Improving the carbon detection limit with Secondary Ion Mass Spectrometry (SIMS)

A. Merkulov

Objectives

- ☑ Characterization process target: determining the quantity and position of doping species in the structure, helping to control the fabrication

- ☑ Carbon characterization by SIMS problems statement:
  - Vacuum contamination
  - Surface contamination
  - Carbon mobility

To be addressed →

Vacuum contamination

The vacuum atmosphere contains carbon (gas phase, allotropes)

☑ ○ The vacuum contamination effect can be reduced :

- Plasma cleaner integrated into the SIMS tool
- Continuous energetic sputtering (high removal rate = low detection limit)
- Intelligent background subtraction

To be addressed →

Surface contamination

The sample surface introduced into the analytical chamber contains carbon

- Surrounding analysis area contamination in combination with surface mobility:
  - Background signal due to imperfection of ion focusing optics
  - Mobility is responsible for the segregation effect of carbon sputtering
  - Long tailing of depth profile near the surface

To be addressed

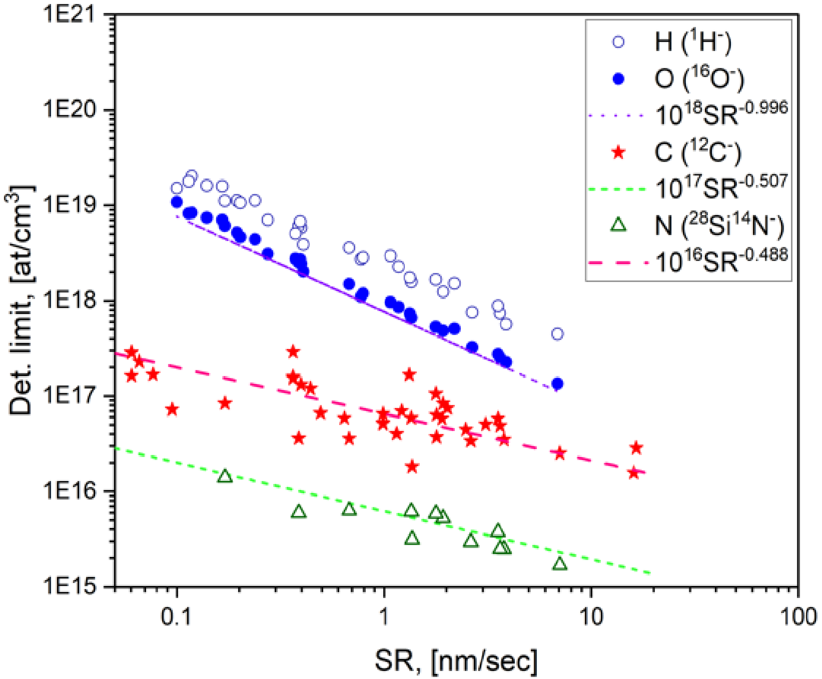
Vacuum contamination

The contamination fraction deposited from the vacuum during the depth profile depends on the removal rate

- Changing removal rate:
  - ☑ To get reasonable detection limit conditions from the background statistics on the removal rate
  - ☑ Background subtraction algorithm based on background statistics on the removal rate

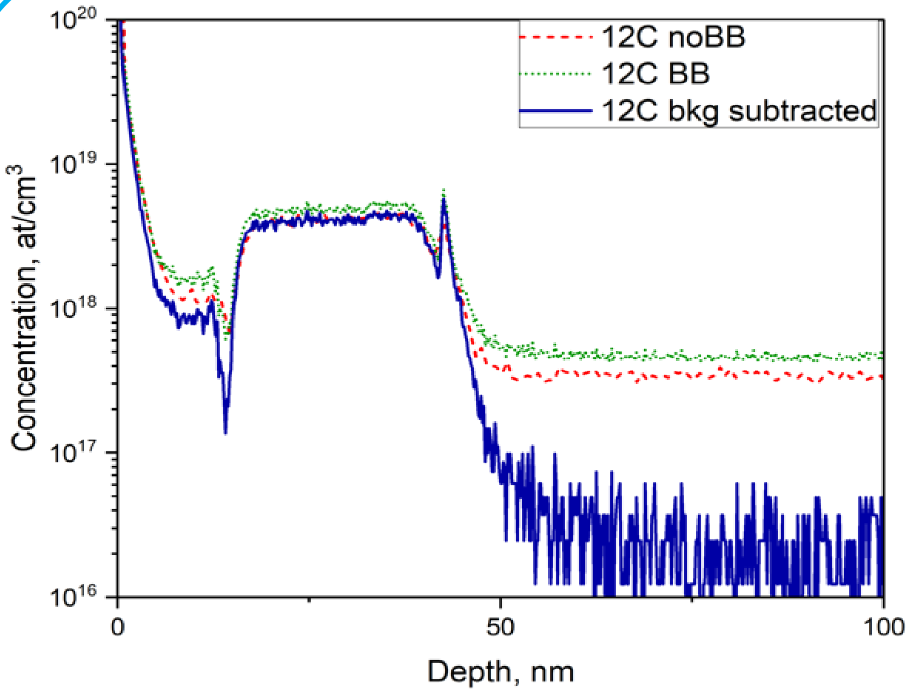
addresses →

Vacuum contamination



- Detection limits tends to depend on inversed sputter rate. Select sputter rate for needed detection limit.
- The Carbon detection limit depends mostly on the environmental contamination, re-sputtering/migration under the ion/electron beam exposure
- There is a Carbon (molecular form) presence in vacuum atmosphere

Vacuum contamination



- The detection limit data statistics can be used for background subtraction

Carbon mobility

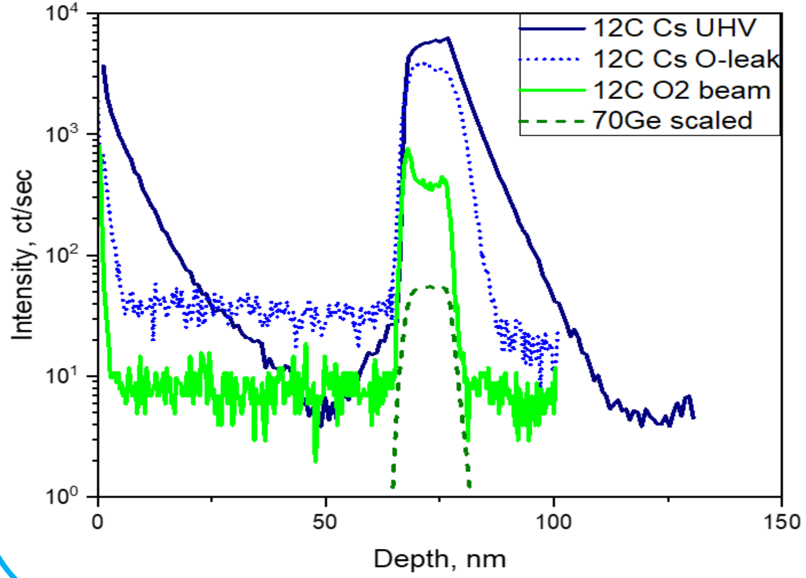
The carbon mobility is addressed by sputtering process adjustment

- SIMS analysis condition selection:
  - Oxygen sputtering reduced the surface mobility by oxidation. Depth profiles close to the real distribution with low sensitivity
  - In case the high sensitivity is required the combination of Cs and O2 beams can be used for the analysis
    Cs bombardment + O2 backfilling
    Cs+O2 bombardment: co-sputtering

addresses

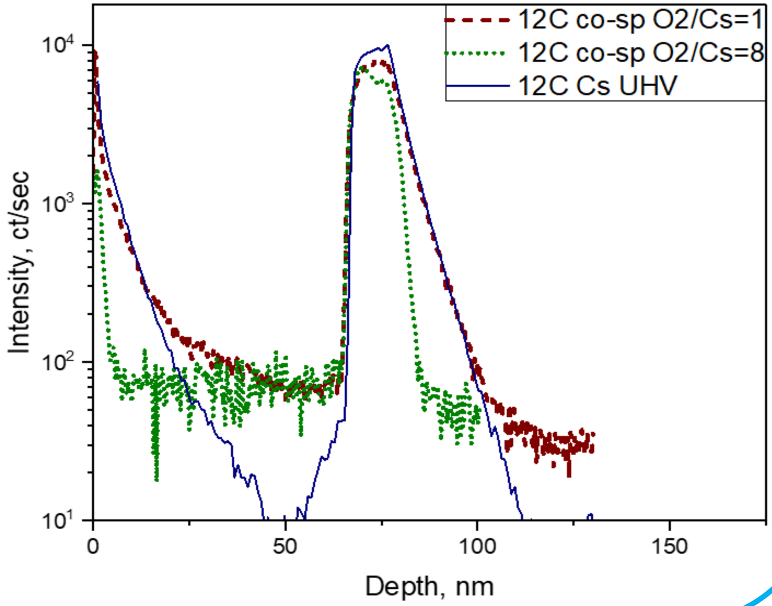
Carbon mobility

- Focused ion beam O2@350eV and Cs@350eV
- The O/Cs arrival rate to reach the O-leak conditions effect must be x8 at least



Carbon mobility

- Focused ion beam O2@90eV is used together with Cs@350eV
- The O/Cs arrival rate to reach the O-leak conditions effect must be x8 at least



Surface contamination

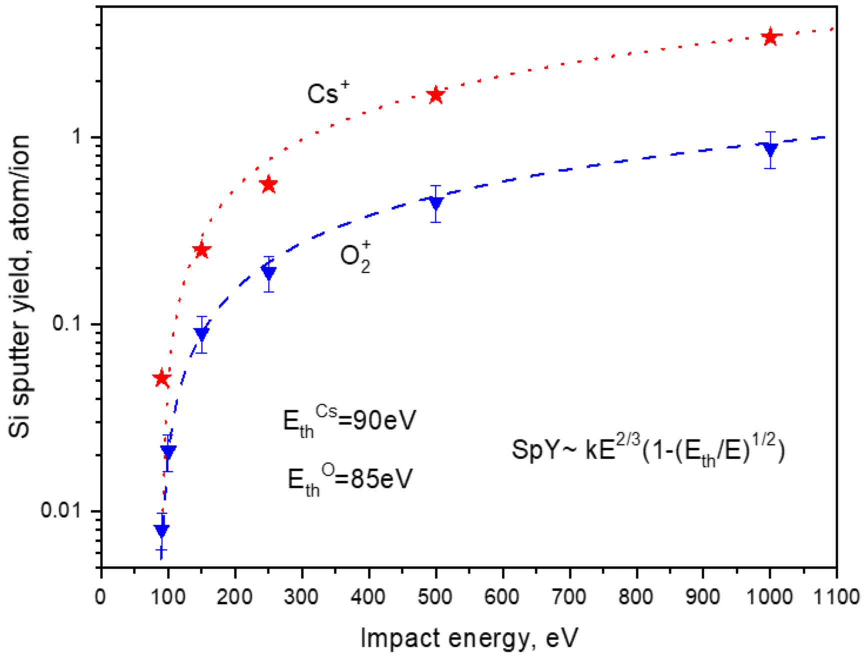
Best approach the surface decontamination by gentle ion cleaning (selective)

- Sputtering ions energy near the sputtering threshold of Si (matrix):
  - Very efficient decontamination with 90eV O2 focused beam (<10minutes)
  - Decontamination with 90eV Ar^+ focused beam (~hour)

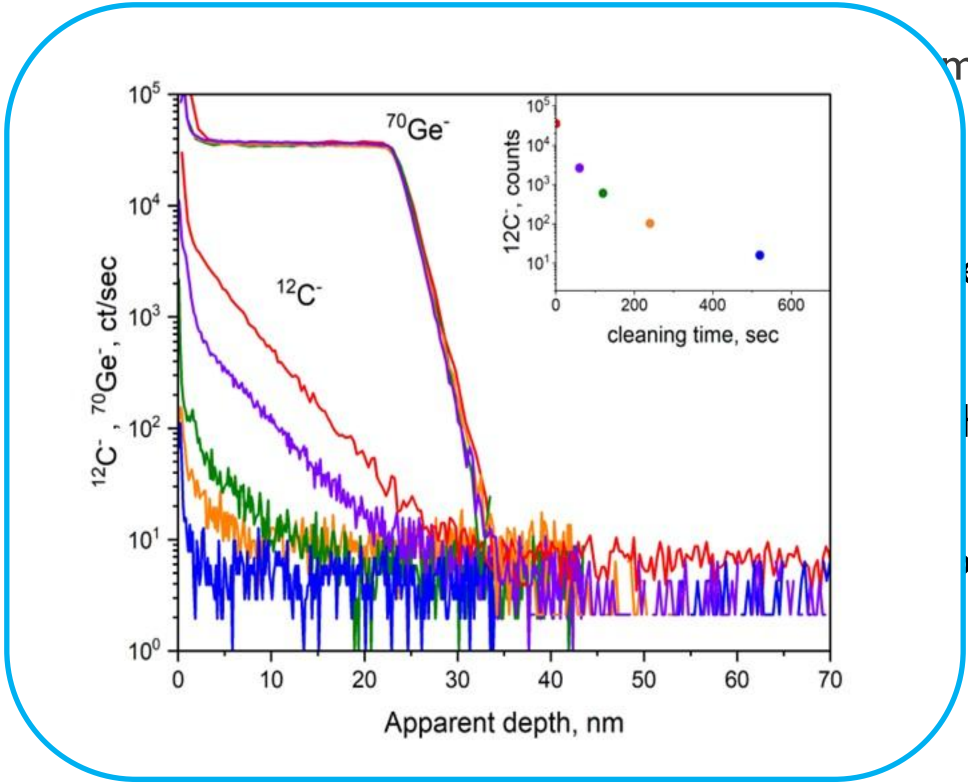
addresses

Surface contamination

- Proposed to provide conditions for surface oxidation by O2 (or O-) ions with energy below or equal sputtering threshold Ei<Eth
- Data on Si partial sputter yield for Cs and O2 in very low impact energy range
- O2 focused beam with 90eV to be used for co-sputtering with Cs (250-500eV range)



Surface contamination



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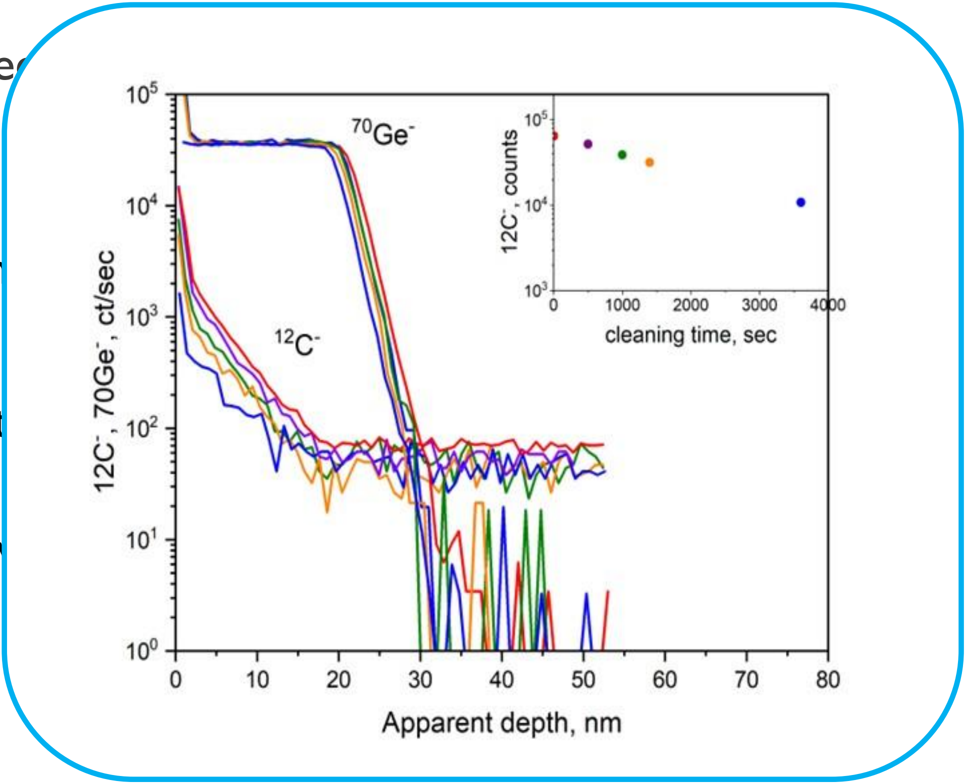

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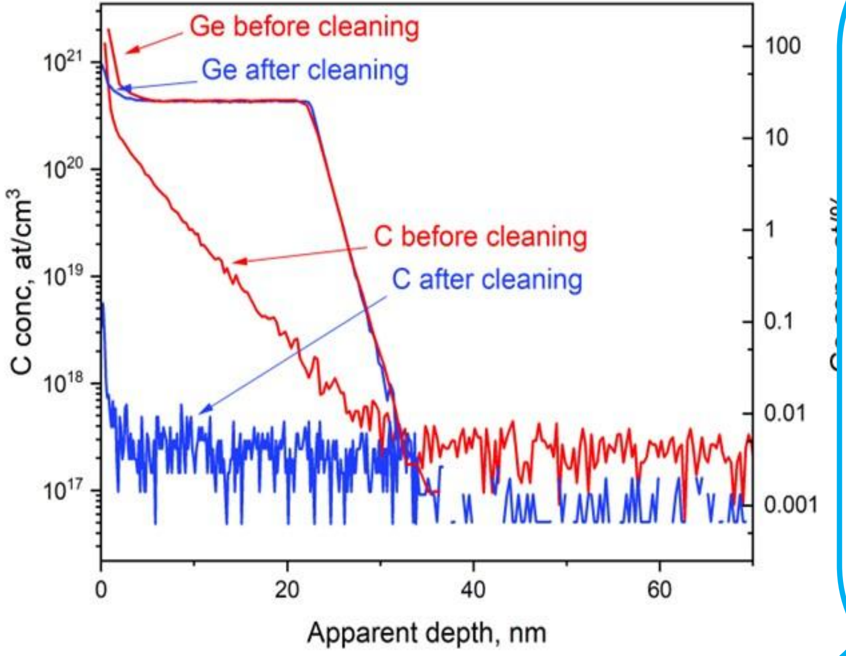
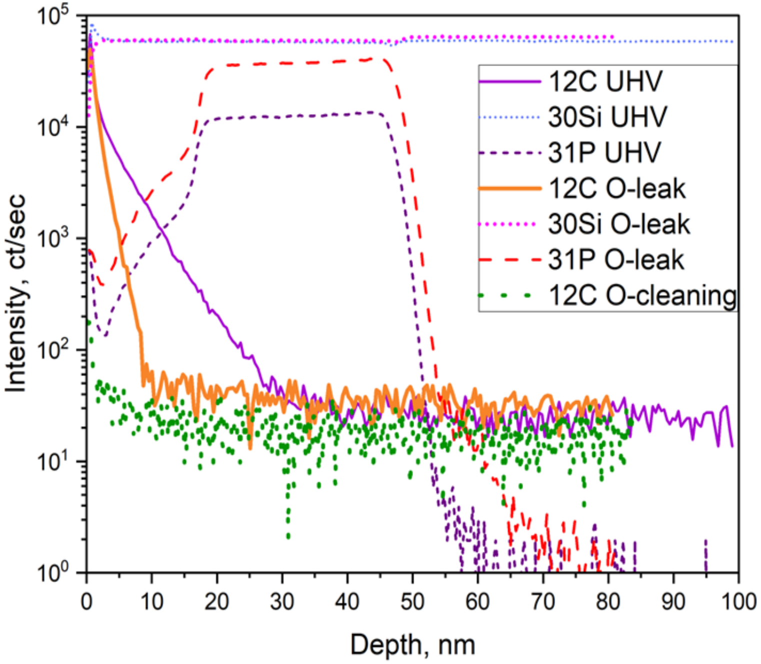




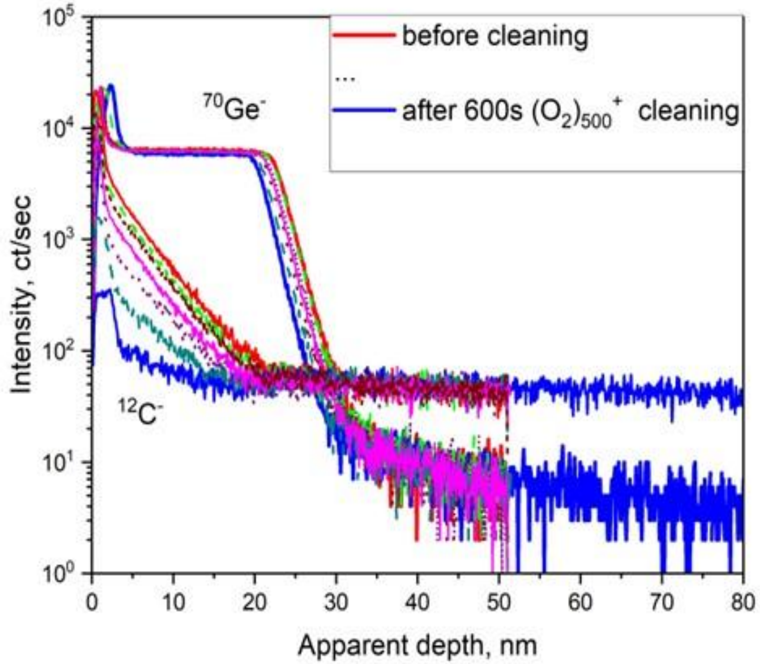
Surface contamination

The surface decontamination by GCIB

- Sputtering atoms energy <5eV :
  - ☑ Very efficient decontamination with 5keV $^{+}O_{1000}$ focused beam (<10minutes)
  - ☑ Decontamination with 2.5keV $^{+}Ar_{1000}$ focused beam (~hour)

addresses →

Surface contamination



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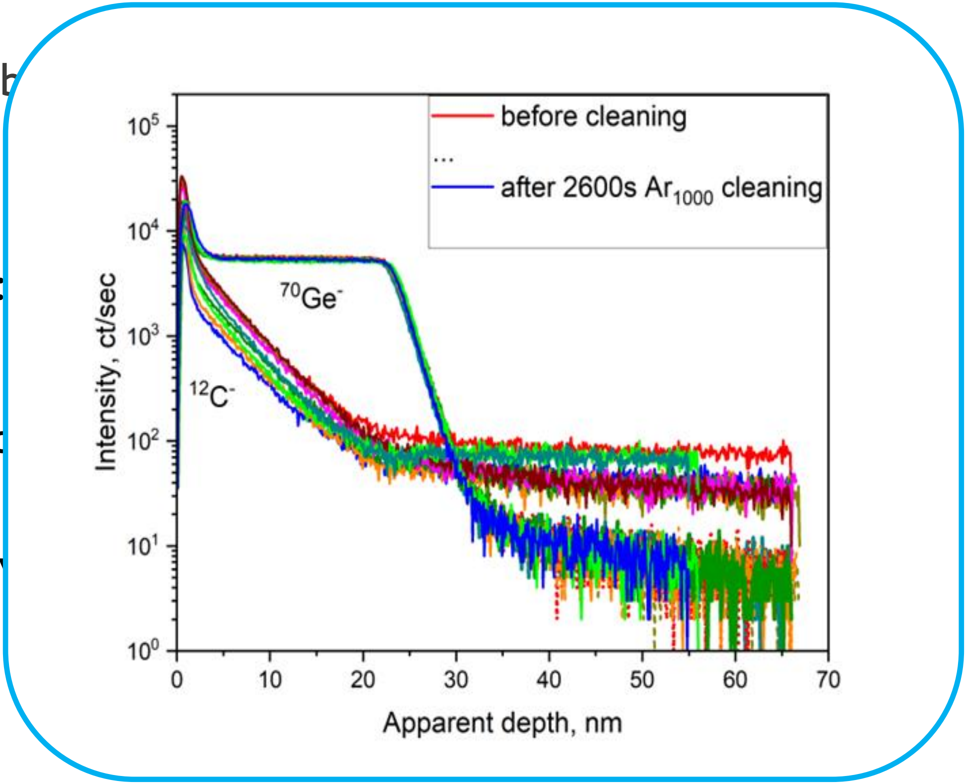


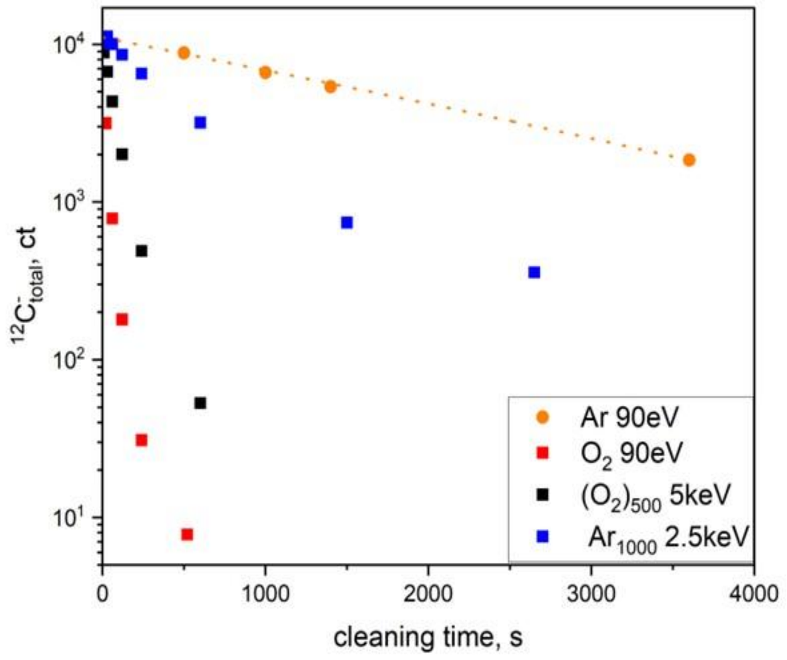
Surface cleaning prior the SIMS analysis

The surface decontamination by gentle ion cleaning comparable to the O-radicals plasma cleaner

- ☑ Very efficient decontamination with Oxygen ($O2^{+}$ or O^{1000})
- Decontamination with Ar^{+}/ Ar^{1000} is practically used elsewhere, but less effective compared to Oxygen for Carbon
- ☑ Not a big difference between single ion and gas cluster cleaning when atomic fluence is taken in the integration

addresses →

Surface cleaning prior the SIMS analysis



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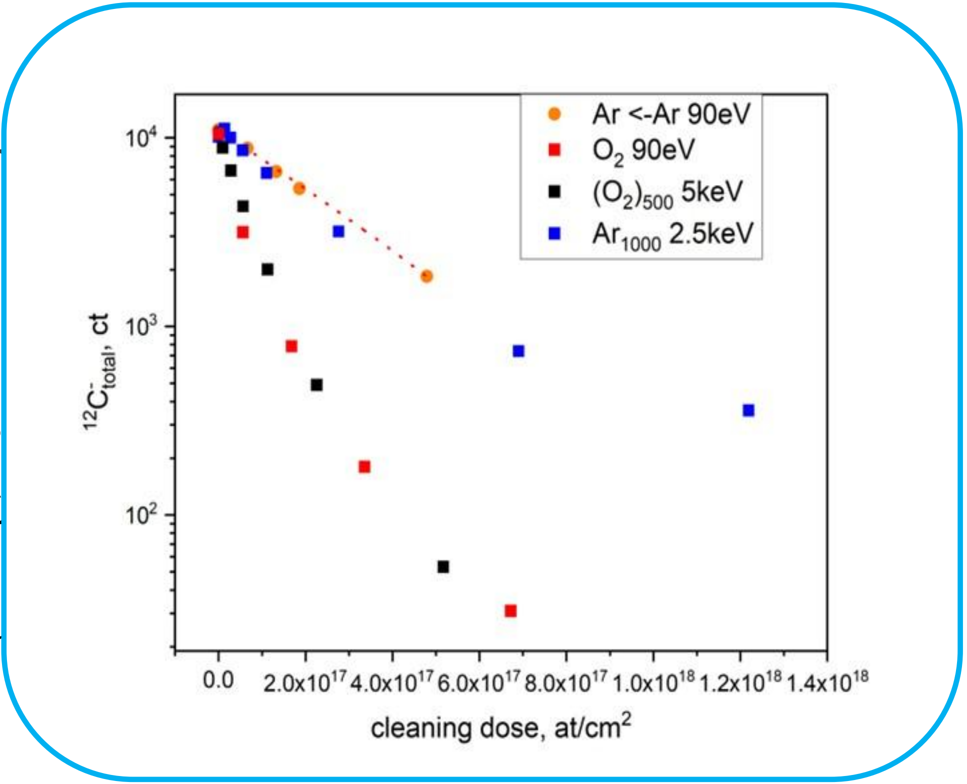

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- Decontamination with Ar^+/ A compared to Oxygen for Car
- Not a big difference between fluence is taken in the integra

Summary

Carbon detection limit improvement

- Carbon detection limit can be improved by:
  - Analytical condition selection
  - Background subtraction based on the detection limit statistics
  - Gentle ion beam surface cleaning

  - Oxygen presence on the surface seems to play the main role in carbon dynamics on the surface