automatic detection and analysis of the defectivity. More details on the processing on poster “Advanced Processing for Quantitative SubSurface Data Extraction.”*

High Resolution High Sensitivity SSPM

The application of SSPM in semiconductor metrology requires high resolution imaging and high Signal to Noise Ratio to be of added value in High Volume Manufacturing, for example in defect characterization (Fig 1). A good understanding of the physics of the method is required to optimize it for these applications.

Contrast mechanism in SSPM

The contrast in this method is based on sensing differences in surface elasticity of stacks of materials. Changes in dimensions or composition of a layer result in a change in the local surface elasticity of the stack, which can be sensed by the AFM tip in contact with the top surface.

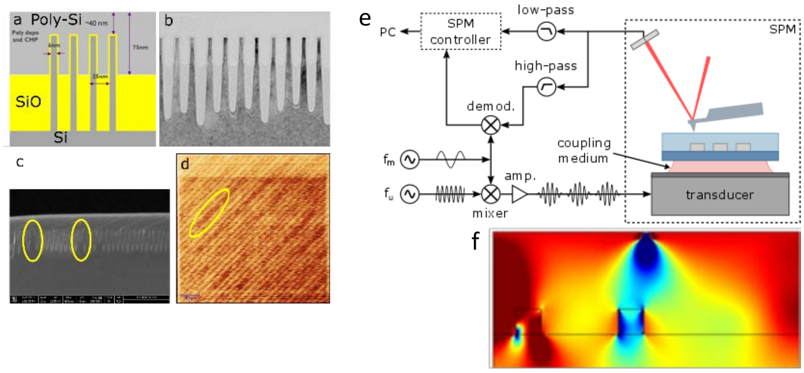

Figure 2 *– (a) Schematic of sample used for high resolution SSPM finFET measurements. (b) Cross-sectional TEM image of fins. (c) Cross-sectional SEM image of fins showing defects. (d) high resolution SSPM image showing the fins and their defects in a non-damaging measurement. (e) Typical bottom actuation SSPM setup showing hardware and signals. (f) Result from Finite Element Model showing the stress distribution within a sample which is the basis for the contrast.*

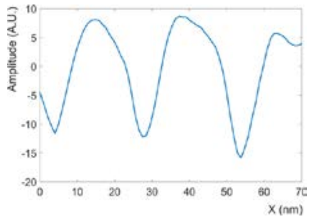

Figure 3 *- Cross section through SSPM phase data showing clearly 3 individual fins with a non-harmonic profile. This indicates there is more information besides pitch in the data, potentially allowing us to extract width and height.*

Quantification of data

Combining our knowledge of the SSPM contrast mechanism with extensive mechanical modeling of the samples and of the SSPM cantilever response, we aim to be able to quantitatively interpret the measured data in terms of material properties and dimensions of features. Although it is clear that the data is suitable to allow extracting such information (as shown in figure 3), the modeling is not straightforward, as can be appreciated from figure 2f where both features influence the stress field in a complex way. Implementing an inverse model to reconstruct (simple) features with high resolution from the data will be a major milestone for this year’s research.

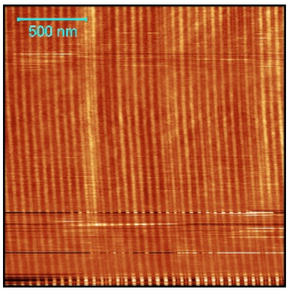

Figure 4 *– Another image of the same wafer showing a less defective area. Here, however, every other fin is less clearly visible. The precise implication for the realized fin geometry is not clear yet*

Repeatability

The images show that the current setup does not have absolute repeatability, see e.g. figure 4 where the contrast changes a number of times from one scanline to the next. However, it is known that most difficulties arise from contact mode scanning causing wear on the tip. We will implement different control schemes and measurement modes to alleviate this issue.

CONCLUSIONS

SSPM allows high resolution imaging of small sub 10nm, buried features under arbitrary (opaque) covering layers. We have successfully imaged defects of various kinds and are working towards quantifying results to reliably extract geometric parameters and material properties of small, complex, 3D structures (see also P4 and P6)

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