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Tunable Raman Selectivity for Semiconductor Metrology

We present significant developments in Raman spectroscopy of state-of-the-art semiconductor devices, where the sensitivity of the characterization can be fully tuned to the structures of interest. In a previous report we showed how Raman can be employed as a dimensional metrology in semiconductor manufacturing, but here we extend that concept to full selectivity to the different materials that make up a modern semiconductor device. We demonstrate the implementation on so-called forksheet transistor modules [1], which are characterized by two gratings of first the n- and pMOS transistor structures and then subsequently the tri-gate stack with both gratings orthogonal to each other. When we align the incident polarization to the transistor structures, the spectra are entirely free of signals from the gate stack, and we regain the previously enabled capabilities of e.g. extreme sensitivity to remaining SiGe cavity material during an etch process. Indeed the sample before etch shows signatures of Si-Ge and Si-Si vibrations coming from the SiGe, and these signals progressively disappear as more and more of the SiGe is etched from between the Si transistor channels. In contrast, when the polarization is aligned to the gate lines, the SiGe-like features completely disappear, and an entirely different Raman spectrum emerges that now shows the amorphous Si (aSi) signature from the gate material. As the etch process is not selective to the gate materials, the intensities of the aSi remain constant throughout the different etch steps. The result is that we can probe the different constituents of modern transistor architectures completely independently and in a fully non-destructive manner, which represents an important advancement for in-line spectroscopic semiconductor metrology.

References

[1] H. Mertens *et al.* 2021 Symposium on VLSI Technology, T2-1 - 9:20.

Figures

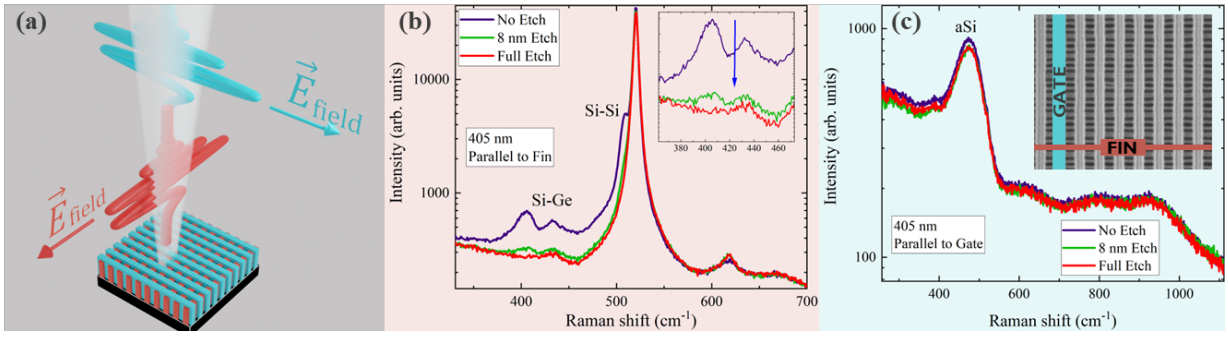

Figure 1: (a) Artist impression of the incident laser light coupling into the bimodal grating that is formed by the transistor channels and gate lines. When the polarization is aligned along the gate (blue), the light couples into that grating exclusively. Similarly, when the E-field is oriented along the transistor channels (red), the light probes that grating only. (b) Raman spectra with polarization parallel to the fin structures. A strong sensitivity on remaining SiGe content is observed, and no aSi material from the gate is detected. (c) Raman spectra recorded with polarization parallel to the gate. Only the aSi is observed in the spectra, and since this material is not subject to the etch process, the intensity is unaffected. The inset shows a top-down SEM image of the structures under investigation with gate and fin directions indicated.