Strain analysis in semiconductor devices through Tip-Enhanced Raman Spectroscopy

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The miniaturization trend in nanoelectronics is imposing challenges and obstacles to the researchers community for more than fifty years, a period during which it dictated the design of transistors and devices for each technology node. One of the crucial challenges is the characterization method employed for the quality control of products. Semiconductor industries need reliable characterization techniques which can guarantee real-time quality control with a non-destructive and multiscale approach; in addition to that, the compatibility with manufacturing environments, such as a cleanroom, is undoubtedly a huge benefit for in-line analysis. Tip-Enhanced Raman Spectroscopy (TERS) offers an excellent solution to all these requirements. In addition to providing chemical composition through the integrated Raman spectrometer, TERS leverages the high lateral resolution of the coupled Atomic Force Microscope, enabling chemical and morphological characterization of samples down to the nanometer scale. This work proposes a TERS analysis performed with a TiN-coated probe, which is engineered to operate in cleanrooms while guaranteeing remarkable signal-enhancing performances. The testbed of the technique is a strained-silicon based device, a very diffused technology for innovative CMOS architectures designed to enhance the carriers' mobility in a MOSFET channel depending on the strain imposed. The sample consists of a very thin epitaxial $Si_{1-x}Ge_x$ layer grown on a bulk silicon with various geometrical patterns, where the presence of Germanium imposes the deformation in the silicon crystal lattice. TERS provide both the detection and the magnitude of strain despite the penetration depth of the laser employed. This study is a result of the activities carried out in the framework of the European Union founded project CHALLENGES – real-time nano-CHAracterization reLatEd techNoloGiES – included in the Horizon2020 program.