Bulk Concentration of Atmospheric Species:

Achieving Best Detection Limits using the D-SIMS Raster-Change Method

Due to its high sensitivity, ability for depth profiling at high throughput, and good detection limits, dynamic secondary ion mass spectrometry (D-SIMS) plays an important role in evaluating the concentration of impurities (H, C, O, etc.) in semiconductor materials. Using the raster-change method, one can further improve the detection limits for atmospheric elements[1].

The D-SIMS Raster-Change Method

Using this method, the net content of a selected atmospheric elements in the sample can be determined, therefore eliminating the instrumental background contribution. Indeed, two separate contributions coexist for atmospheric species:

1) the instrumental background signal - dependent of the analysis area - which is held constant when reducing the raster size,
2) the bulk contribution which is proportional to the sputter rate and thus increases when reducing the raster size.

The raster-change method is based on the atomospheric element signal intensity variation when reducing the raster size during the analysis (Figure 1). For instance, for carbon, bulk concentration can be computed using a simple equation:

$$[C] = RSF \times \frac{I(C) - i(C)}{I(Si) - i(Si)}$$

[C] = bulk carbon concentration in the test specimen
RSF = relative sensitivity factor for converting the ion intensity ratio to concentration
*I(C) = secondary ion intensity of carbon using large raster 2*R*
i(C) = secondary ion intensity of carbon using small raster R
*I(Si) = secondary ion intensity of the silicon matrix using large raster 2*R*
i(Si) = secondary ion intensity of the silicon matrix using small raster R.

Results

This method has been applied to bulk analysis of carbon in five silicon samples. A large raster (100 x 100 µm²) was applied during the first ~15 minutes, it was then reduced to 50 x 50 µm², while the collection area for secondary ions remained unchanged. Total analysis time was 30 min per run (three runs / sample). The C concentration data is shown in table 1.

Figure 2 shows the depth profiles obtained on two samples corresponding to the higher and lower measured concentration levels. It should be noted that the smaller the C intensity increase (when switching to the smaller raster), the lower the C bulk concentration as shown in the above equation. Considering that the minimum intensity step that can be measured with confidence for such intensity level is ~3 counts/sec, calculations show that a carbon bulk concentration down to ~1E14 at/cm³ could be measured.

Conclusion

The detection limit for atmospheric species on bulk samples can be significantly improved using the raster-change method. This simple and powerful method can also be applied to implanted samples by performing separate analyses using different raster values.

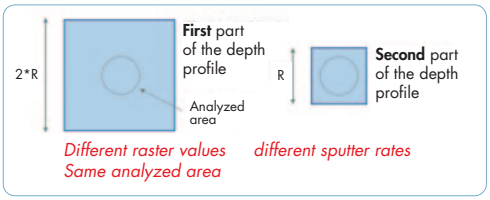


Figure 1: D-SIMS raster-change method.

Table 1: SIMS measurements of carbon concentration levels on five different samples.

Sample	C bulk concentration	
#1	2.74E+15 2.75E+15 2.89E+15	2.8E+15
#2	1.25E+15 1.24E+15 1.12E+15	1.2E+15
#3	7.59E+15 7.81E+15 7.51E+15	7.6E+15
#4	9.20E+15 9.23E+15 8.93E+15	9.1E+15
#5	1.84E+16 1.83E+16 1.85E+16	1.8E+16

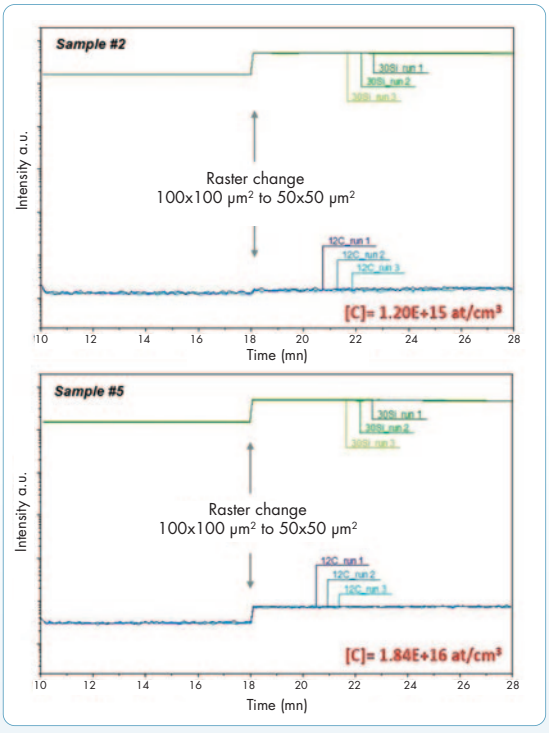
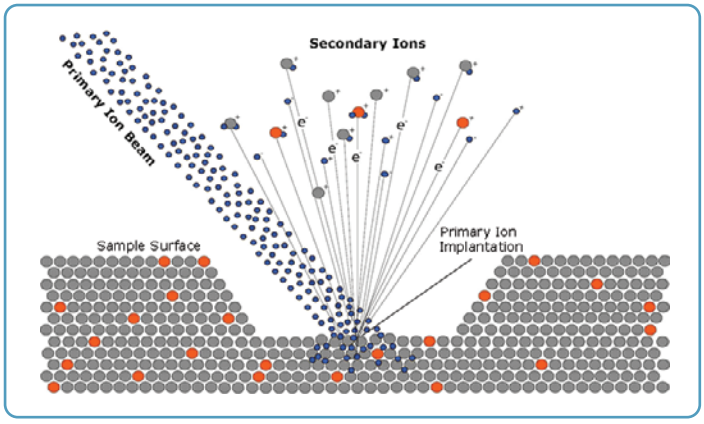


Figure 2: Carbon depth profiles for samples #2 and #5 using the raster-change method.

1. *SEMI 5072A New Standard: Test Method for Simultaneously Measuring O, C, B and P in Solar Silicon Wafers and Feedstock by Secondary Ion Mass Spectrometry.*

The technology behind

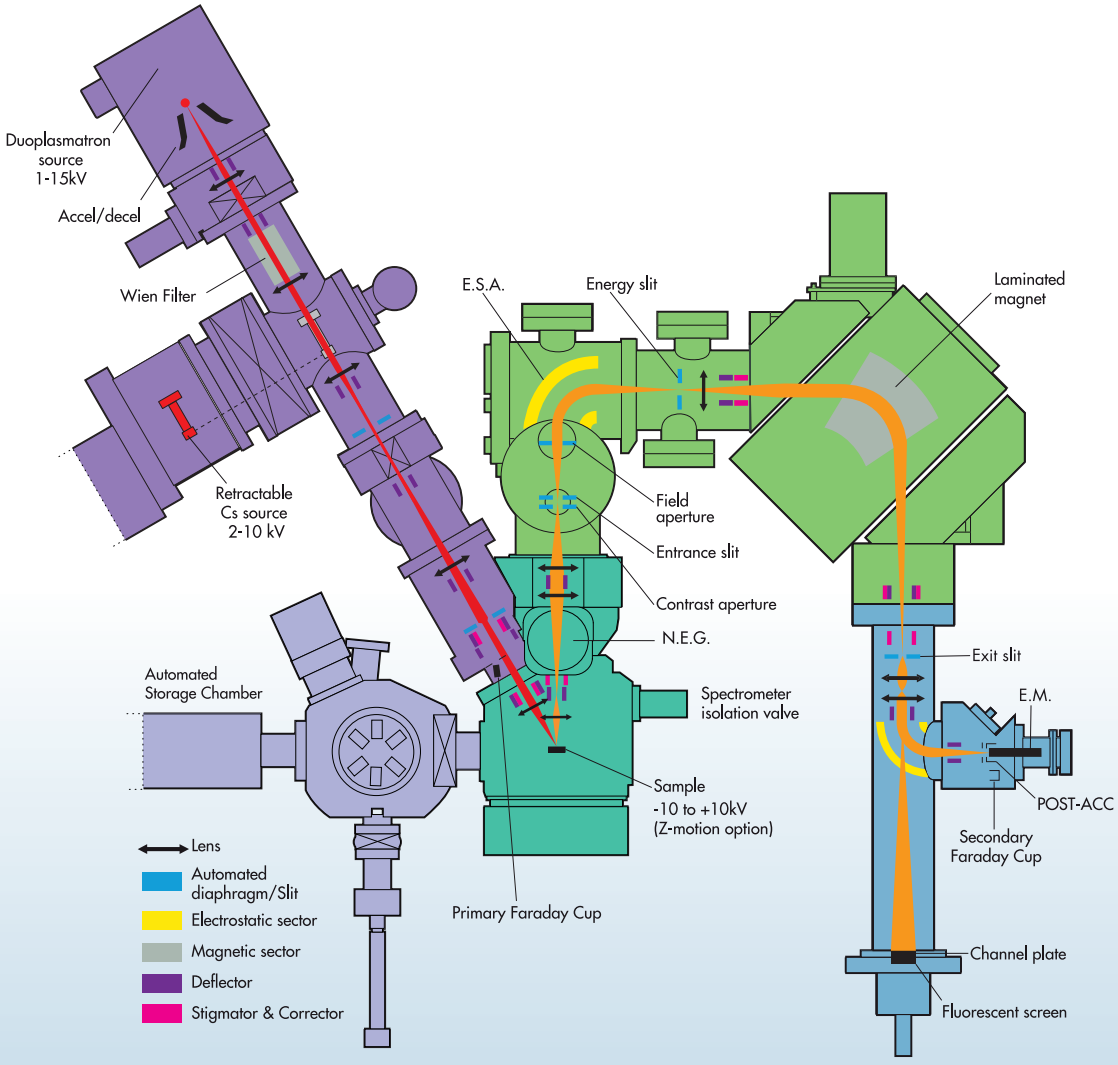


Dynamic SIMS

When a solid sample is sputtered by primary ions of few keV energy, a fraction of the particles emitted from the target is ionized. Secondary Ion Mass Spectrometry consists of analyzing these secondary ions with a mass spectrometer.

The SIMS technique is "destructive" by its nature (sputtering of material). It can be applied to any type of flat, solid material that can be kept under vacuum.

In dynamic SIMS, bulk composition and in-depth distribution of trace elements are investigated with a depth resolution ranging from sub-nm to tens of nm. SIMS is recognized as the most sensitive elemental and isotopic surface analysis technique.



CAMECA IMS 7f-Auto

The IMS 7f-Auto is a versatile SIMS tool offering reference detection sensitivity with high throughput and full automation. Its motorized storage chamber and sample transfer allows the analysis of multiple samples in chained or remote mode.

For more information please visit www.cameca.com/products/sims/ims7f-auto

Reprint 2024. Ref. AP_SIMS-011_raster-change