SiC/SiO₂ Interfacial Compositions by EFTEM and Spectrum Imaging

J. Bentley,¹ K.-C. Chang,² Y. Cao² and L.M. Porter²

¹Metals and Ceramics Division, Oak Ridge National Laboratory, PO Box 2008, Oak Ridge, TN 37831-6064, USA
²Dept. of Mat. Sci. & Eng., Carnegie Mellon University, Pittsburgh, PA 15213, USA

For a long time SiC has held promise as a material for advanced microelectronic devices, not least because among its attractive properties, just as for Si, SiC can be easily oxidized to form insulating SiO₂ films. However, the electronic properties of the SiC/SiO₂ interface are inferior. This is believed to be due in part to compositional inhomogeneities resulting from oxidation. We have performed extensive measurements of interfacial composition at the 1-nm scale on a large number of materials subjected to a wide range of processing conditions (variables such as 6H or 4H polytypes, C- or Si-terminated [0001] surfaces, wet or dry oxidation, oxidation temperature, reoxidation, and post-oxidation annealing in NO) [1-4]. Monolayer levels of inhomogeneously distributed excess carbon are present at the interface for certain processing conditions and SiC crystallography. Following post-oxidation annealing in NO, sub-monolayer levels of interfacial N (≤1.0 ± 0.1 x 10¹⁵ cm⁻²) have been measured. Obtaining significant results such as these required special attention to data acquisition and processing. For EFTEM elemental mapping, besides optimizing acquisition parameters such as energy-window (slit) width and position, collection angle, pixel size, incident intensity, and exposure time, image alignment among the different core-loss series for a given area was critical for reliable measurements of interfacial composition. Diffraction contrast in protective Cr or poly-Si layers deposited on the typically 50-nm thick oxide was essential for image alignment. However, shrinkage of the oxide due to electron beam damage during the inevitable prolonged exposures to obtain Si-L, C-K, O-K and low-loss series resulted in movement of the Cr or poly-Si layers with respect to the SiC/SiO₂ interface and compromised simple drift correction. In extracting N core-loss intensities from spectrum lines acquired in STEM mode, the most critical step by far was reliable background subtraction. Background shapes near the N edge are significantly different for SiC and SiO₂ regions, mainly due to the presence/absence of the C-K edge. Log-polynomial fitting [5] and modified variants of that scheme were among the procedures used for background fitting [6].

References
[6] Research at the ORNL SHaRE User Facility sponsored by the Division of Materials Sciences and Engineering, Office of Basic Energy Sciences, U.S. Department of Energy, under contract DE-AC05-00OR22725 with UT-Battelle, LLC. Financial support from DARPA via Contract No. N00014-02-1-0628 is gratefully acknowledged. The authors thank L.C. Feldman and S. Dahr (Vanderbilt Univ.), C.-Y. Lu and J. Cooper, Jr. (Purdue Univ.) and J.R. Williams (Auburn Univ.), for materials processing and continuing collaborations.