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# Overview and recent developments within Task 17.5

ARIES WP17 Annual Meeting
14 July 2020, online meeting

Marilena Tomut, GSI, WWU

# Task 17.5 description

*Task 17.5. Broader accelerator and societal applications*

This task follows broader applications of new developed materials for high-power accelerators, space, society (energy, medicine, computing)

- Irradiation induced defect centers in diamond for luminescent screens, medical imaging and quantum computing.
- Application of novel materials for high power targets, beam catchers, beam windows

Participants: GSI, CERN, RHP Technology, NIMP, WWU

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# Task 17.5 - after Malta

*Task 17.5. Broader accelerator and societal applications*

1. *Reduce diamond particle sizes amd improve their surface distribution for better beam-spot reproduction – (RHP-GSI) – new Ti and Cu matrix samples were produced in WP 14*

2. Understand the contribution of (irradiation induced) color centers in diamond to iono– and photo-luminescence, for different applications (luminescence screens, QD’s and medical imaging)

3. Continue radiation damage and beam induced pressure wave response studies for different carbon materials for high power targets and beam dumps - joint activities for tasks 17.2 and 17.3.

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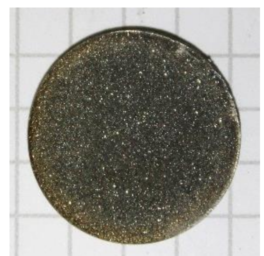
# Task 17.5 – optimization of diamond-metal composites for luminescence applications

- Ti-based composites consisted of diamonds with a nominal diameter of 45 µm and embedded into either Ti Gd2 or Ti Gd5 under different hot-pressing parameters. The samples had an approximate diameter of 20 mm and an overall thickness of 1 mm.


IHP5231-TiGd2

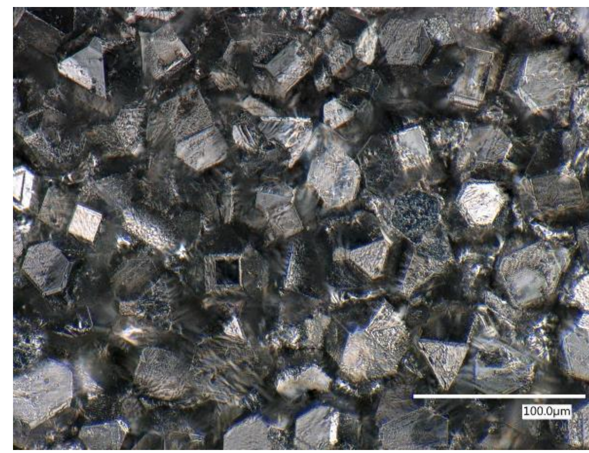

IHP5232-TiGd2


IHP5233-TiGd2


IHP5231-TiGd5

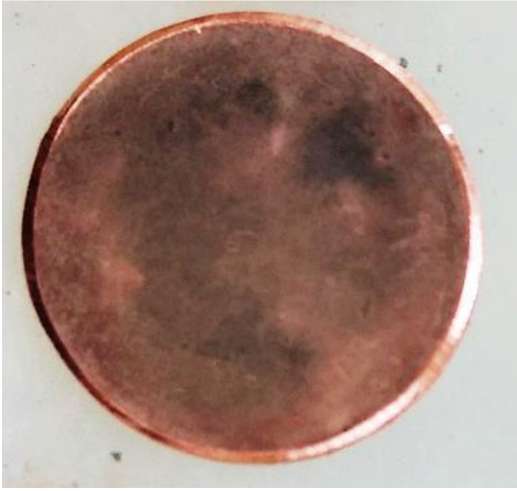

IHP5232-TiGd5

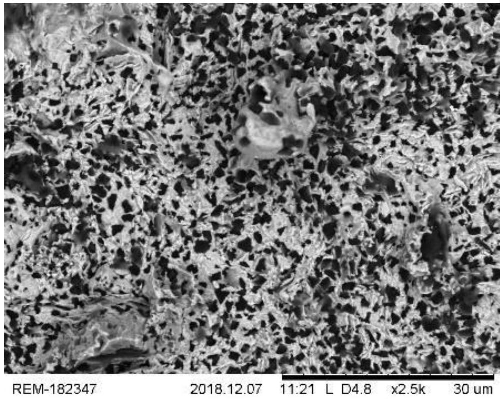

IHP5233-TiGd5



# Task 17.5 – optimization of diamond-metal composites for luminescence applications

- In February 2019, a third set of samples have been produced and sent for testing at GSI - Cu base and very find diamond fractions. RHP tested the use of a spray system to coat an inert substrate with a fine layer of diamonds, following which this would be transferred into a Cu surface during a hot-pressing process.



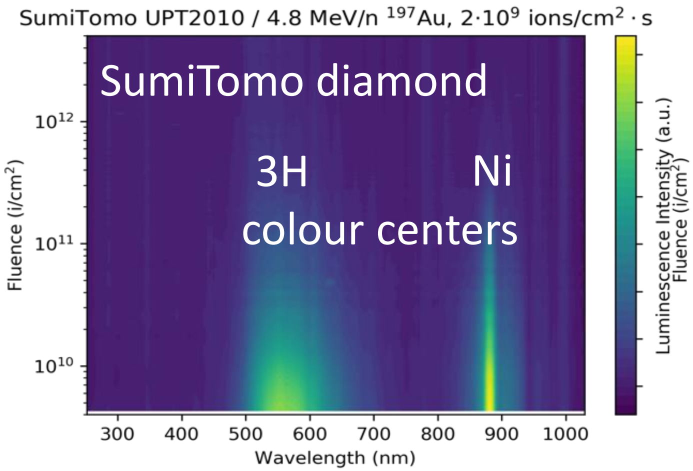


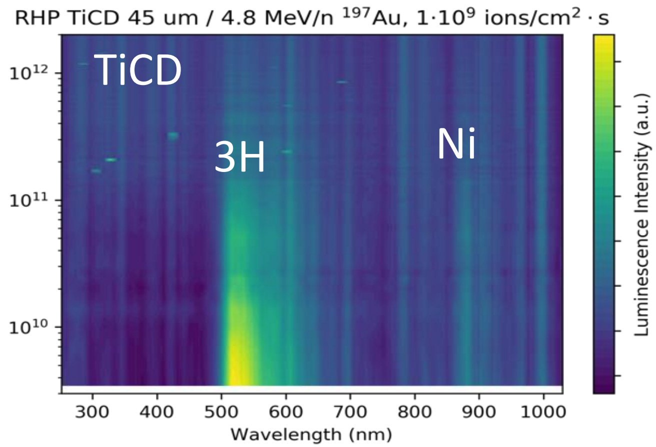
# Task 17.5. Broader accelerator and societal applications

- Irradiation of N- containing diamonds, CuDia and TiDia composites for luminescesnce applications at GSI – UNILAC
- High intensity and high fluence irradiation with: 4.8 MeV/n Ca, Sn, Xe and Au
- Various on-line experiments: iono-luminescence, photoluminescence  and FTIR and UV/c spectroscopy

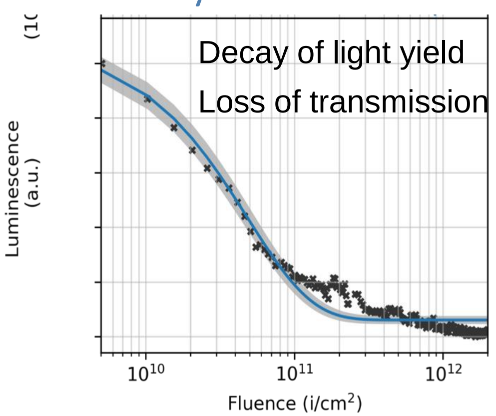
# Luminescence of ion-irradiated diamond and diamond- metal composites

## Online iono-luminescence measurements

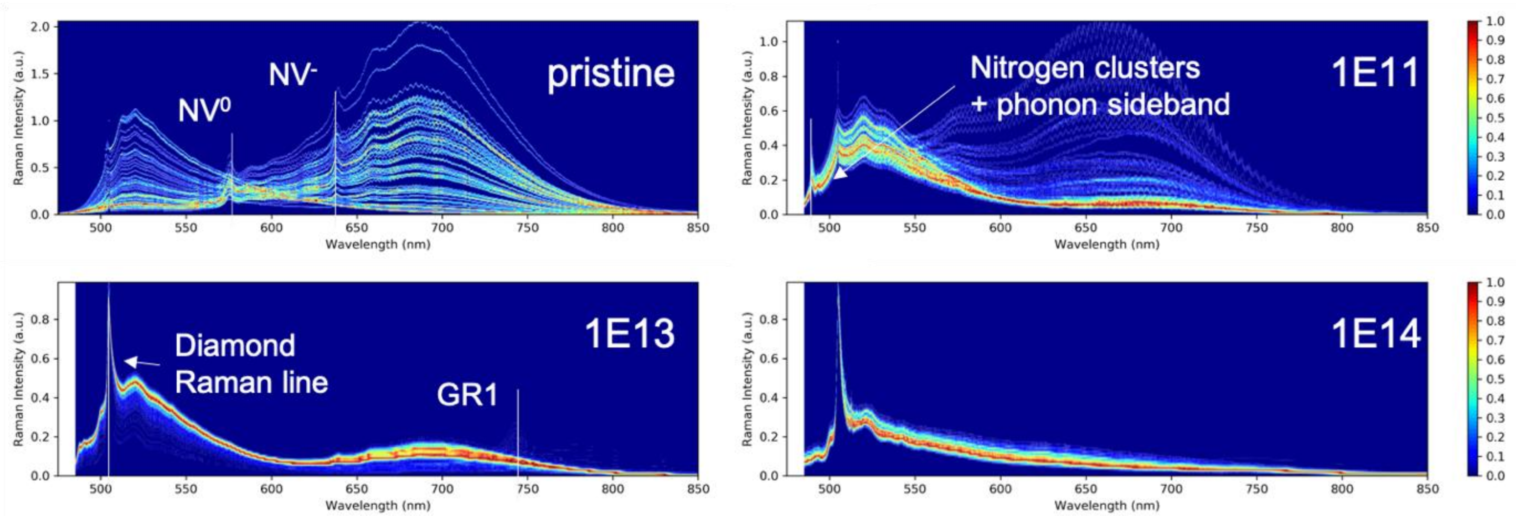


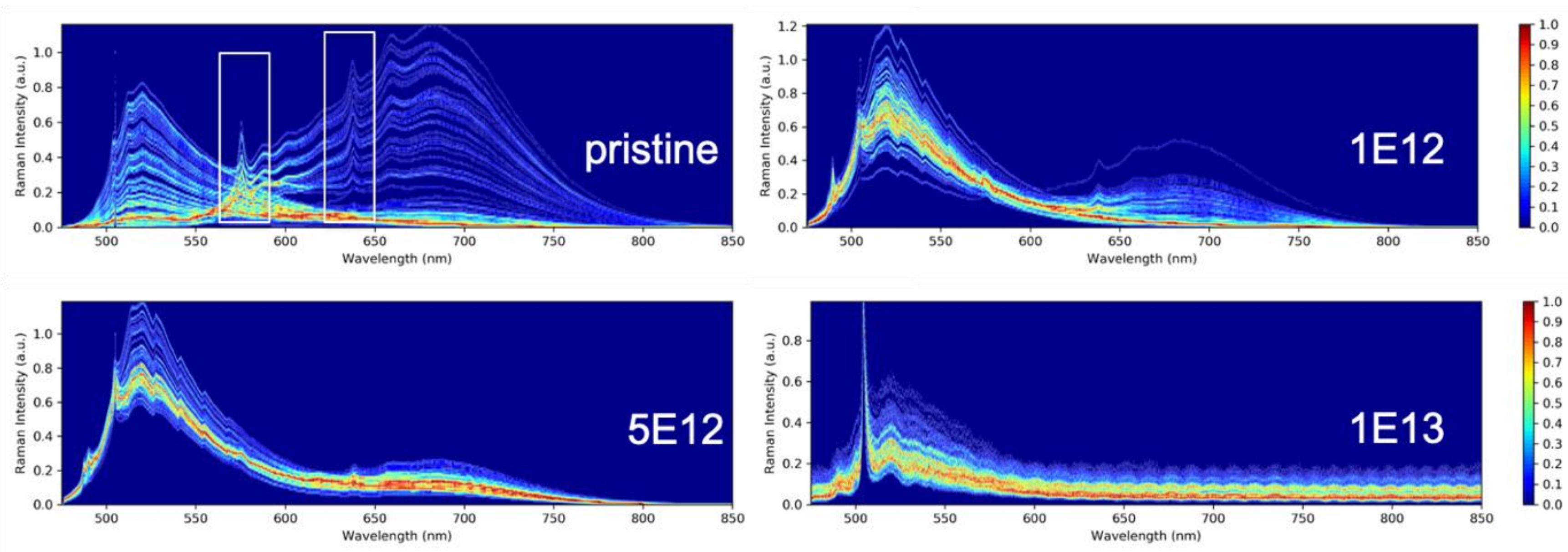

## Iono-luminescence decay with fluence




## CuCD- photoluminescence spectroscopy



# Ti-Dia / Photoluminescence spectroscopy

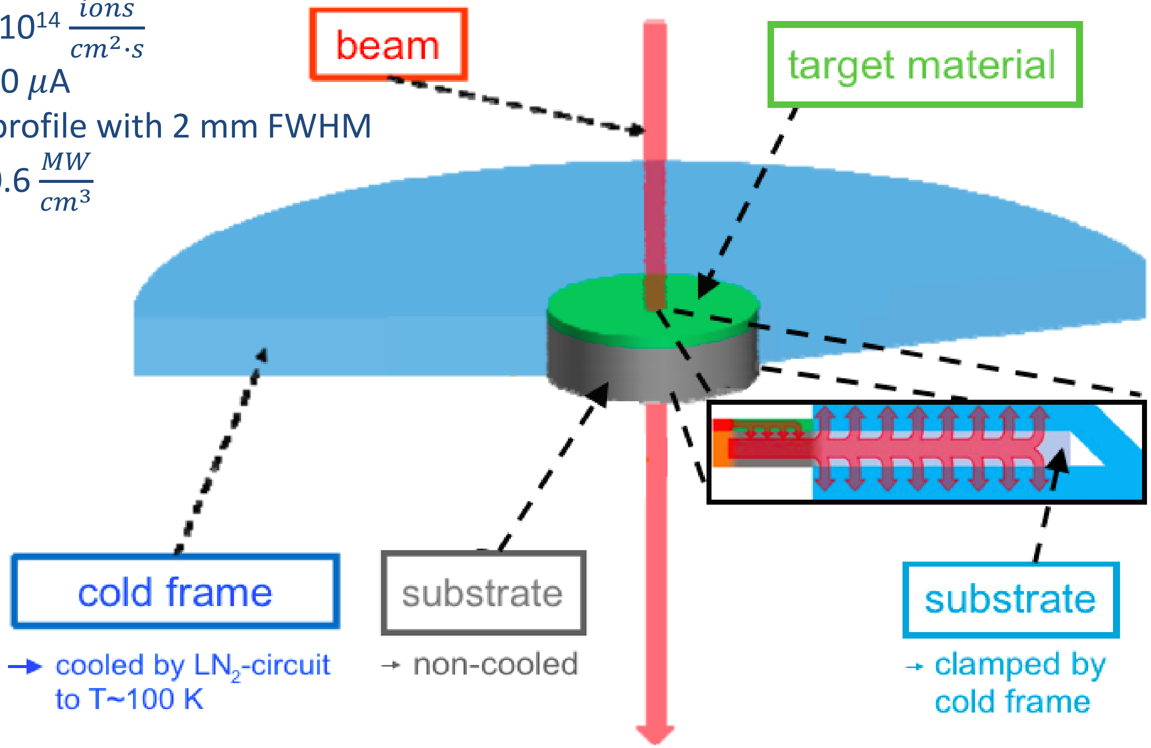



- High statistics photoluminescence spectra on diamond/Ti-matrix composite
- Nitrogen-related color centers (N-V, 2N-V, 3N-V, N-N) sensitive to ion-irradiation
- Dramatic changes in spectra beyond fluence of $1{\cdot}10^{12}$ i/cm$^2$
  - Nitrogen-related color centers apparently do not play a major role in SHI-luminescence

# Task 17.5. Pyrolytic graphite foil as heat sink for production targets in NUMEN-project

15 MeV/u $^{18}$O-ion irradiation [2]:

O-ion flux : $8.6\times10^{14}\ \frac{ions}{cm^2\cdot s}$
beam current : 50 $\mu$A
Gaussian beam profile with 2 mm FWHM
power density: 0.6 $\frac{MW}{cm^3}$




Cooling system for high intensity ion beam operation in the NUMEN-project [1]

Pyrolitic graphite:

- low atomic number (Z=6) (low energy loss)
- high thermal conductivity

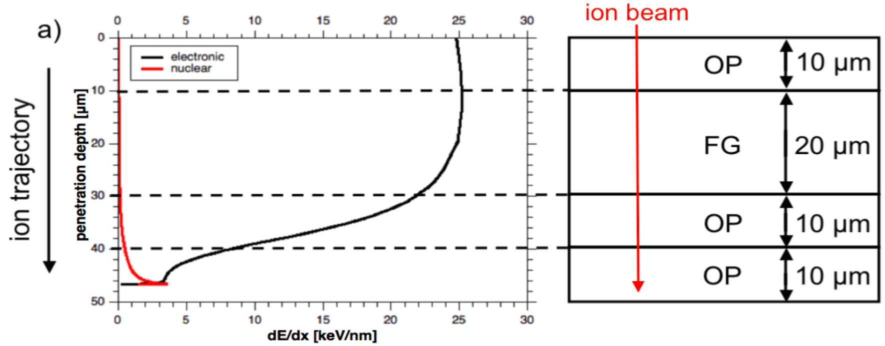
evaluation of degradation of thermal conductivity of graphite foils

# Irradiation of pyrolytic graphite foils

- Pyrolitic graphite foils- stacked for 4.8 MeV/u $^{197}$Au-irradiation on 2 sample holders

  - Stack thickness covers an ion range of approx. 47 $\mu$m
  - probing different energy loss levels along ion path


OPTIGRAPH samples on first holder for 4.8 MeV/n $^{197}$Au-irradiation



# Deliverables & Milestones

Task 17.5. - MS 62 – Dissemination of R&D results on novel materials for accelerator and societal applications (month 46)

- Planned initially as an Workshop “Extreme Beams meet Extreme Materials”
- To be replaced by an online workshop or by a Special Issue in a open access journal (“Materials”- IF 3.4)

| 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 |
| 14.4 | | | | M | | | | D | | | | | | | | |

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# What's next - IFAST – WP4.3

- **IFAST Task 4.3. - GRAPH&BEAWIN**

M. Losasso and M. Tomut

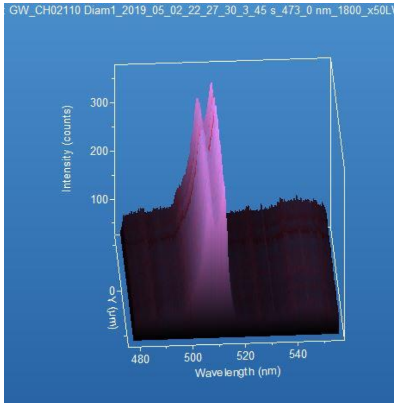
**Beam windows for high-power accelerator applications. Suspended graphenic membrane and novel metallic beam windows for next generation accelerators**

Continuation of activities in task 17.5. on materials for broader accelerator applications

Objectives:

- Production of innovative materials suitable for beam-windows applications in high power accelerators
- Particle transport and thermomechanical simulations for beam windows under high intensity operation conditions
- Characterisation of beam windows materials under thermomechanical load and extended radiation damage and their integration in accelerator environment
- **Participants**: CERN, GSI, WWU Münster, RHP
- **EC contribution: 100 k€ / Duration: 32 months**

**graphenic membrane**




**Raman spectra of graphenic membrane**

Thank you for your attention!

# Iono-luminescence in diamonds and diamond-metal composites

- Swift heavy-ion (SHI) induced luminescence in monocrystalline diamonds and diamond/titanium-matrix composite
- Luminescence during SHI-excitation dominated by (intrinsic) 3H color center (~500 – 600 nm) & nickel-related color center (~883 nm)
  - Incorporation of nickel during synthesis
  - No evidence for additional iono-luminescenct beam-induced defects
- Critical fluence of ~$1 \cdot 10^{12}$ i/cm$^2$ (4.8 MeV/n $^{197}$Au) where more than 90% of luminescence intensity vanishes
- Emission from 3H also observed in nitrogen-free CVD diamonds