UPDATES OF IRRADIATION TESTS AT GSI ON LHC COLLIMATOR MATERIALS

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Outline

- Motivation and Objective
- GSI irradiation facility
- Feb-Mar 2014 irradiation campaign
- July 2014 irradiation campaign
- What’s next?
Motivation and Objective

Collimators subjected to high level of radiation doses during the normal LHC operation which lead to **DRAMATIC CHANGES** in the material properties:

- Decrease in thermal conductivity
- Increase in electrical resistivity
- Increase in Young’s modulus
- Deformation

Collimator materials **MUST** **MINIMIZE** the WORSENING of phys/mech properties due to radiation-induced effects

Will the present and the novel collimator material survive the HL-LHC scenario?

The answer will take into account their **behaviour** in highly **irradiation environment**.
GSI facility

all ion species
p, Ar, Au, Pb, U

Ion Sources

UNILAC 100 m

M-Branch

Mikroprobe

UNILAC beamlines
Energy: 3.6-11.4 MeV/u
Range: 40-120 µm
beam spot area: 10x10 mm to 50x50 mm
Feb-Mar 2014 irradiation campaign

- **²³⁸U** irradiation: 1.14 GeV, 0.5 ms, 0.6 Hz, 4x10⁹ ions/cm²s
- **²⁰⁸Bi** irradiation: 1 GeV, 0.5 ms, 3.4 Hz, 1.2x10⁹ ions/cm²s

- **CuCD, CFC** (2 orientations), **MoGr** (MG 3110P, 2 orientations, samples not annealed) irradiated with fluences up to 5e13 i/cm²
July 2014 irradiation campaign

- $^{197}$Au irradiation:
  - ion energy: 945 MeV
  - pulse frequency: 40 Hz
  - flux: $\sim$1-2x$10^9$ ions/cm$^2$s
  - beam spot: 2.2x2.2 cm

- $^6$C irradiation (ongoing): 11.4 MeV/u, flux: 5x$10^9$ ions/cm$^2$s
Thermal properties degradation

**On-Line** monitoring during irradiation with thermal camera (acquisition rate: 2kHz).

**Estimation of time constant at cooling on:**
- **Mo-Gr:** 2 orientations x 2 different annealing processes (1150°C and 1300°C for 4h)
- **CFC:** 2 orientations
- **CuCD**

Another batch of samples is currently under C-ions irradiation at fluence up to 1e14 i/cm²

Fluences: 1e11, 1e12, 1e13, 5e13 Au-ions/cm² at fluxes ~2e9 Au-ions/cm²s

Fluence up to 1e13 Au-ions/cm² at fluxes ~1e9 Au-ions/cm²s
Radiation-induced deformation

Measurement at optical microscope of **shortening after irradiation** on:

- **carbon fibers** (3 mm, Ø= few µm, Granoc XN-100-03Z), used as MG composite reinforcement

Quite challenging to mount on the holders!!

fluences: 1e11, 1e12, 1e13, 5e13 Au-ions/cm² at fluxes ~ 1e9 Au-ions/cm²s
What’s next?

- Thermo-mechanical and structural characterization of irradiated samples
- Quantitative evaluation of online thermal camera monitoring data
- Further irradiation during next beam-time (preliminary schedule):
  
  **Mid-August:**
  - Low duty cycle **Au-ions** irradiation
  
  **Mid-September:**
  - irradiation with **Xe-ions** and **Au-ions**

  **October/November:**
  - irradiation with **laser**
THANK YOU FOR YOUR ATTENTION
Backup slides
CFC AC-150K

- Developed by Tatsuno (Japan)

**Composition:**
- Graphite flakes
- Carbon fibers

**Density:** 1.67 g/cm$^3$

Currently used as TCPs and TCSGs active jaw material

**Main limitations:**

- **Poor electrical conductivity (0.18 MS/m)**
  - RF Impedance induced beam perturbations

- **Limited Radiation Hardness**
  - Reduced Lifetime for LHC operations
  - Need for replacing degraded Collimators
**Copper-Diamond composite**

- Developed by **RHP-Technology** (Austria)

**Composition:**
- 60%v diamonds (90% 100 µm, 10% 45 µm)
- 39%v Cu powder (45 µm)
- 1%v B powder (5 µm)

- No diamond degradation
- Thermal (~490 Wm\(^{-1}\)K\(^{-1}\)) and electrical conductivity (~12.6 MSm\(^{-1}\))
- No direct interface between Cu and CD (lack of affinity). Partial bonding bridging assured by Boron Carbides limits mechanical strength (~120 MPa).

- Cu low melting point (1083 °C)
- CTE increases significantly with T due to high Cu content (from ~6 ppmK\(^{-1}\) at RT up to ~12 ppmK\(^{-1}\) at 900 °C)

**Limitation for collimator!**

BC “bridge” stuck on CD surface. No CD graphitization
MG: composition and production

Basic composition & main production parameters:
• 40%v natural graphite flakes (Asbury)
• 20%v short carbon fibers (300 µm, Cytek DKD)
• 20%v long carbon fibers (3 mm, Granoc XN-100-03Z), blended
• 20%v Mo powder (5 µm)

• Powders pre-cleaning under H₂-N₂ atmosphere at 600°C
• RHP: complete melting of Mo₂C at ~2600°C, 35 MPa applied pressure (in steps), reducing H₂-N₂ atmosphere at 10⁻⁴ mbar.