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Simultaneous DualEELS and EDS Analysis Across the Ohmic Contact Region in FinFET Electronic Devices – Exploring the Effects of Electron Beam Damage

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Over last decade, we have witnessed a tremendous improvement in the microelectronic industry. The 14nm node has been reached and devices with such dimensions are being manufactured. This latest generation of electronic devices that show small dimensions with unprecedented low power consumption and high electrical properties can be only possible as the result of the implementation of the FinFET technology. FinFET devices are 3d structures where the conducting channel is wrapped by thin a silicon fin, the gate that forms the body of the device. This geometry ensures a much better control of the conducting channel by the gate and as result the amount of leakage current when the device is in off state is greatly reduced. This leads to the reduction of the power consumption making the whole electronic device much more efficient. For the fabrication of FinFET devices with good electrical performance, it is very important to overcome some design first and then manufacturing challenges. One of the most challenging areas in a FinFET device is the ohmic contacts region. Here, small changes in the chemistry and the morphology at the sub nanometer level strongly influence the electrical properties and performance of the entire device.

Here we show an approach where the simultaneous high-speed acquisition of EELS and EDS spectra allows the possibility to carry out a full compositional and chemical characterization of the SiGe / TiN / W ohmic contact stack region. To achieve efficient fast joint EELS / EDS data acquisition, we have linked the STEM scan system with the EELS and EDS detectors via a single clock mastered off the EELS detector to ensure all the systems are in exact synchrony. To ensure data fidelity, the native detector applications are used to acquire the data into buffers and the data is transferred to the final application (in this case DigitalMicrograph) in blocks while the CPU is idle.

Data were acquired at Precision TEM, Santa Clara, CA, USA using a Tecnai FEI Osiris STEM operating at 200 kV and equipped with a fully upgraded Gatan Enfinium as EELS spectrometer and a large area solid angle EDS system that uses the FEI Chemistem technology that employs 4 SDD detectors fitted around the TEM specimen to increase the X-rays collection efficiency. The EELS chemical analysis at sub-nanometer resolution was carried out with the spectrometer set up in DualEELS mode where the low-loss (0 eV to 200 eV) and core-loss (380 eV – 580 eV). EELS spectra were acquired nearly simultaneously with 10 µs transition time between exposures. The low-loss spectrum provides an accurate energy reference allowing absolute chemical shift measurements. The spectrometer was set up for moderate energy resolution with a dispersion of 0.1 eV / channel yielding a measured energy resolution of 1.5 eV with 200 eV energy range in the spectrum. It is important to mention that un-monochromated X-FEG microscope systems deliver pretty poor energy resolution compared to those equipped with a standard Schotkky FEG or Cold FEG. In order to study the effects of the electron beam current on the SiGe / TiN / W ohmic contact region stack, simultaneous EELS and EDS analysis was carried out using a beam current of 150 pA followed by another one at 850 pA. All the other experimental conditions were kept exactly unchanged between the two different datasets. Figure 1 is the

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ADF STEM survey image. Figure 2 shows an EELS colorized elemental map of Cu, Ge, O, N, Ta, W and Ti. There seems to be some elemental diffusion across the SiGe / TiN / W ohmic stack contact region around the selected area in Figure 1. Figure 3a shows the comparison of the extracted EELS spectra of the N K-edge at 401 eV from the selected region in Figure 1 with the beam current of 150 pA and 850 pA respectively. There is a clear difference in the π* pre-peak that appears to be much stronger and more defined at higher beam current. Figure 3b shows the EELS spectrum of the N K-edge extracted from a crystalline TiN standard sample. It is quite striking to notice that the shape of the N K-edge at 850 pA is very similar to that extracted from the crystalline TiN standard sample. The π* pre-peak in the spectrum extracted at 850 pA appears to be split by 2 eV just like that shown in the case of the TiN crystal standard sample. This split is caused by the excitation of an N 1s electron in unoccupied t_{2g} and e_g orbitals formed by the hybridization of N 2p and Ti 3d electrons. There is strong evidence that the high electron beam flux used for the acquisition of the dataset at 850 pA clearly changes the chemistry and morphology across the ohmic contact region. In this paper, we will describe in details the damage effects of the SiGe / TiN / W ohmic contact stack region as a result of the exposure under the electron beam.

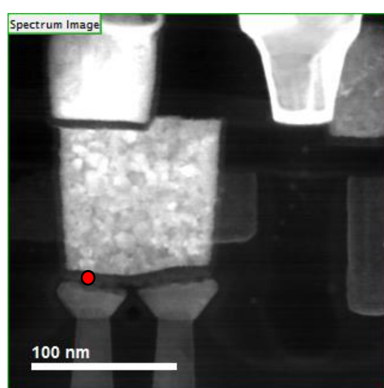


Figure 1. ADF STEM survey image. The green area is the region where the EELS and EDS data were extracted for the compositional analysis. The red mark is the area where the spectra in Figure 3 are extracted.

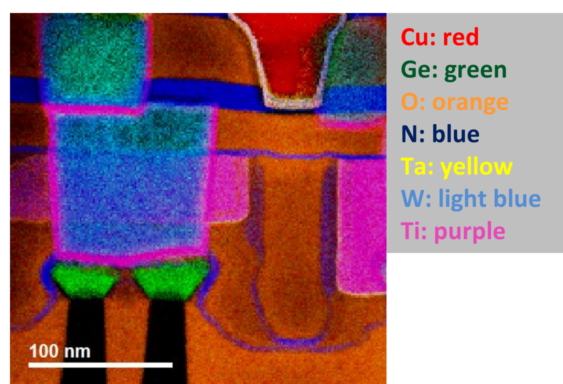
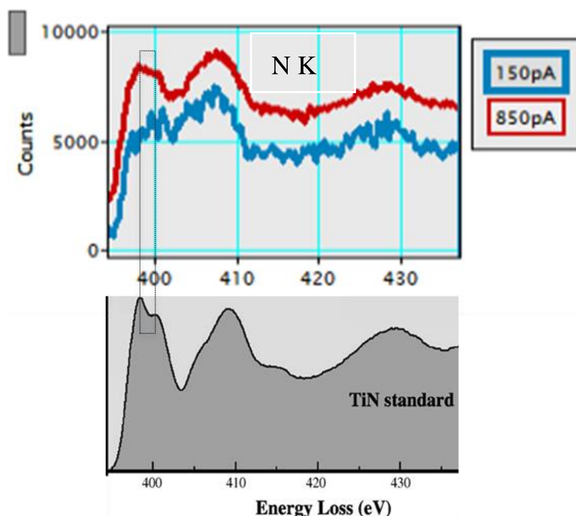


Figure 2. EELS color maps of Ti L at 456 eV in purple, W M at 1809 eV in light blue, N K at 401 eV in blue, Ta M at 1735 eV in yellow, O K at 532 eV in orange, Ge L at 1217 eV in green and Cu L at 931 eV in red.



Figures 3. a,b: a) EELS spectra of the N K-edge extracted from the selected region in Figure 1 in the case of the electron beam current of 150 pA and 850 pA. Strong differences can be observed between the two spectra caused by the high electron dose employed in the case of the acquisition carried out with 850 pA of electron beam current; b) EELS spectrum extracted from a crystalline TiN standard sample. Figure from: O. Lichtenberger et al. / Materials Chemistry and Physics 81 (2003) 195-201

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