Amorphization and siliconization of SiC as a first wall material

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Presented at the DIII-D Wall Change Community Workshop

June 12-13, 2024

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019-19/JG/jy

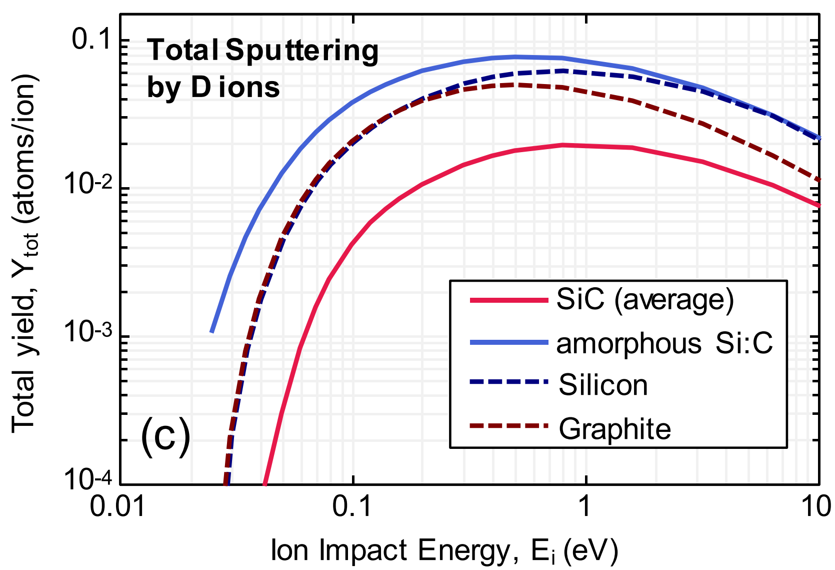
SiC has significant advantages over graphite as a first wall material

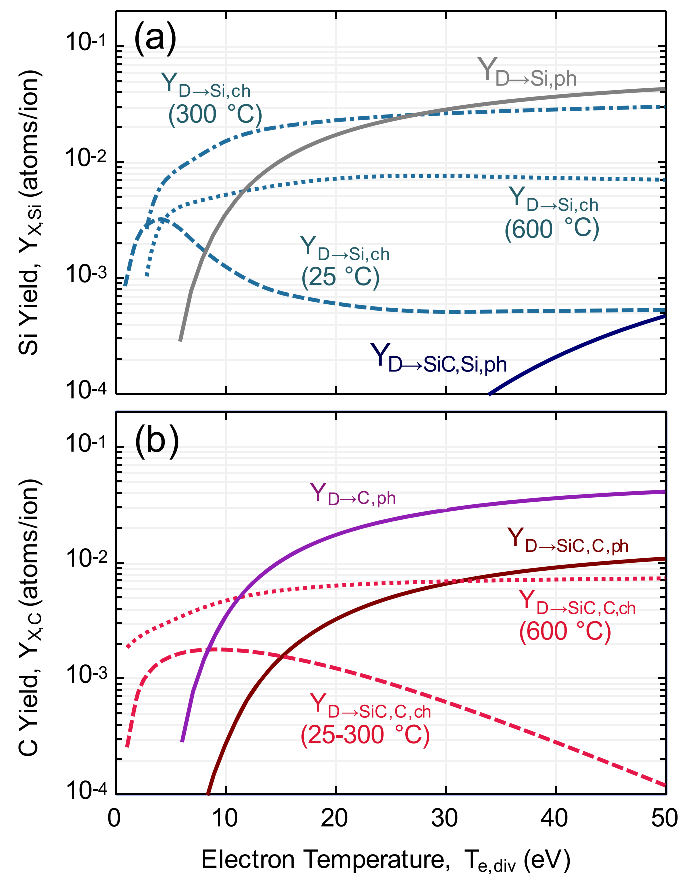
- We need high performing plasma facing components (PFCs) that can survive a nuclear radiation environment – maintains mechanical strength under high dpa.
- Excellent thermal conductivity.
- Low sputtering – both physical and chemical as compared to graphite.
- Low activation under neutron irradiation.
- Extremely low tritium diffusivity and reduced tritium co-deposition.
- Low Z impurity – therefore, low radiation losses.
- Ensure low PFC erosion that can ensure long lifetime of component.
- Ensure low plasma contamination and fuel dilution.
- Good chemical compatibility with PbLi as a structural material in lead-lithium blanket.

SiC physical sputtering is lower than graphite by 2-10x, chemical sputtering by 10x

- **SiC physical sputtering is lower than graphite (2-10X) Abrams et al 2021**
- **Westerhout et al 2009, Balden et al 2000**
- **C from SiC chemical sputtering is 10x lower than graphite(Abrams et al 2021)**
- **No observed Si chemical erosion from SiC (Sinclair NME 2021, Balden JNM 2001) although there is chemical erosion of Si from pure silicon.**

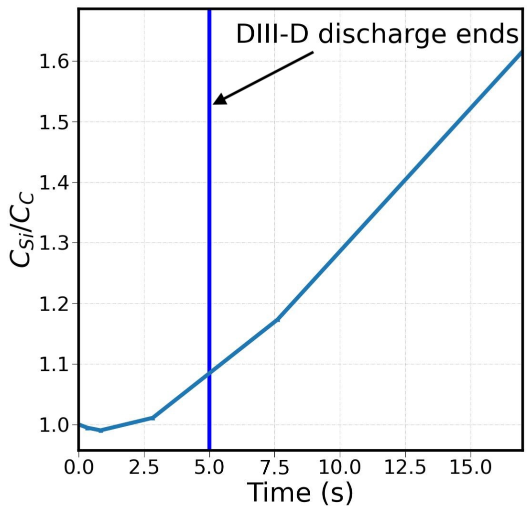
Abrams et al 2021

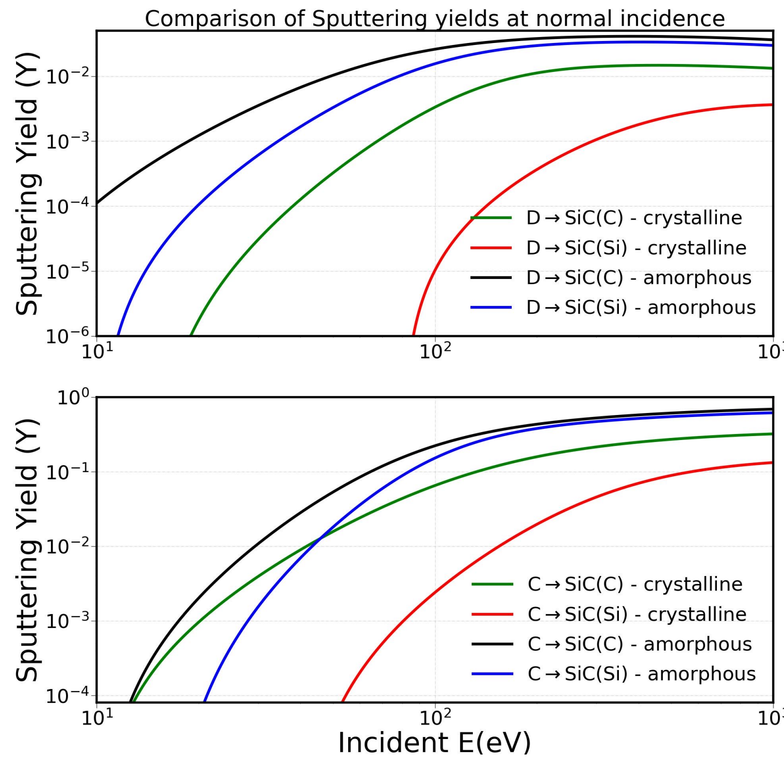




Enrichment of Si is predicted due to preferential sputtering of C from SiC

De et al 2024 In Preparation



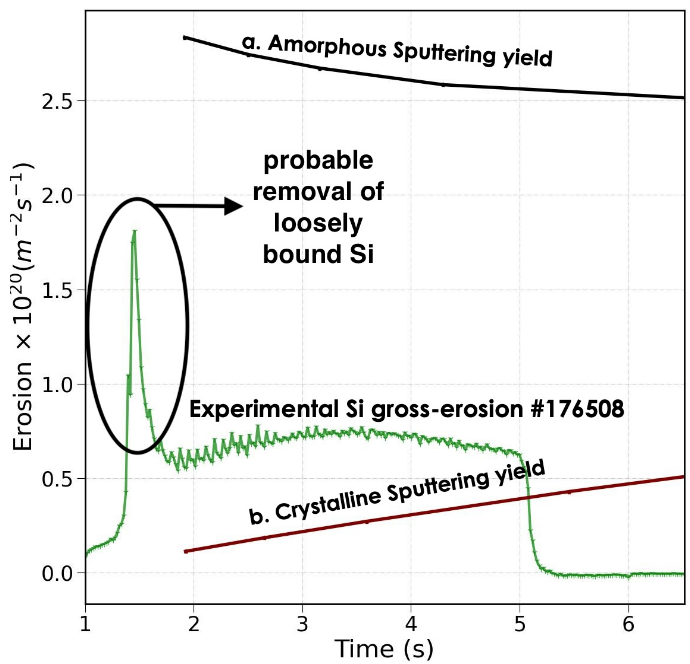


- **DiMES experiments where Si gross erosion rates have been measured spectroscopically.**
- **Preferential sputtering of C from SiC leads to silicon enrichment**
- **Oxygen gettering properties of Si and potential for wall conditioning – Samm JNM 1995**

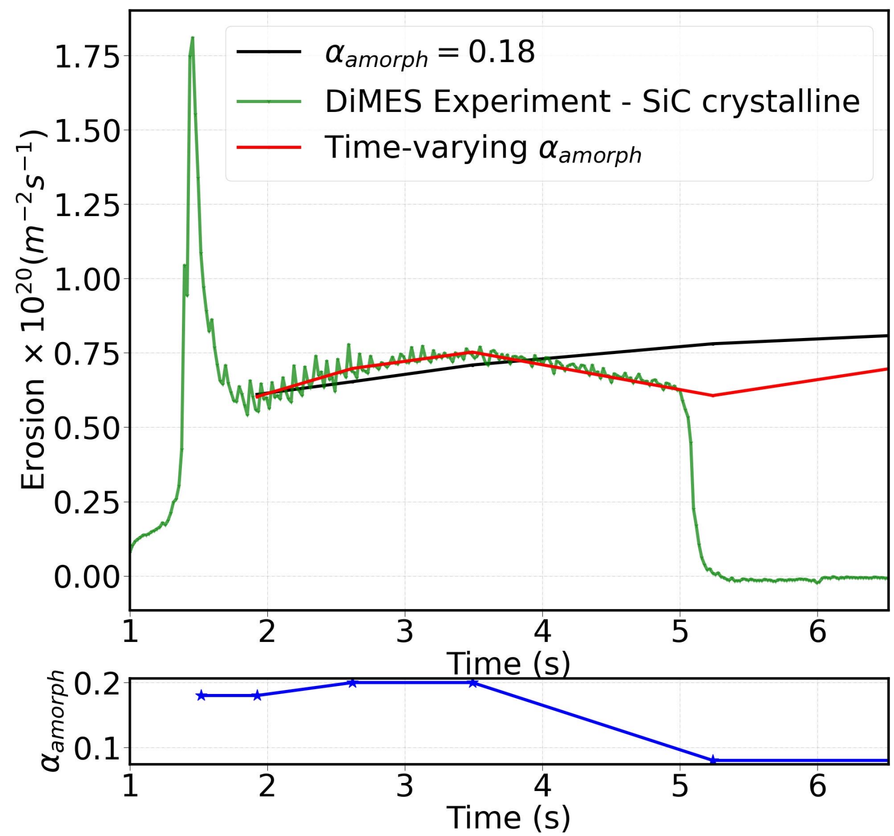
Amorphization of SiC due to accumulation of displacement damages under ion, neutron irradiation

- **A time-varying amorphization ratio of around 0.2 is needed to explain experimental Si gross erosion rates.**
- **Effect of amorphization on the Si gross erosion rates ~ 1.5 x the gross erosion from pure crystalline SiC.**
- **Implies a shorter lifetime than a pure SiC wall.**

De et al 2024 In Preparation

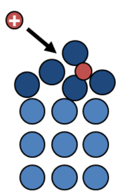


$$\bar{Y} = \alpha_{amorph}\bar{Y}_{amorph} + (1-\alpha_{amorph})\bar{Y}_{crystal}$$

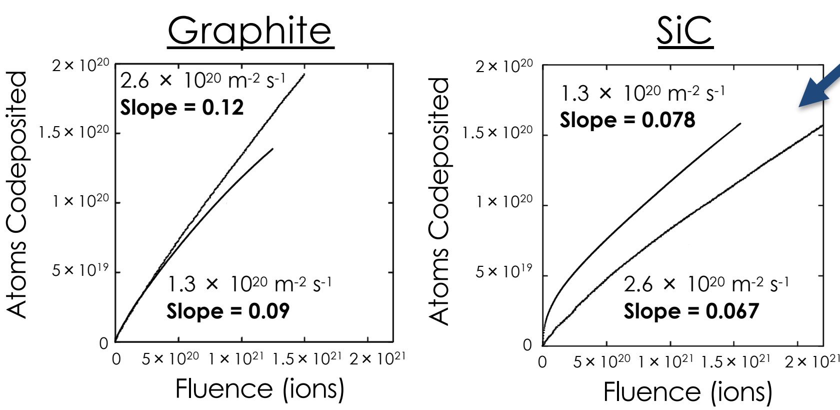


Difference in co-deposition between C and SiC is unclear; high temperatures reduce co-deposit growth rate

- **Co-deposition refers to trapping of H/D/T in re-deposited material**
  - **high T co-deposition in C cited as primary reason for dismissal as FPP-relevant PFM**
- **Two studies in last 20 years present conflicting results on difference in co-deposition between graphite and SiC**
  - **role of co-deposit composition is unclear**



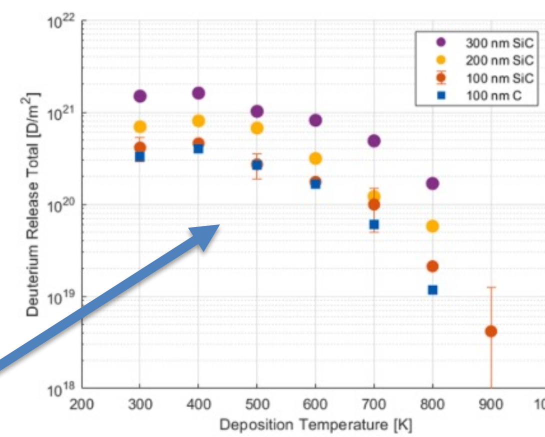
Retention
(co-deposition)



Causey, J. Nucl. Mat., 2003

Co-deposition probability is 1/3 lower in SiC vs. graphite

2× higher D retention in SiC co-deposits vs. C co-deposits at 800 K



Lantaigne et al., Nucl. Mat. Ener., 2022

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Conclusions

- Using SiC walls will lead to decrease in C gross erosion - "Replacing the graphite wall with a SiC wall yielded a 5 to 20× decrease in the estimated carbon gross erosion rate and up to a 7.5× decrease in the carbon impurity content at the OMP separatrix."(Sinclair et al FST 2021)

- Si gross erosion estimates for using crystalline SiC walls should be adjusted by about 1.5 due to amorphization of SiC. This occurs due to the accumulation of defects under ion, neutron irradiation.

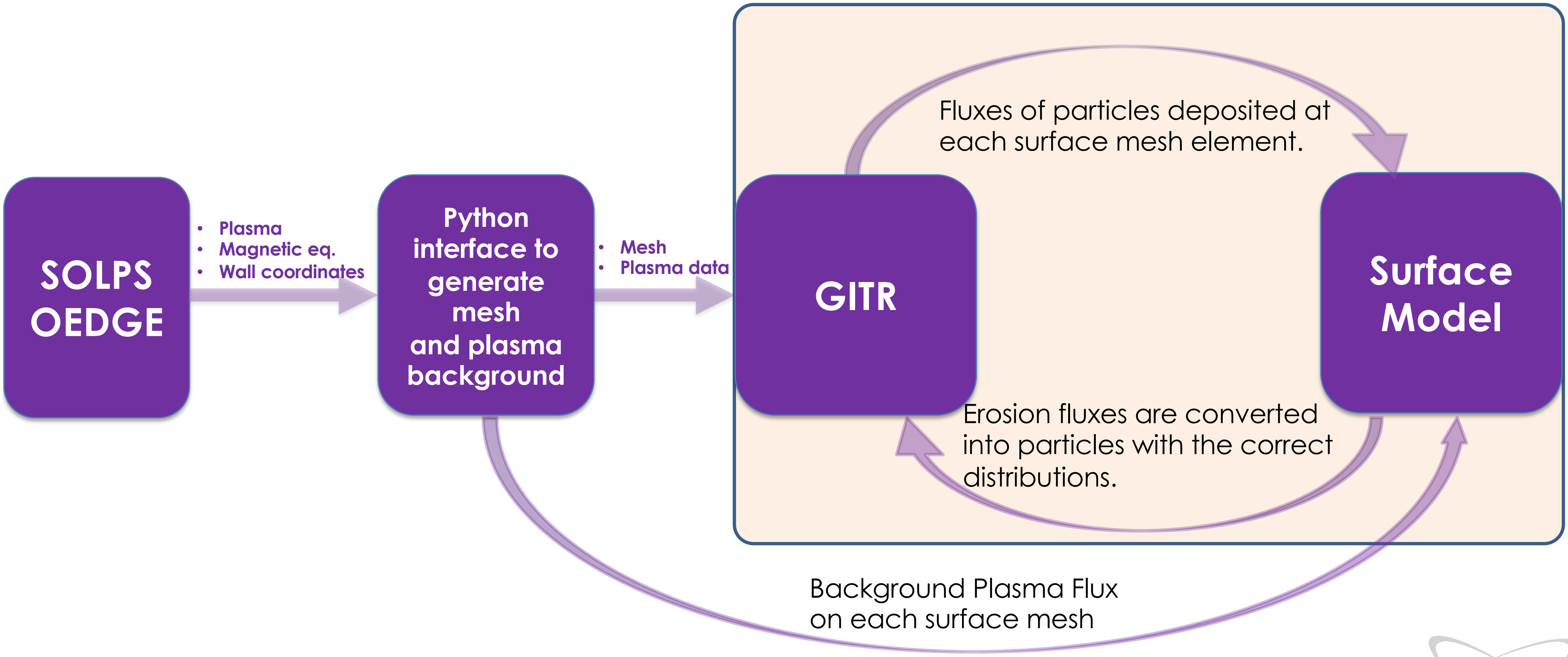
- Preferential sputtering leads to siliconization – "SiC walls can be expected to self-condition" (Zamperini NME 2023) - oxygen gettering capabilities of SiC need to be investigated.

- The prospects of tritium retention via codeposition are unclear – Can it be mitigated by operating at high temperatures? – Further research required.

- Mechanical strength of SiC in reactor relevant scenarios need to be investigated as well as good matching of the thermal expansion coefficient with the heat sink material.

Thank you for listening

GITR workflow with auxiliaries is modular



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