SIMS Correction And Depth Profiling Of Ion Implantations Using Grazing Incidence XRF

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PTB
X-Ray and IR spectroscopy

Introduction

To determine implantation depth profiles, GIXRF uses the in depth changes of the X-ray standing wave field intensity (see fig. 1) dependent on the angle between the sample surface and the primary beam. The implantation depth profile is convolved with this intensity distribution and relevant geometrical and fundamental parameters which results in a specific fluorescence curve when a GIXRF measurement is performed. This characteristic curve is then calculated and fitted by variation of an assumed depth distribution to derive the implant distribution and dose. A detailed description of the presented method can be found in reference [1].

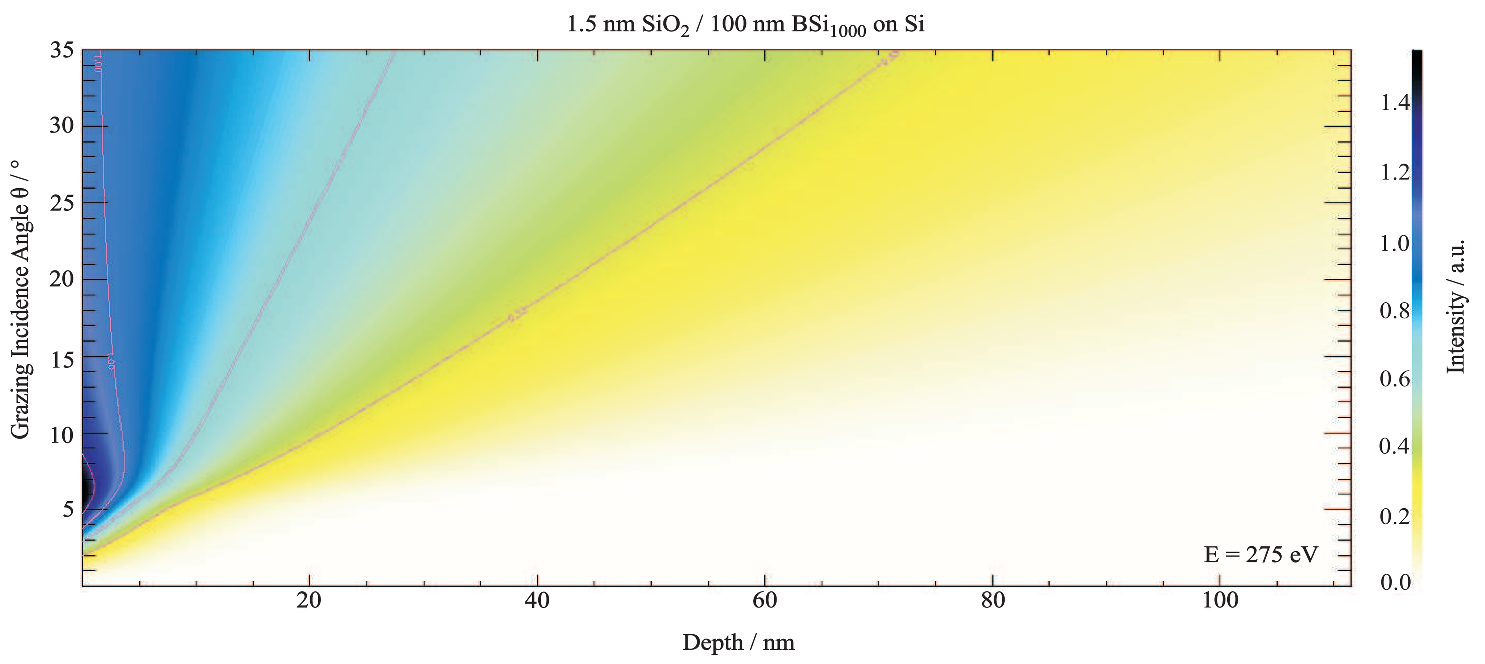

FIGURE 1. IMD [2] calculation of the intensity distribution as a function of depth and incident

The technique is capable of determining both total retained doses and elemental depth profiles of ion implantations directly. For both ultra shallow and deeper implants, this yields reasonable results (see figs. 2-5) with good agreement in comparisons to other methods [1,3]. It is a very flexible method with regard to both the implant element and the implanted matrix. Due to the very high surface sensitivity of the method, it is very suitable for USJ characterization. However, a mathematical model for the implant distribution is necessary limiting the applicability to non-annealed implants.

By replacing the mathematical function for the elemental depth profile with, e.g. a SIMS measurement, the GIXRF technique can be used to either qualify different SIMS approaches on an identical sample, calibrate a SIMS measurement when no appropriate standard is available or even correct for the profile shape manipulating effects in the surface near parts.

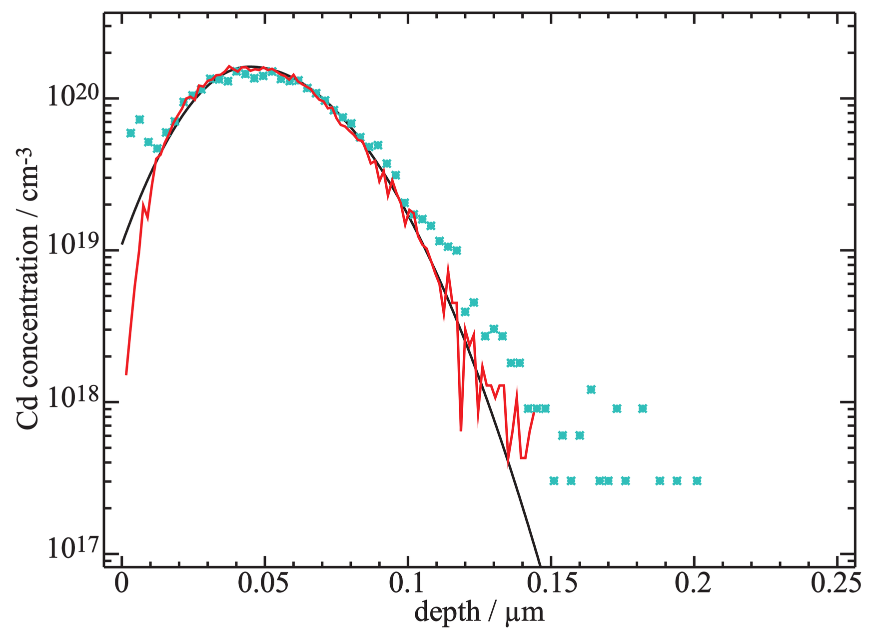

FIGURE 2. Determined depth profile on a 150 keV Cd implant into GaAs with a nominal dose of 10^{15} cm^{-2} in comparison to SRIM calculations and SIMS.

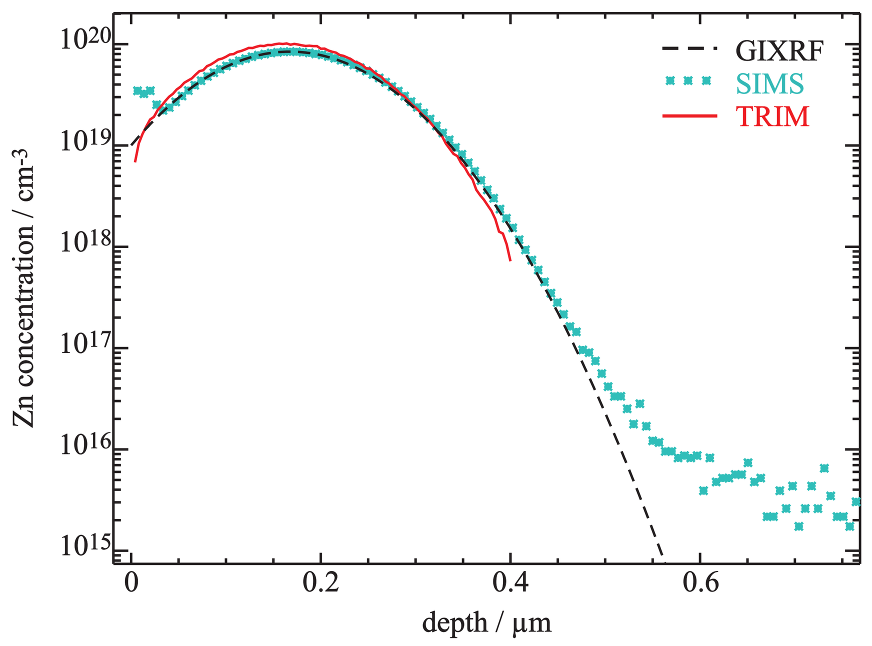

FIGURE 3. Determined depth profile on a 300 keV Zn implant into InP with a nominal dose of $2x10^{15}$ cm^{-2} in comparison to SRIM calculations and SIMS.

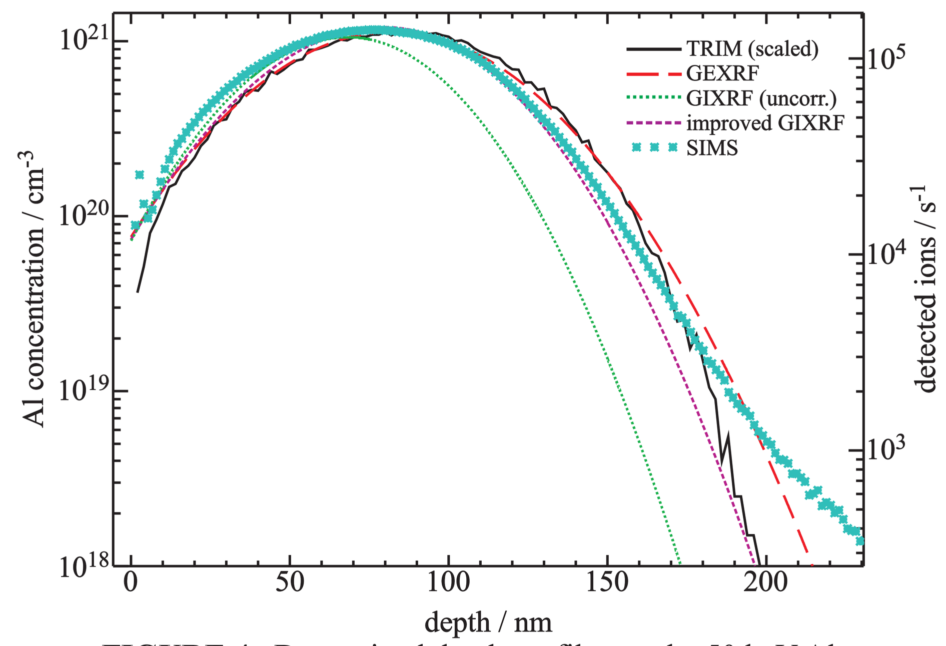

FIGURE 4. Determined depth profiles on the 50 keV Al implanted sample using XRR and GIXRF in comparison to SRIM calculations, GEXRF results and SIMS [4].

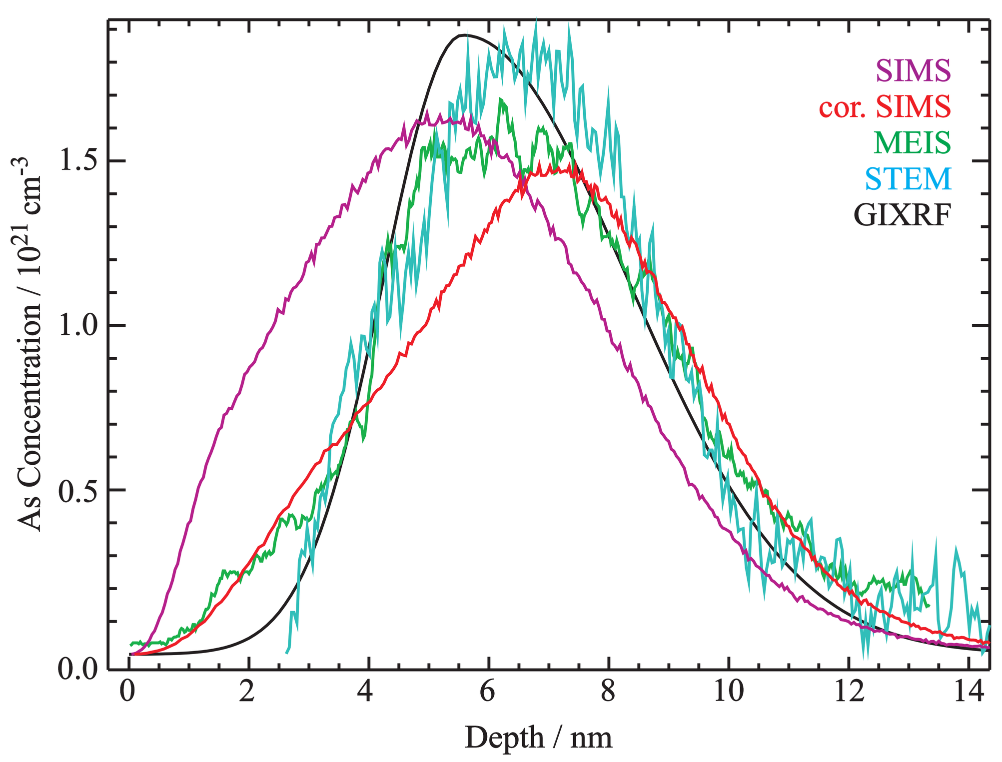

FIGURE 5. Comparison of depth profiles determined with different techniques on silicon wafer with a 3 keV As implant, see ref [1] for details. The SIMS profile has been corrected by GIXRF leading to an improved agreement with the other methods.

The method is very well suited for correcting SIMS measurements, where the surface near parts of the depth profile may be manipulated by different effects. Since these effects falsify the profile in depth ranges close to the sample surface, where GIXRF is most sensitive, such a combination of both methods is very fruitful.

A depth scale correction adopted from ref. [4] was applied to take into account the sputter rate variations close to the surface. To further improve the agreement between GIXRF measurement and SIMS based calculation, a correction function to modify the shape of the depth profile close to the surface was introduced here. Both correction functions are derived by fitting the measured GIXRF angular fluorescence curve. In the upper left part of fig. 8, the two correction functions for a different SIMS profile are shown.

A 3 keV As implant into Si was characterized with various methods, showing good agreement (see fig. 5). The varying SIMS was corrected using the GIXRF approach leading to an improved agreement.

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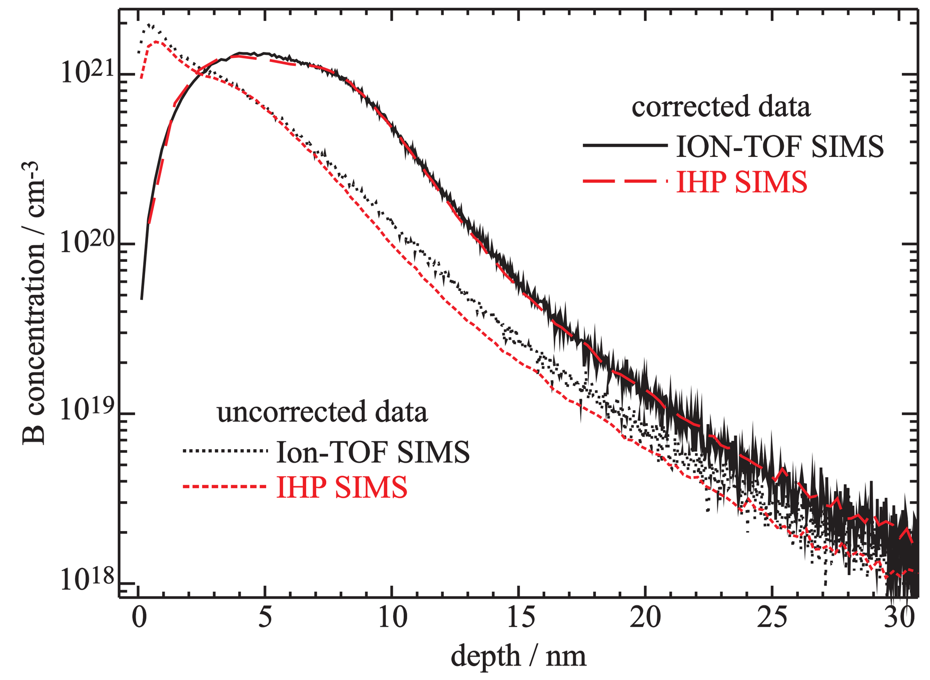

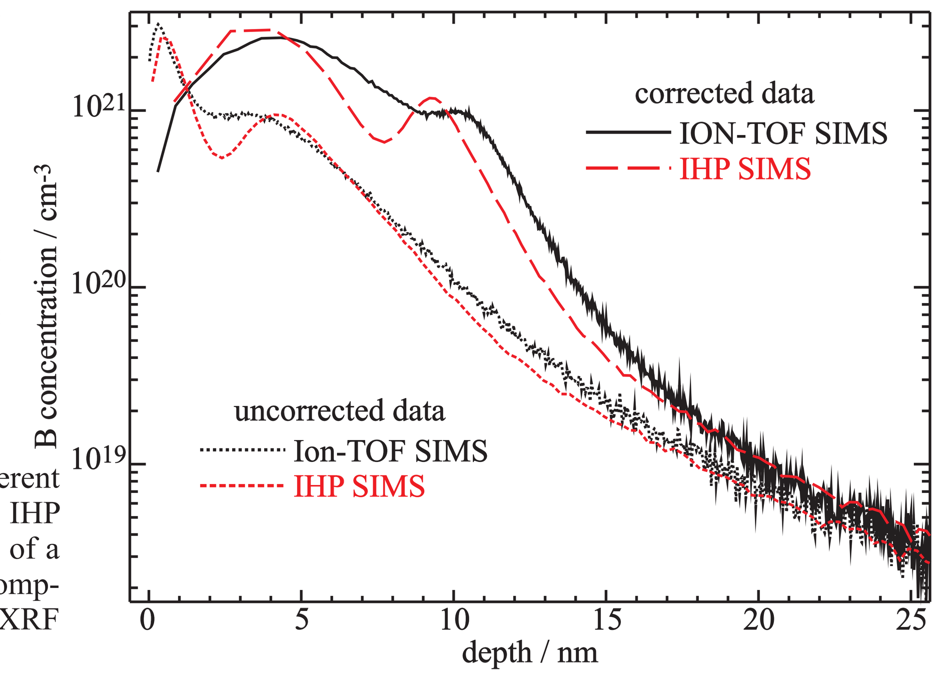

FIGURE 6 (top). Two different SIMS profiles (measured by IHP Microelectronics and Ion-TOF) of a 0.75 keV B implant into Si in comparison to the respective GIXRF corrected depth profile.
FIGURE 7 (bottom). Two different SIMS profiles as well as their corrections of a an identical implant, which was annealed in N_2 at 800°C for 10 s.

Two SIMS measurements (measured by IHP Microelectronics and Ion-TOF) of a both an as implanted and an annealed 0.75 keV B implant into silicon with a dose of 10^{15} cm^{-2} were corrected and compared. The corrected SIMS profiles of the non annealed sample are shown in Fig. 6 together with the measured profiles. In Fig. 7, the results of the annealed (in N_2 at 800°C for 10 s) are shown.

On the as implanted sample, the deviations between the SIMS results at both the surface and also the different drop-off are being drastically reduced by the GIXRF correction and the profiles are shifted. Both SIMS curves are leading to an identical result of the correction algorithm.

The results on the annealed sample show similar behavior, but the agreement between the corrected SIMS profiles is worse. This is presumably caused by the XSW field calculation. By applying X-ray reflectivity in parallel, the XSW calculation can be greatly improved. This should lead to better results on annealed implants.

Fig. 8 shows the Comparison of two different SIMS approaches (500 eV O_2^+ with either UHV conditions or O_2 flooding) for a 3 keV BF_2^+ ion implant into silicon. The two SIMS profiles show significant deviations, which are drastically reduced by the GIXRF correction algorithm. In addition, both the determined correction functions as well as the calculated GIXRF angular fluorescence profiles are shown.

References

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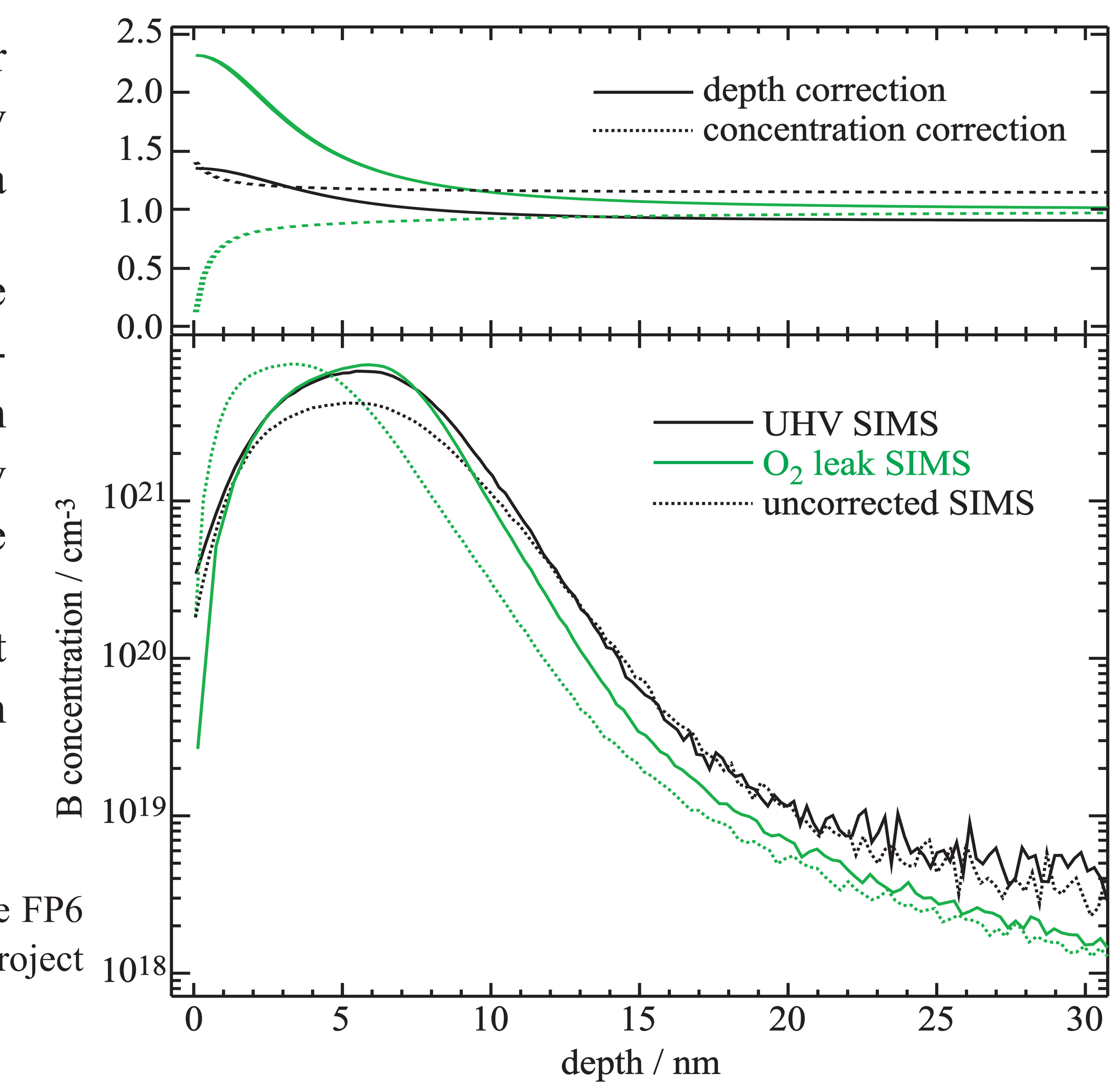
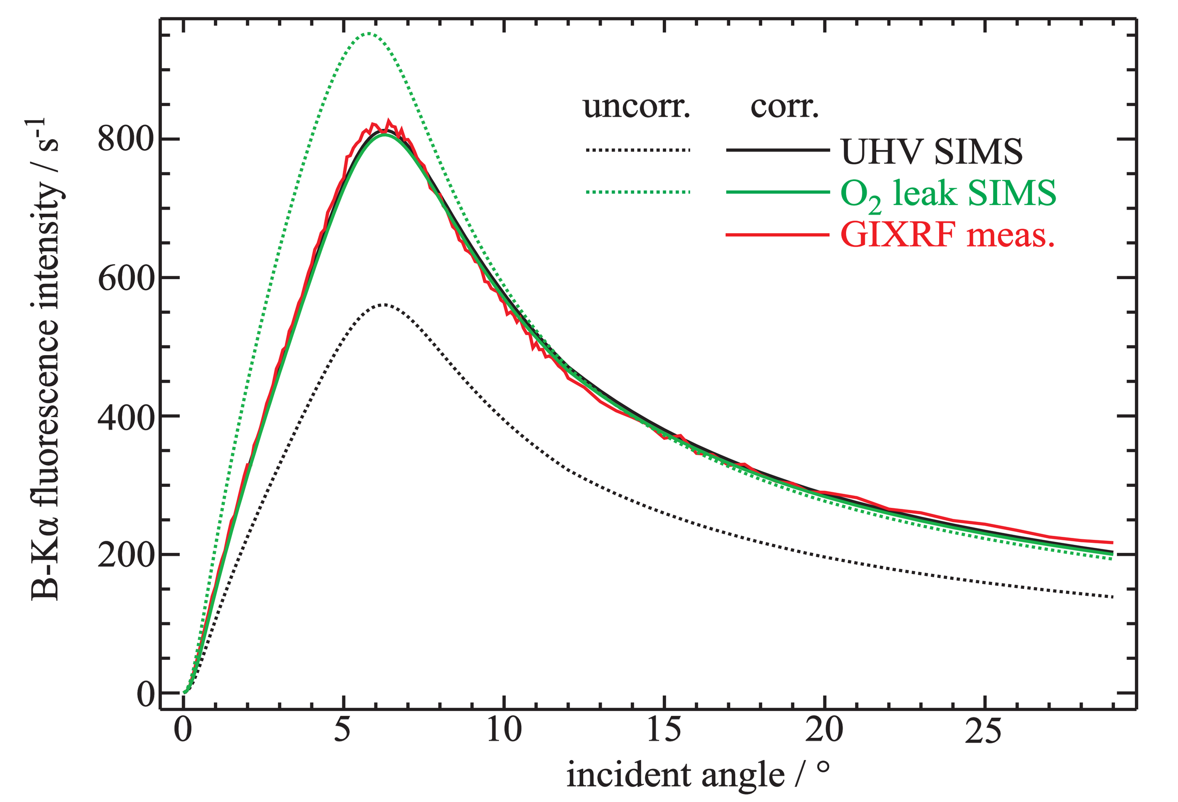


FIGURE 8. Lower left: Comparison of two different SIMS approaches (500 eV O_2^+ with either UHV conditions or O_2 flooding) for a 3 keV BF_2^+ ion implant into silicon (dotted lines) in comparison to the GIXRF corrected SIMS profiles (solid lines).
Upper left: The corresponding correction functions for both the depth axis and the concentration correction (dotted lines).
Lower right: Calculated angular fluorescence curves for the two SIMS profiles (dotted lines) in comparison to the corrected SIMS and the measured GIXRF.



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