Quantitative characterization of buried $B_xC_y$ nanolayers by complementary methodologies – a round-robin study

Burkhard Beckhoff$^1$, Beatrix Pollakowski$^1$, Rainer Unterumsberger$^1$, Spyros Ladas$^2$, Labrini Sygellou$^2$, Annemarie Schroeder-Heber$^3$, Andreas Nutsch$^3$, Salvatore Gennaro$^4$, Damiano Giubertoni$^4$ and Lia Vanzetti$^4$

1. Physikalisch-Technische Bundesanstalt (PTB), Abbestr. 2-12, 10587 Berlin, Germany
2. Surface Science Laboratory (SSL), University of Patras, 265 00 Patras, Greece
3. Fraunhofer Institute for Integrated Systems and Device Technology (IISB), 91058 Erlangen, Germany
4. Fondazione Bruno Kessler (FBK), Via Sommarive 18, 38123 Povo Trento, Italy

Improved metrology and characterization techniques for nano- and micro-electronics are required by both novel materials and shrinking dimensions. Providing complementary analytical methodologies [1] through cross-comparison, round-robin, and benchmarking was an objective of the European Integrated Activity of Excellence and Networking for Nano- and Micro-Electronics Analysis (ANNA). A corresponding ANNA round Robin addressed the quantitative characterization of buried nanolayers consisting of the light elements B and C. A set of different samples was to be analyzed by complementary methodologies. The sample structure was $SiO_2$ cap layer / $t$ nm thick $B_xC_y$ / Ti, Ni or $SiO_2$ on a Si wafer where the buried layer thickness $t$ ranged between 1 nm and 50 nm.

XRF and GIXRF investigations were performed with synchrotron radiation and calibrated instrumentation [2] in the PTB laboratory at BESSY II. The elemental sensitivity and penetration depth could be varied. XRF analytical results for B are well in line with the nominal layer values. GIXRF results (fig.) depend on the x-ray standing wave field. NEXFAS investigations were performed for the speciation of the buried layers. Samples with overlayers thinner than 10nm, were studied at SSL by standard XPS. Binding energies were referenced to the main C1s component at 284.8 eV. Buried $B_xC_y$ gave a C1s component near 282 eV (fig.) and a single B1s peak near 188.0 eV. Using data from the substrate, the $Si/SiO_2$ cap layer and $B_xC_y$, empirical sensitivity factors and a SSL procedure based on ISO18118(2004):E [3], atomic composition and layer thicknesses were sequentially determined, along with the respective estimated uncertainty. Non-destructive depth profiling is possible with angle resolved XPS (ARXPS) which was employed at IISB without any sample tilt or analyzer turning. The analyzer has a lens system, which collects the electrons from a solid angle of 60° being displayed on a detector array so that a specific angle interval can be related to particular detector channels. B4C depth information for a buried layer was obtained from modeling (fig.). At FBK, XPS investigations were replicated to match SSL findings, and SIMS (by magnetic sector and Time of Flight) was applied to assess the thickness of the BxCy films and to attempt a relative quantification of the stoichiometry of the probed layers. The results show a good agreement on the thickness evaluated using the two different techniques, whilst a clear assessment of the exact film composition resulted to be challenging.

Figures: GIXRF scan          XPS angular probe             XPS depth profiling      Fitted XP spectrum in the C1s region