Sub-nanometer mapping of strain-induced band structure variations in semiconductor devices

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Germanium and silicon-based devices for quantum computing are experiencing a huge rise in popularity over the last few years. They have proven to be magnificent candidates for efficient qubit generation, and are flexible enough to hold different quantum computing paradigms. Based on the morphology and dimensionality of the devices they may act as either spin qubits or (topological) superconducting qubits. For this purpose, heterostructures contacting combinations of pure Ge, pure Si, and alloyed SiGe with varying Si/Ge ratios are successful candidates towards the obtention of qubits [1].

Interestingly, the low effective mass and the electrically tuneable g factors that are key for the qubit performance closely correlate with the strained interface that rules the energy splitting. This constitutes an interesting materials science problem that is worth tackling at the high spatial resolutions the transmission electron microscope can offer, in search of local effects. Therefore, in the present contribution we present a new methodology that can sub-nanometrically map the band structure of semiconductor devices.

The proposed new methodology is based on the correlation of high-resolution low-loss electron energy loss spectroscopy (EELS) and strain mapping to link the accumulations of strain with bandgap shifts [2]. Importantly, we ensure the obtained results are physically meaningful by removing and cleaning the parasitic signals that can arise when studying the low-loss spectral regime (i.e., Cherenkov radiation). The original methodology was developed and applied to an optoelectronic device based on a planar ZnSe/ZnTe core-shell heterojunction, although preliminary results will be shown on quantum devices, more specifically Ge/SiGe quantum wells for holding spin qubits and Ge/Si nanowires aiming towards topological quantum computing.

References

[1] Jirovec, D. et al. *Nature Materials*, (2021) doi.org/10.1038/s41563-021-01022-2
[2] Martí-sánchez, S. et al, Nat. Commun. 13, 4089 (2022).

Figures

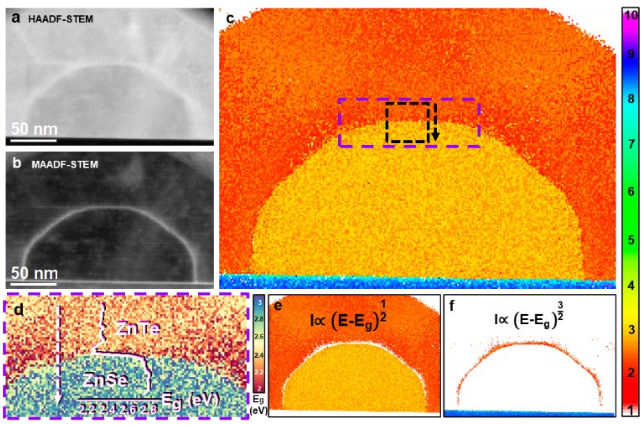

Figure 1: Bandgap maps obtained from applying the proposed methodology to a ZnSe/ZnTe nanowire.