SiC for fusion applications : ^{3}He and ^{2}H behaviour in extra-pur CVD coatings and at SiC/W interface

IPNL / LMI / MATEIS / CTµ

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Partners

Partner	Tools and skills
IPNL (UCBL/CNRS-IN2P3)	Particle accelerators, ion beam analysis
LMI (UCBL/CNRS)	Synthesis : CVD thin layers
MATEIS (UCBL/INSA/CNRS)	Synthesis : Sintering (SPS)
CTµ (UCBL)	Electronic Microscopy

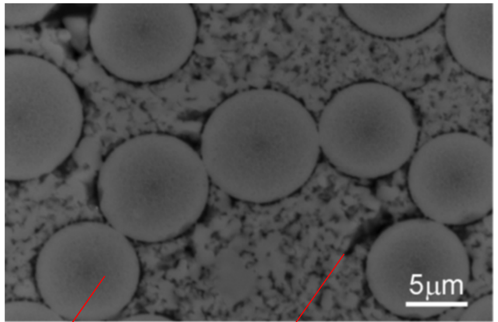
Expert « Fusion » involved : C. Grisolia (IRFM, CEA)

PhD student at IPNL (Ministerial Fellowship) since October 1st 2016

Starting Grant in 2016 from FR-FCM : 3 k€

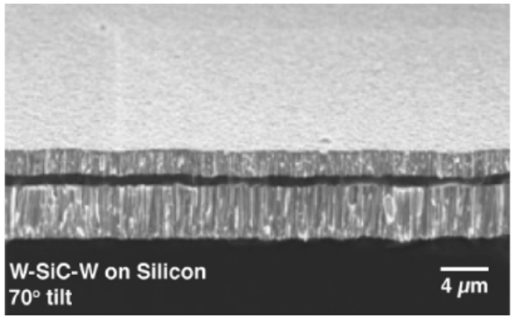
Context

SiC$_f$/SiC for DEMO project



SiC fibers

Nano-grained SiC



Figures from Ivekovic et al.(2013)[1] and [2] Wright G.M et al. (2015) respectively

Need for ultra pure β-SiC with no porosity (dense) nor additives to prevent long lives decay products

CVD coating could be used to achieve gas impermeability on SiC$_f$/SiC composites

SiC$_f$/SiC as blanket material [1] or as plasma facing component (PFC) using CVD coating coupled with W coating [2]

<u>Key properties :</u>

- Resistance to sputtering, macroscopic erosion, de-lamination… under high ion fluxes for PFC
- Purity, Low activation
- Preserved integrity up to 1000°C (PFC) and high level of dpa (breeder blanket)
- Resistance to oxidation in the presence of oxygen impurities
- Low swelling (due to neutron irradiation and gas incorporation)
- SiC is a good tritium permeation barrier (no trapping) [2] : depending on cristallinity, microstructure, impurities, etc…
- SiC/W association for PFC : similar thermal expansion , similar thermal conductivity
- Etc…

Our tools in Lyon

4 MV Van de Graaff accelerator

- Accelerated particles : from H^+ to Ar^{n+}
- Energy from a few hundred of keV to :
  4 MeV (monocharged)
  8 MeV (bi-charged)
  12 MeV (tri-charged)
- Intensity from some tens of nA to several µA depending on the species and charge

For irradiation and ion beam analysis (elemental profiling):

- RBS (heavy elements in light matrix)
- NRA (light elements including ^2H)
- ERDA (^1H or ^2H)

400 kV ion implantor

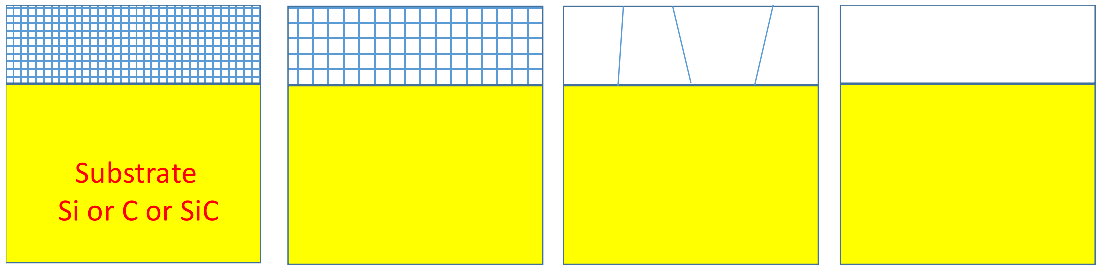
- Accelerated particles : almost all
- Energy from a few tens of keV to :
  400 keV (monocharged)
  800 keV (bi-charged)
  1200 keV (tri-charged)
- Intensity typically several µA
- Upgrade 2017 : low (cryo) and high (up to 1000°C) temperature system

\+ many furnaces…

Coupled with electronic microscopy techniques in the Technological Center of Lyon University (CTµ)

Studied material

β-SiC deposited on C or Si or SiC



Nanograins (10-30 nm)	Micrometric grains (~ 1-10 µm)	Large grains (~ 100 µm)	Monocrystal

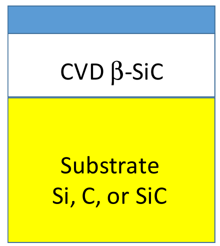
Several **microstructures** can be obtained from nanograins to monocrystal

Thickness from 1 to several µm

High purity : [N] < 10^{14} at.cm^{-3}

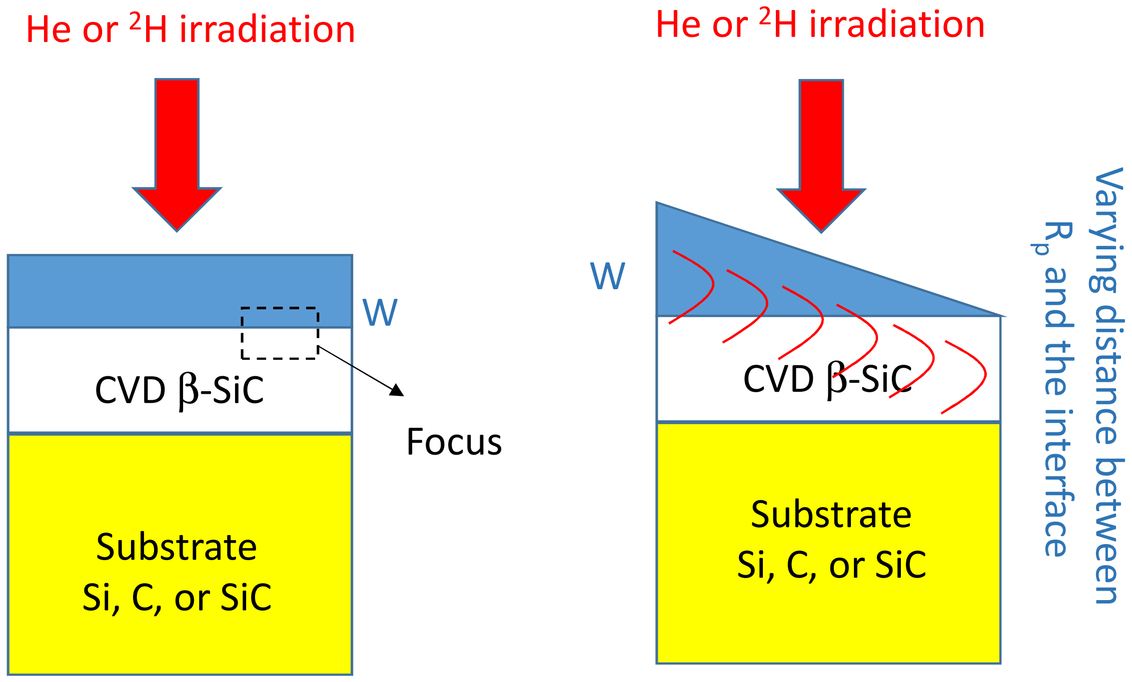
Dense, no porosity

Additional W coating (IBS)



Amorphous, dense and pure W layer

Specific focus on SiC/W interface



<u>Questions :</u>

- SiC, W, SiC/W interface : diffusion barrier for ^2H ? ^2H trapping ?
- Chemical reactions between SiC and W poorly known
  - Preserved integrity during irradiation ?
- He behaviour at the interface : Exfoliation, bubbles ?
- Oxydation of this bi-layer during irradiation

…

As a function of :

- Ion fluence ?
- Irradiation temperature ?
- Post-irradiation thermal treatments

Additional Slide

Studied parameters

- Ion Implantation (He and H) :
  - Controlled fluence : $10^{15} < \Phi < 10^{18}$ at.cm^{-2}, i.e for example up to $[He]_{max}$ ~ 50 %at. to study blistering and exfoliation effects, and up to dpa_{max} ~ 40 (higher dpa can be achieved with other species, Si or C for example)
  - Controlled temperature : from cryogénic T (current upgrade) to 600°C (and soon 1000°C, current upgrade) to study healing effects.

- Rôle of grain size, initial microstructure and temperature on :
  - Species behaviour (release, blistering, formation of bubbles, etc…)
  - SiC oxidation during irradiation
  - SiC structure : Swelling, Defects, healing, amorphization, etc…
  - Other properties…

- Overall questions :
  - Role of the substrate/deposit interface on species behaviour ? Diffusion Barrier ? ^{2}H trapping ? De-lamination, agglomeration of bubbles
  - Role of grain boundaries density (and grain size) on species behaviour and on SiC properties ?