This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

New Materials for Extreme Thermal Management – PowerMat: Task 17.2

ARIES WP17 Kick-off Meeting, CERN Geneva 05.05.2017

Alessandro Bertarelli (CERN)

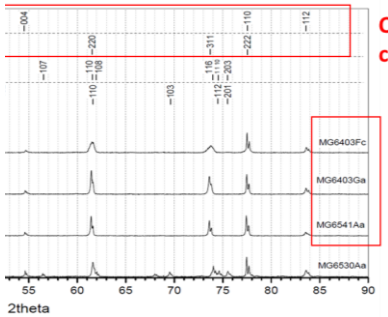
Task 17.2: Materials development and characterization

Coordinator: A. Bertarelli, CERN

Participants: CERN, GSI, NIMP, POLIMI, POLITO, UM (plus **Brevetti Bizz, RHP-Technology** through WP14)

1. Research, investigation, development and characterization of **novel CMC and MMC** based on graphitic, carbide or diamond reinforcements and dopants (in collaboration with Task 14.4).
2. Study and development of **electrically conductive coatings**, resisting the impact of high intensity particle beams.
3. Characterization of **thermophysical and outgassing properties**, **microstructural analyses**, **study of phases** and of their change under various environments …

Task 17.2: Materials development and characterization



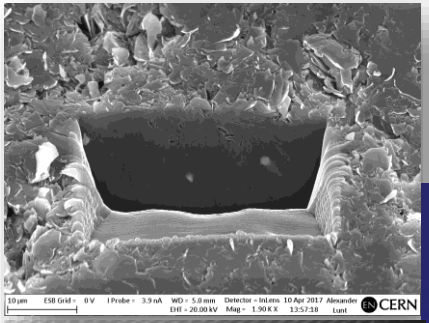
Only one carbide phase

Cubic: More isotropic properties

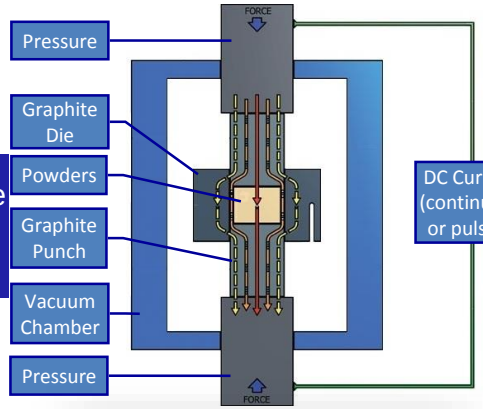
With Ti

Data analysis, investigation, new proposal …

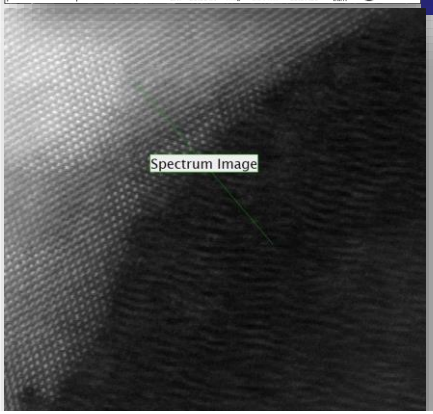
Choice of components (materials, topology, dopants …)



High-temperature manufacturing (SPS, RHP …)



Microstructural characterization (SEM, FIB, XRD, EDS, TEM …)



Thermophysical characterization (DIL, LFA, DSC …)

Task 14.4

in collaboration with University of Zaragoza (SP)

Task 17.2: Materials development and characterization

Research, investigation, development, manufacturing, characterization of novel CMC and MMC based on graphitic, carbide or diamond reinforcements. Continuous material optimization will be fostered by the feedbacks provided by tasks 3 and 4.

Push forward R&D on advanced materials for HEP, Thermal Management.

- Carbide/graphite composites. Explore new compositions (different carbon types, other carbides …). Strictly related to **task 14.3** (specimens needed). Also needs input from task 17.5
- Diamond/metal composites. Improve existing materials (e.g. CuCD) or develop new ones also in view of input/requirements from **task 17.5** for broad applications
- Application of Carbon Foams for to High Power Beam Intercepting Devices

Task 17.2: Materials development and characterization

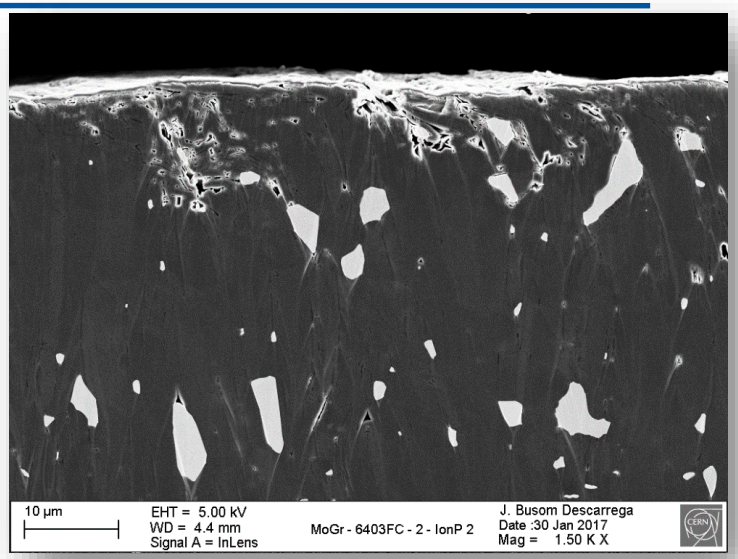
b. Study and development of electrically conductive coatings, resisting the impact of high intensity particle beams.

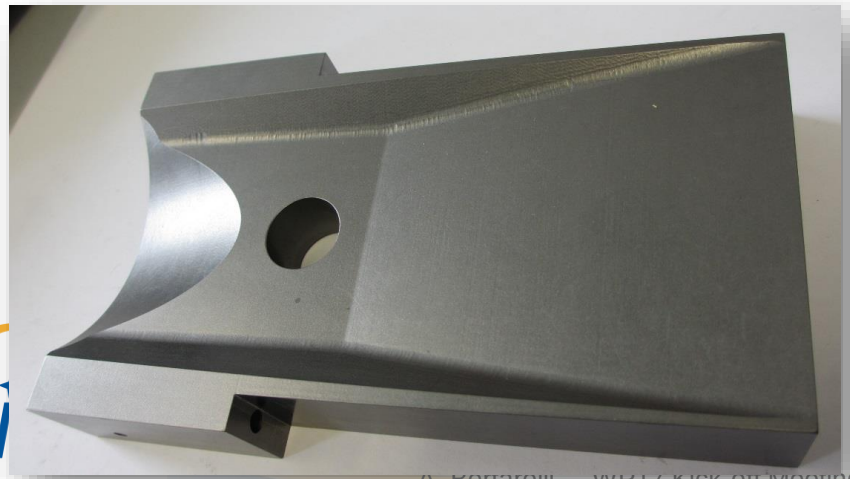
Particular focus on development of new coatings for low-impedance collimators, spoilers etc … Materials to be studied include low-density, high conductive, refractory materials/ceramics

Task 17.2: Materials development and characterization

Example of Ceramic Matrix Composite: Molybdenum Carbide – Graphite (MoGr)

- Co-developed by CERN and Brevetti Bizz
- Produced by **Pressure-assisted Electric Current Sintering** attaining l**iquid phase** of carbides **(T ≅ 2600°C)**
- Excellent crystalline structure of carbonaceous phase with **highly-oriented Graphene planes.** Graphitization favored by the **catalyzing effect** of molten carbides!
- **Excellent thermal properties (up to 4 times Cu diffusivity)!**
- **Electrical conductivity: factor of 10 higher than isotropic graphite!**
- Can be produced in **large components (150 x 100 x 25 mm^3)** and easily **machined**
- **Can be coated** with metals (e.g. Mo) and ceramics (e.g. TiN)

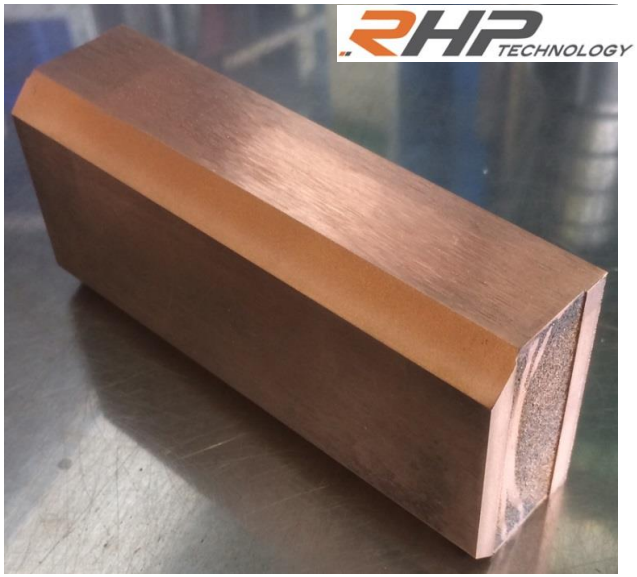


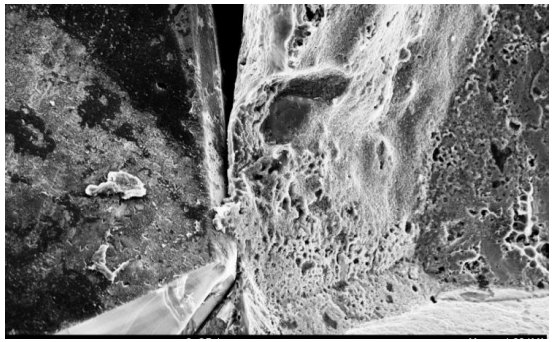


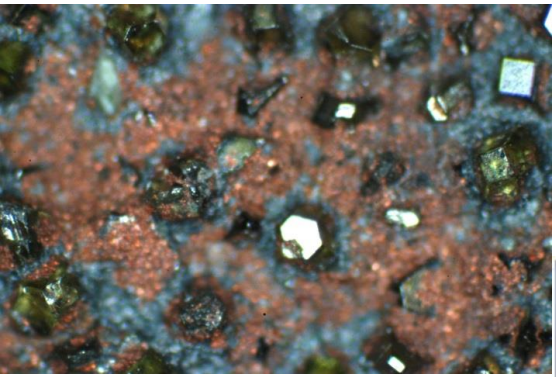
Task 17.2: Materials development and characterization

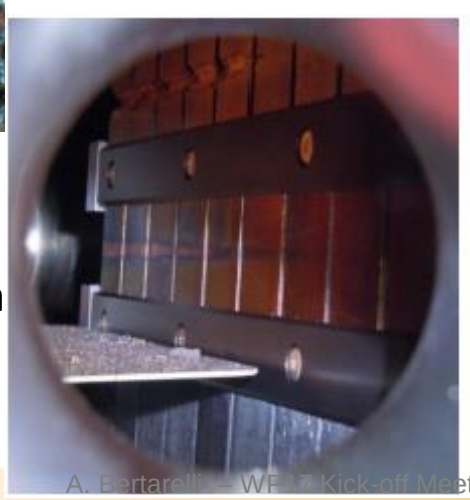
Example of Metal Matrix Composite: Copper – Diamond (CuCD)

- Developed by **RHP-Technology**
- Produced by **Rapid Hot Pressing (T ≅ 1000°C)**
- **Excellent electrical conductivity**, **very good thermal conductivity**
- Shock and Radiation resistant
- Can be cladded with pure copper





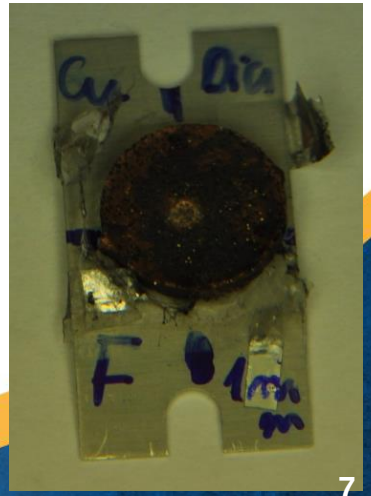




Proton beam HiRadMat, CERN:

Laser shock experiment - GSI:

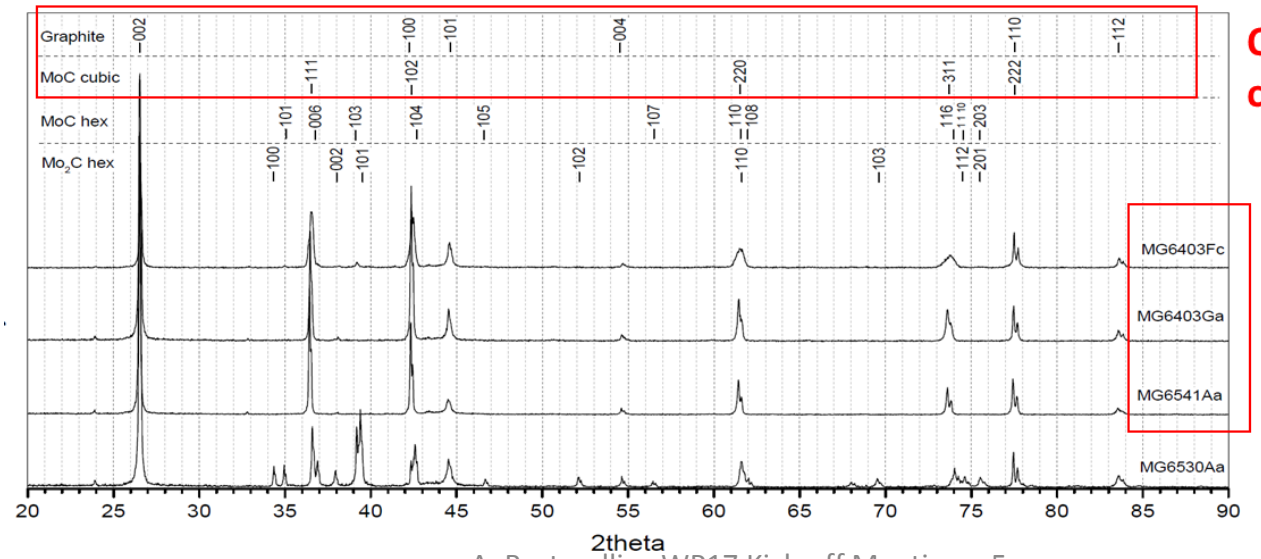
Pulse duration:	0.7-20 ns
energy:	0.3-1 kJ
Max. Intensity:	10^{16} W/cm^2



Task 2 description

c. Characterization of thermophysical properties measurements, microstructural analyses (SEM, XRD, EDS, FIB, TEM ...), study of phases and of their change under various environments …

Systematic thermophysical and microstructural characterization of material under study. Close collaboration with task 17.3 for mechanical testing. Optimization of the thermophysical measurement methods.



Only one carbide phase

Cubic: More isotropic properties

With Ti

Deliverables

- **Task 17.2) Comparative compendium of the developed materials [month 40]**
- Task 17.4) Report on simulations on irradiation effects [month 44]
- Task 17.3) Irradiation test results: Beam impact on new material and composite [month 48]
- **Task 1.4) Production of material samples (as large as possible for each industry to demonstrate workability) [month 24]**

Milestones

- Task 17.1) Organisation of PowerMat kick-off meeting, with publication of talks on Web [month 6]
- **Task 1.4) Prepare first samples [month 12]**
- **Task 17.2) Material characterisation, with publication of results on Web [month 18-24]**
- Task 17.3) Irradiation, with publication of report on web[month 27]
- Task 17.4) Irradiation effects analysis, with publication of report on web [month 36]
- **Task 17.5) Report on studies, with publication of report on web, [month 46]**

Deliverables and Milestones Gannt-Chart

Task	Year 1				Year 2				Year 3				Year 4			
	Q1	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*
17.1		M														
17.2							M						D			
17.3									M							D
17.4												M		D		
17.5																M
1.4				M				D								

Budget

TASK	Lab-Ind	Person•month	From EU (k€)
1. Communication & Coordination	GSI	7	15
	CERN	7	15
2. Materials development and characterization	CERN	36	55 (Meas)
	GSI	16	70 (PhD +30 subc)
	POLITO	5	20 (studies - meas)
	UM	20	50 (studies, part PhD)
3. Dynamic testing and online monitoring	CERN	4	-
	GSI	16	100 (PhD+irradiation)
	POLITO	45	100 (analysis-meas)
	POLIMI	50	80 (PhD)
	ELI-NP	10	30 (laser: target/cons.)
4. Simulation of irradiation effects and mitigation methods	CERN	30	30 (studies)
	GSI	1	10 (studies)
	POLIMI	4	10
5. Broader accelerator and societal applications	CERN	1	5
	GSI	3	20 (subc.)
		255	**645**