

# ION-BEAM INDUCED STRUCTURAL AND CHEMICAL CHANGES IN TARGETS USED FOR SUPERHEAVY ELEMENT PRODUCTION

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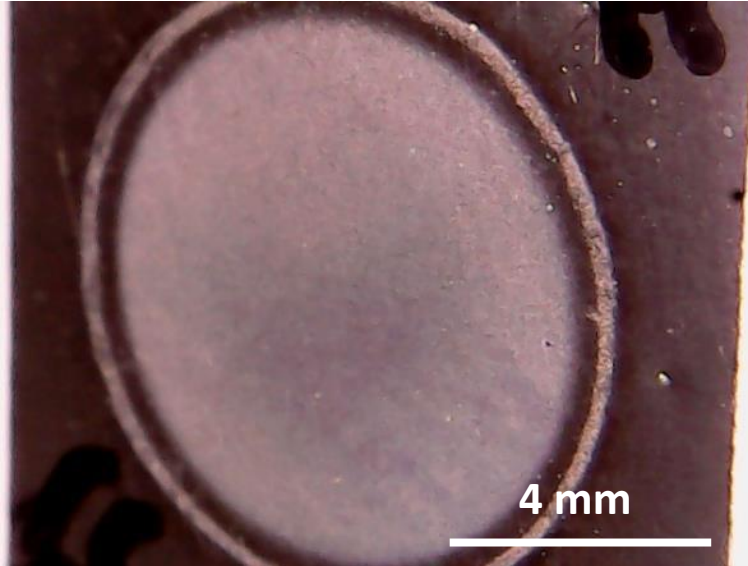
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# Outline

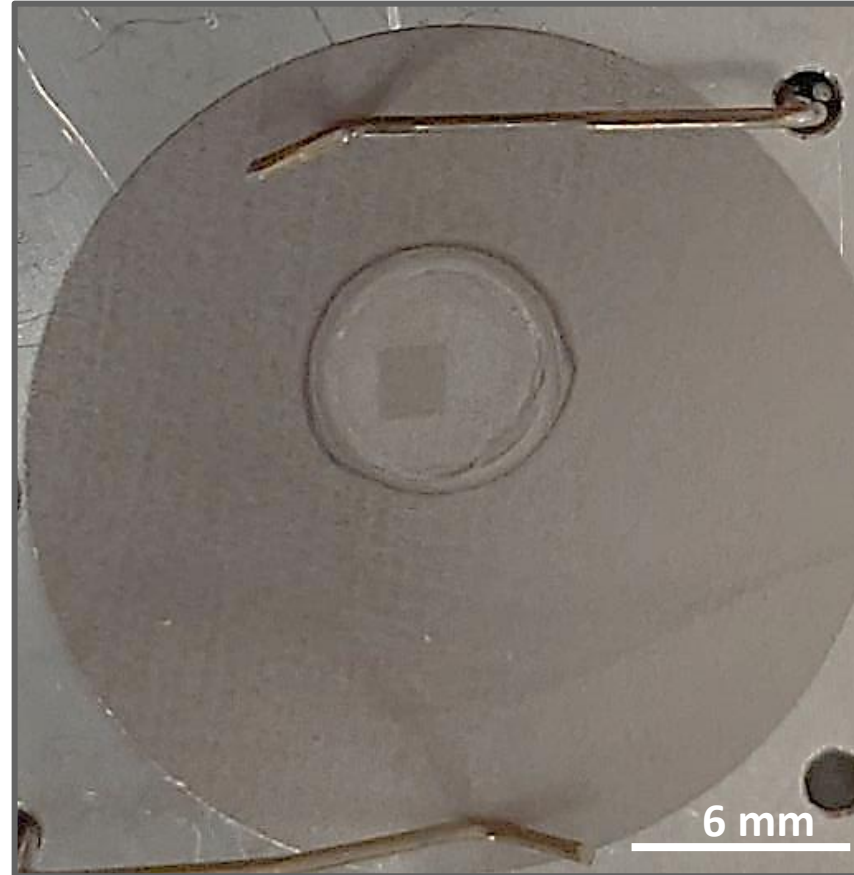
- irradiation of targets made by Molecular Plating (MP)
- new approaches to target analysis
- new insights into the MP process and ion beam induced changes
- using lanthanide substitutes

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

# Model systems



The  $^{169}\text{Tm}$  target after the bombardment with the  $^{197}\text{Au}$  beam dose of  $1 \times 10^{13}$  ions/cm $^2$



The  $^{169}\text{Tm}$  target after the bombardment with the  $^{35}\text{Cl}$  beam dose of  $2 \times 10^{14}$  ions/cm $^2$

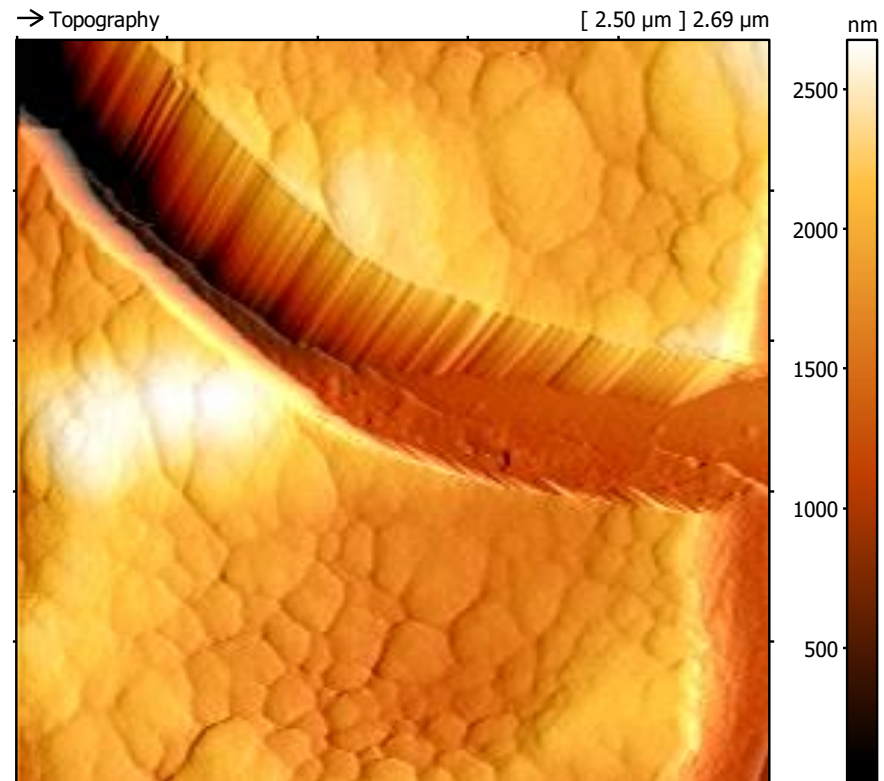
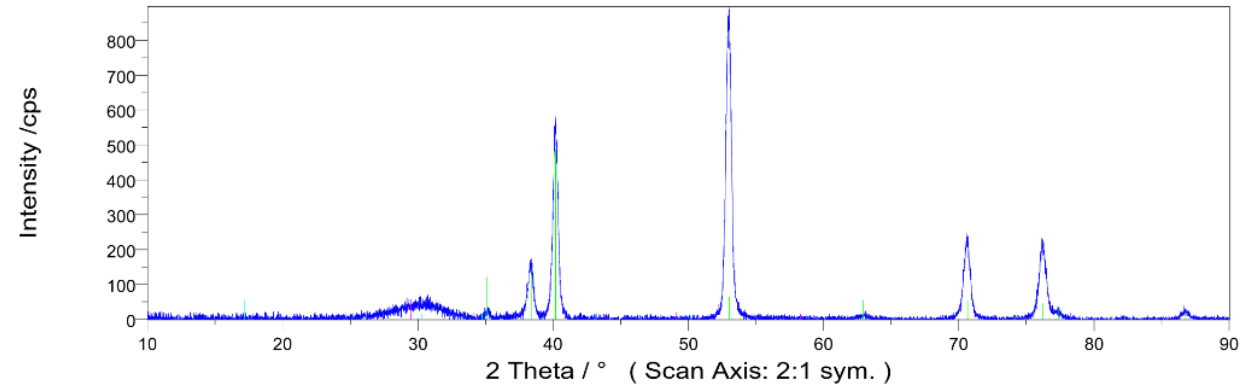
# SHE research



The  $^{249}\text{Cf}$  target wheel after the bombardment with the  $^{50}\text{Ti}$  beam dose of  $4 \times 10^{17}$  ions/cm $^2$

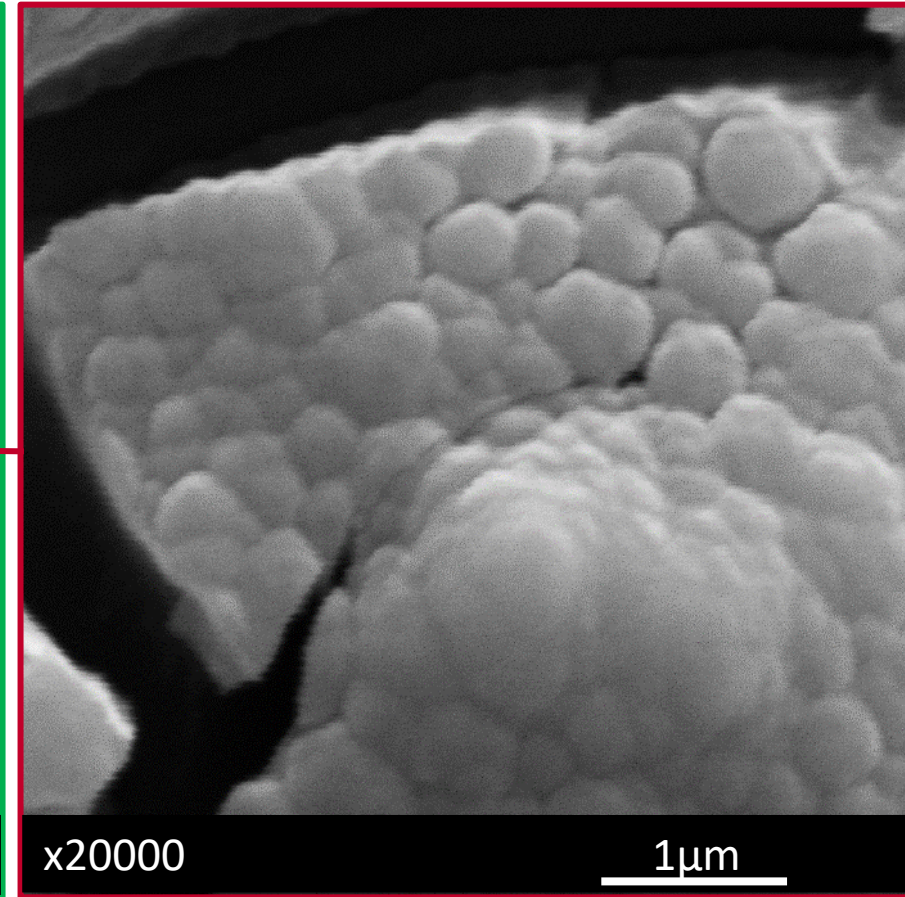
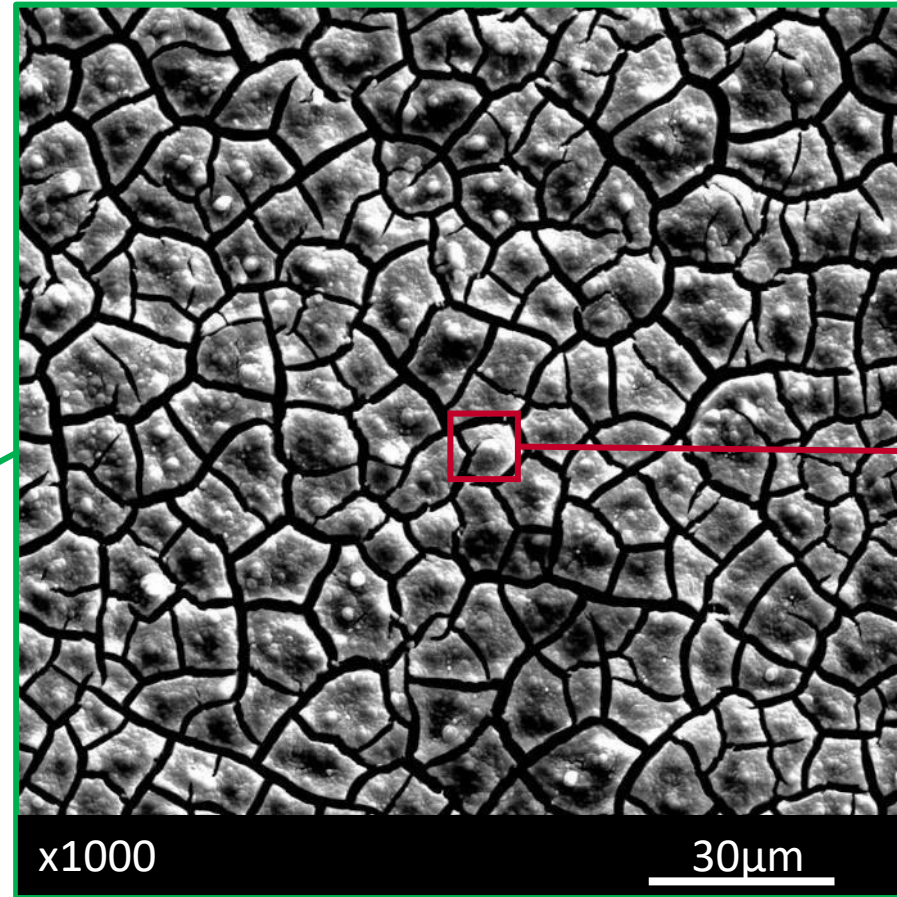
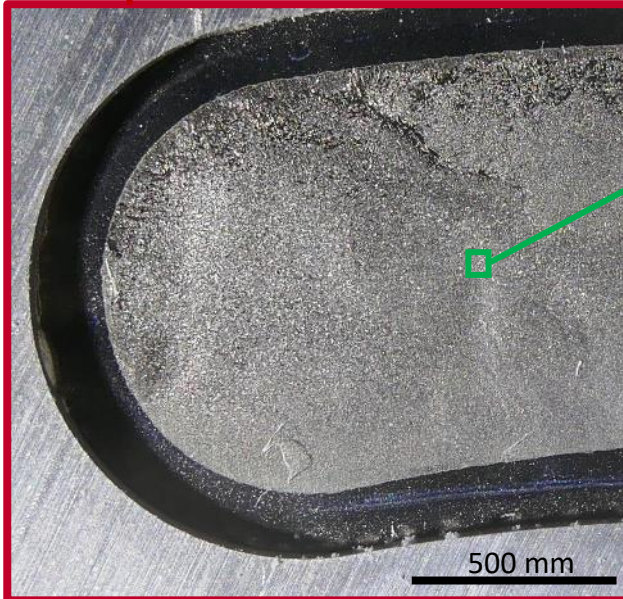
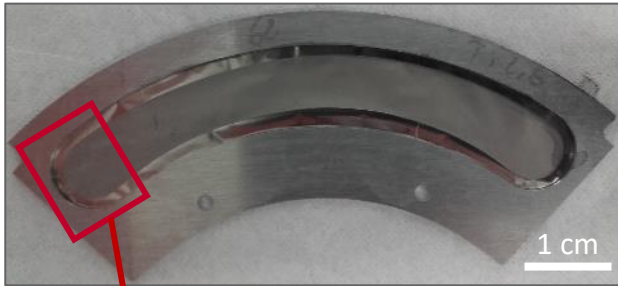
# Scope of the ongoing target analyses

- neutron activation analysis (NAA)
- **confocal Raman microscopy**
- nuclear magnetic resonance (NMR)
- elastic recoil detection analysis (ERDA)
- **Rutherford backscattering spectrometry (RBS)**
- **particle-induced X-ray emission (PIXE)**
- X-ray diffraction (XRD)
- grazing incidence X-ray diffraction (GIXD)
- atomic force microscopy (AFM)
- confocal 3D laser scanning microscopy
- **scanning electron microscopy (SEM)**
- energy dispersive X-ray spectroscopy (EDX)
- radiographic imaging (RI)



# Scanning electron microscopy of fresh MP thin films

La MP sample, 500  $\mu\text{g}/\text{cm}^2$  on a TASCA segment

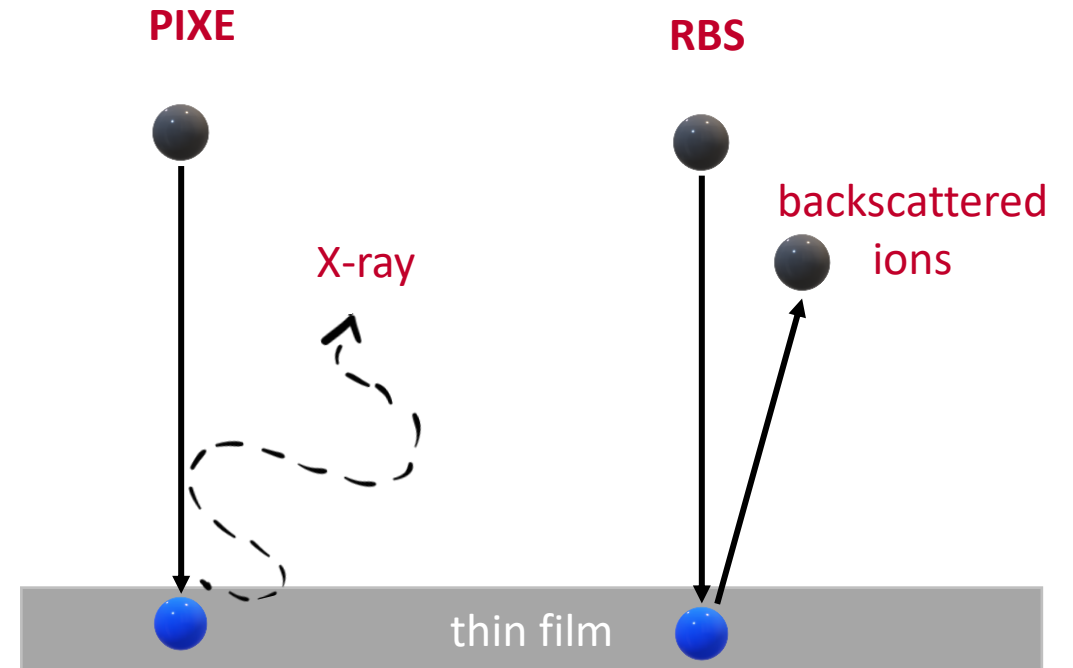
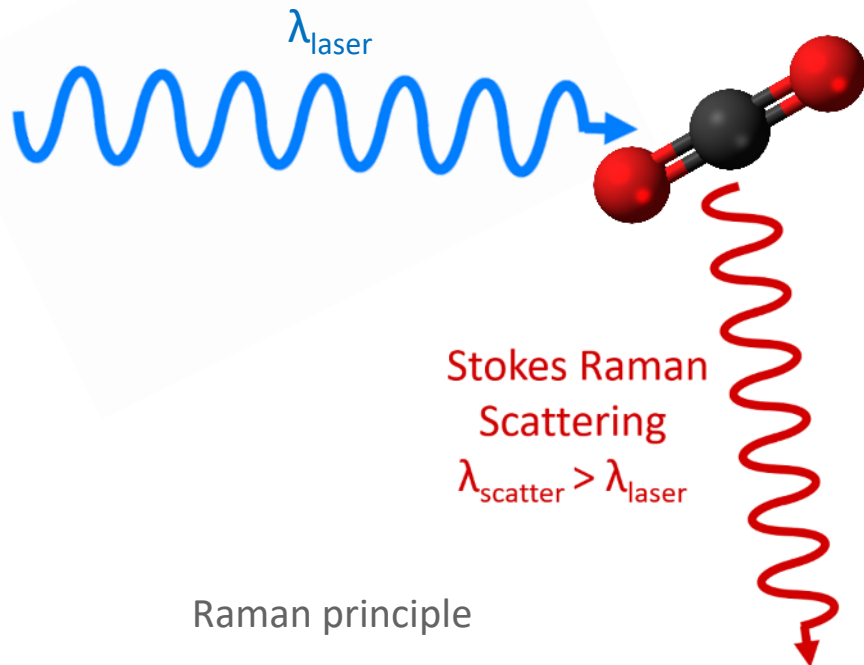


- mudcracking
- brittle tiles

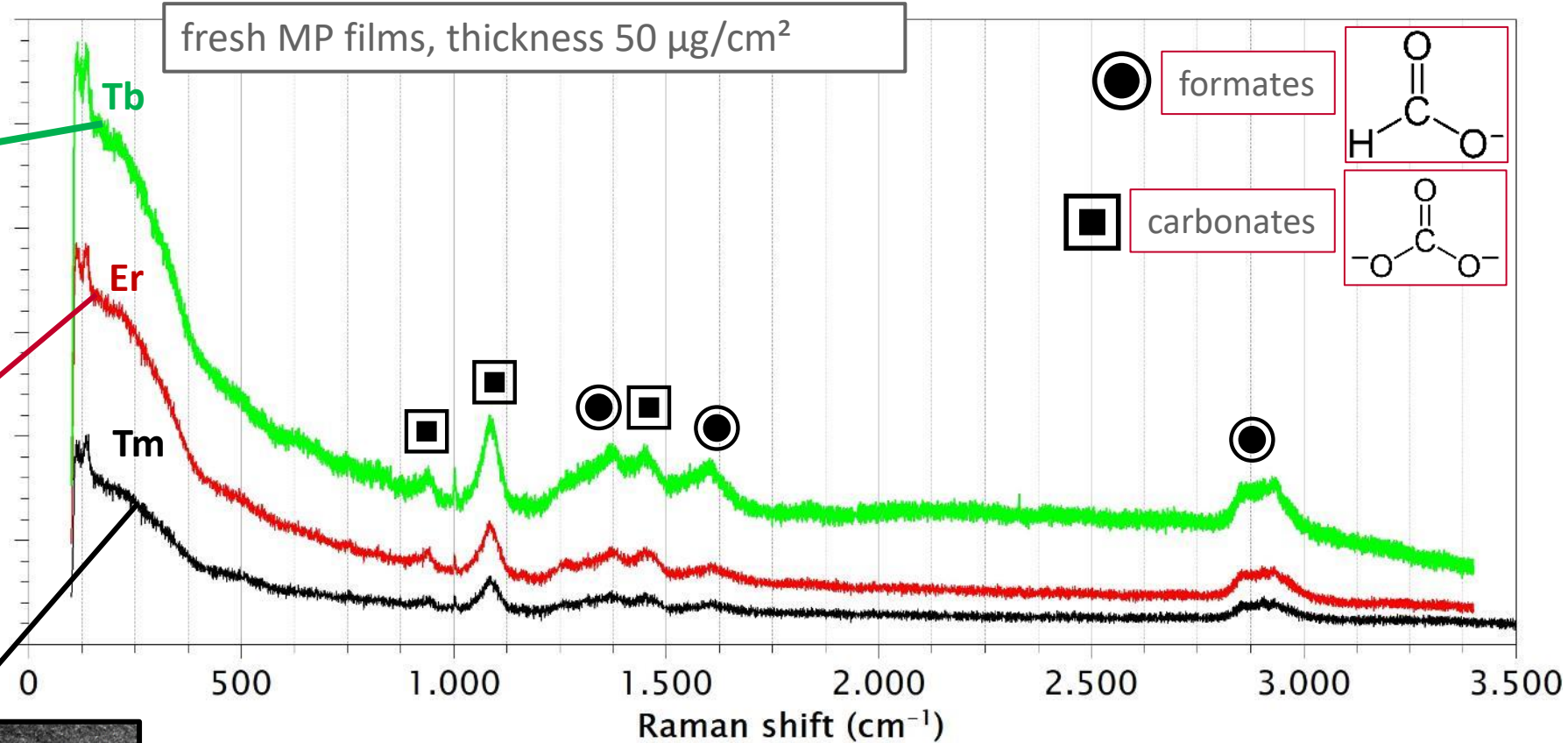
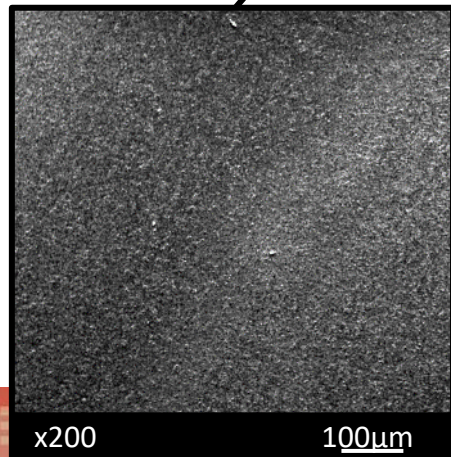
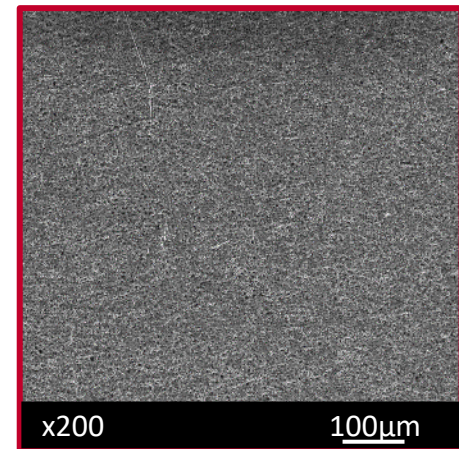
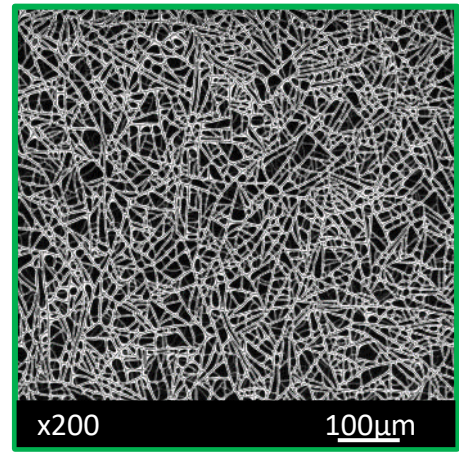
- mountains and valleys on the tiles
- spheroidal substructures in the tiles

# Analytical methods shown

- scanning electron microscopy (SEM) - **morphology**
- confocal Raman microscopy - **chemical information**
- ion beam analysis
  - particle-induced X-ray emission (PIXE) - **qualitative elemental distribution**
  - Rutherford backscattering spectrometry (RBS) - **quantitative elemental composition**



# Confocal Raman microscopy

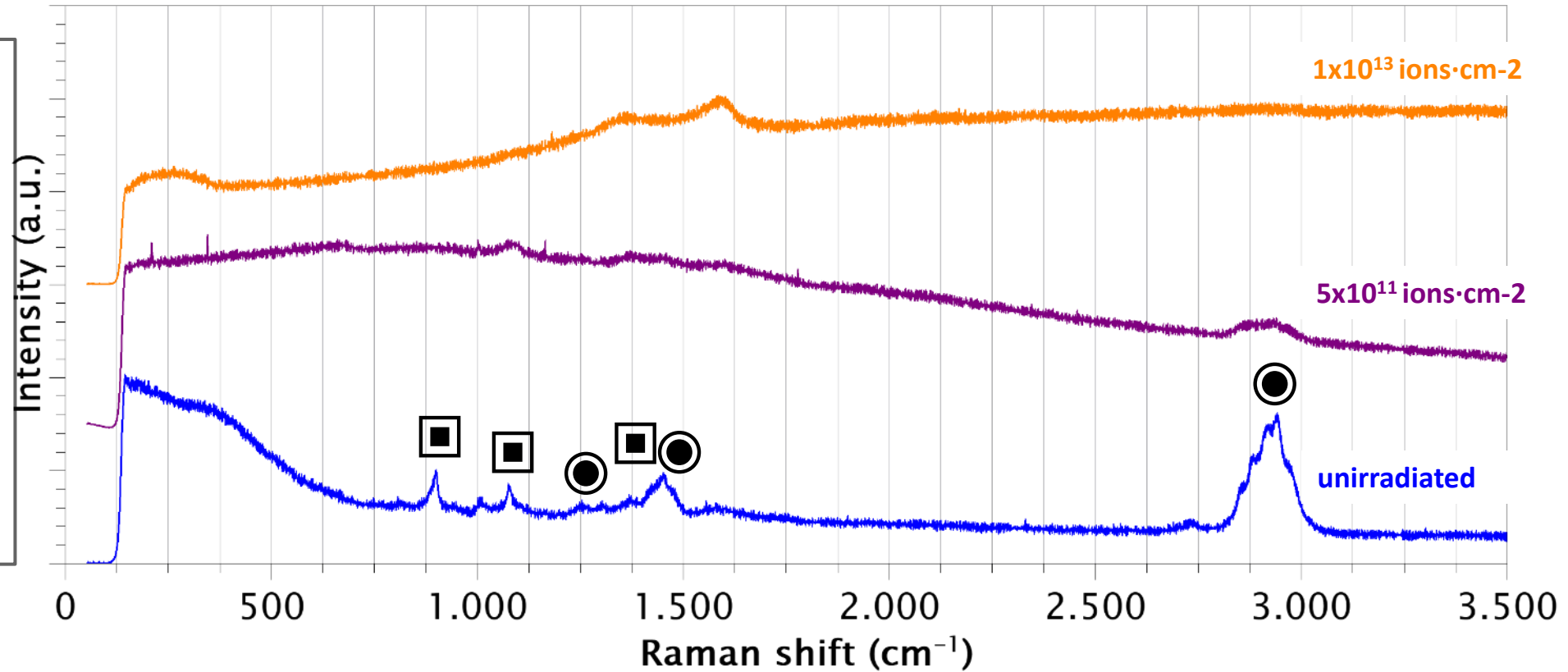


- Confocal Raman microscopy is suitable for investigating MP films
- No systematic connection to morphology
- MP films of **different** lanthanides show the **same** Raman spectrum
- Spectrum shows carbonates and formates

# Fluence series

Tm MP film, 250  $\mu\text{g}/\text{cm}^2$ , on 50  $\mu\text{m}$  Ti foil

- UNILAC irradiation:  
8.6 MeV/u Au-197
- fluence series:  
 $10^{11}$ -  $10^{13}$  ions $\cdot\text{cm}^{-2}$
- ion flux:  
 $2 \times 10^9$  ions $\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$
- characterization:  
Raman



- Carbon species disappears during irradiation
- Resulting chemical compound not identifiable via Raman

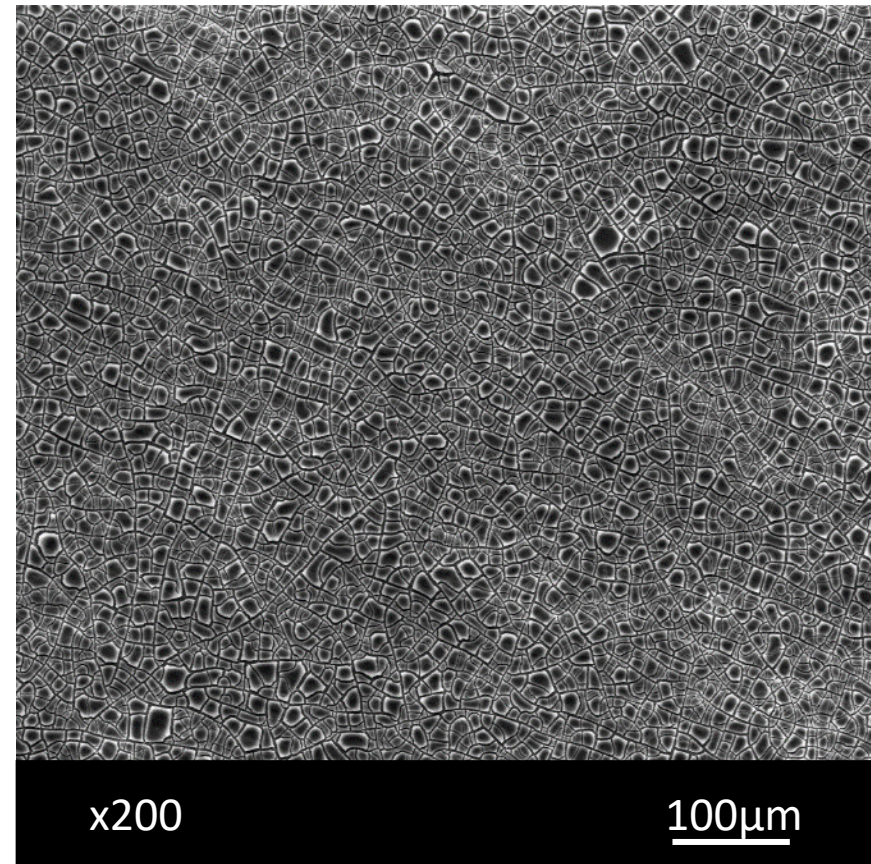


# Ion beam analysis (IBA) of fresh Tm MP targets

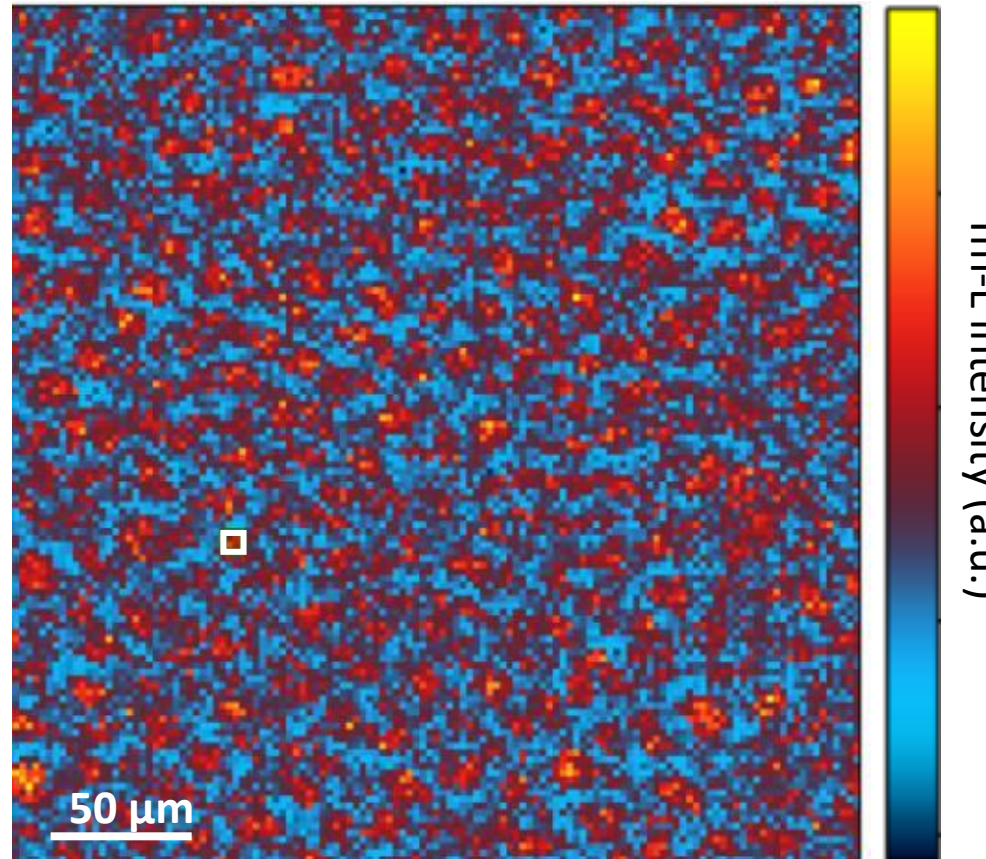
## preliminary data

- 3 MeV H<sup>+</sup> beam
- 7x5 μm<sup>2</sup> beam spot size
- thickness distribution of the tiles and the mudcracking
- individual tiles selected for RBS from the PIXE image

fresh Tm MP film, 500 μg/cm<sup>2</sup>, on 25 μm Ti foil



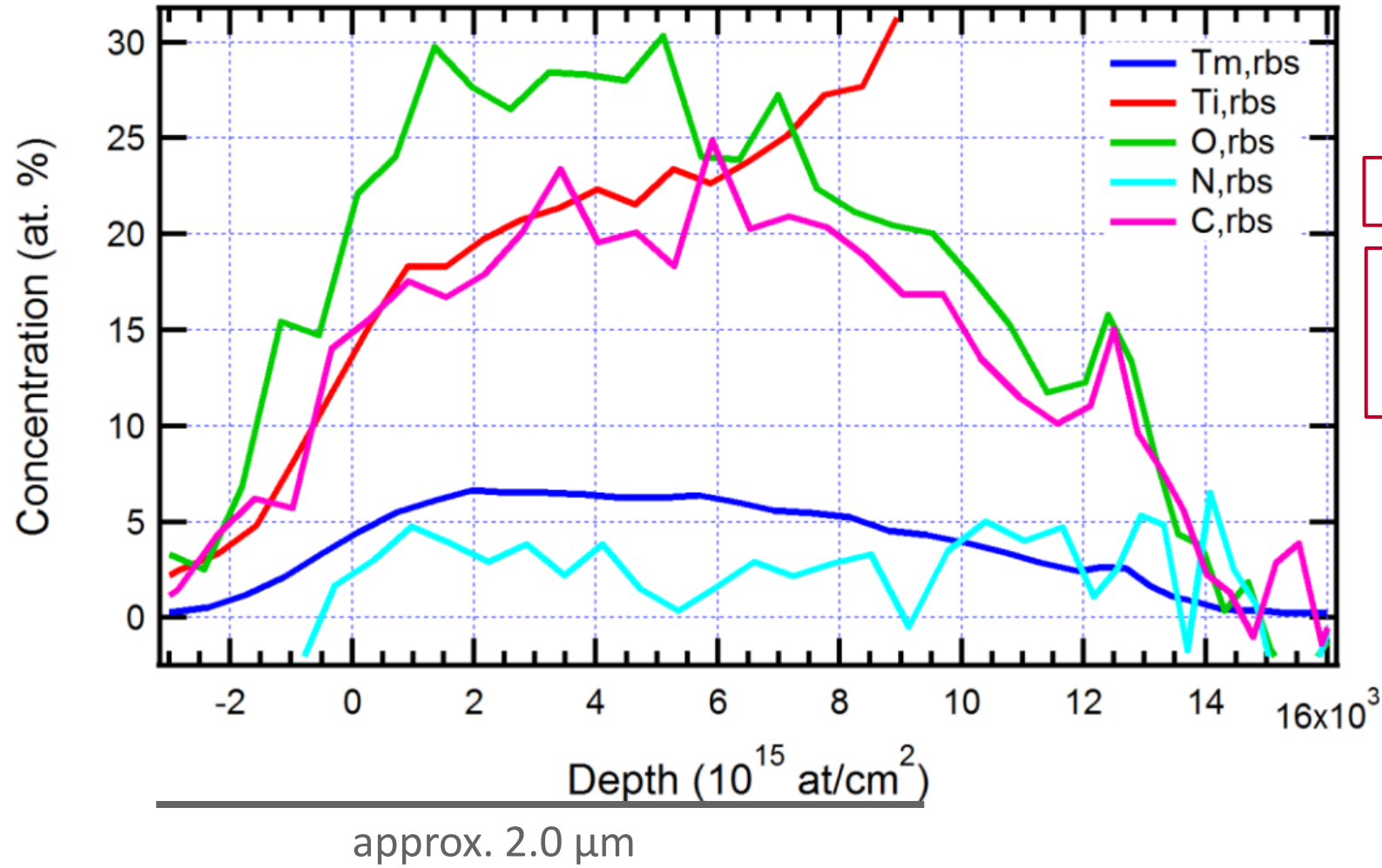
SEM picture from JGU, before irradiation



PIXE image from HZDR, during irradiation

# RBS of fresh Tm MP targets

fresh Tm MP film, 500  $\mu\text{g}/\text{cm}^2$ , on 25  $\mu\text{m}$  Ti foil

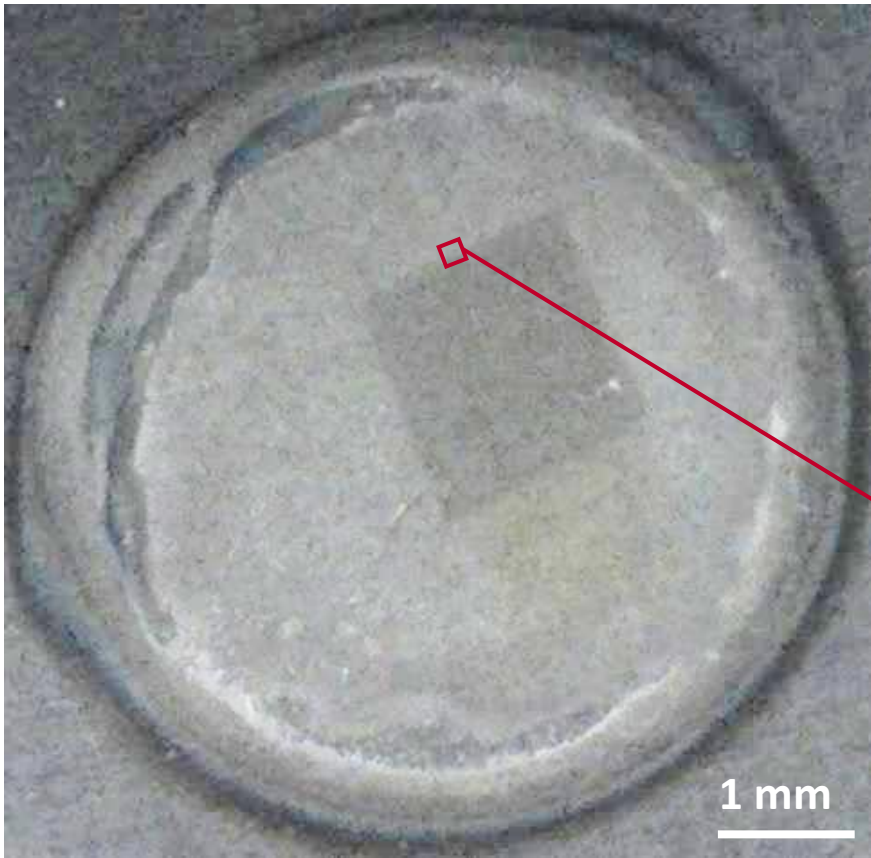


preliminary data

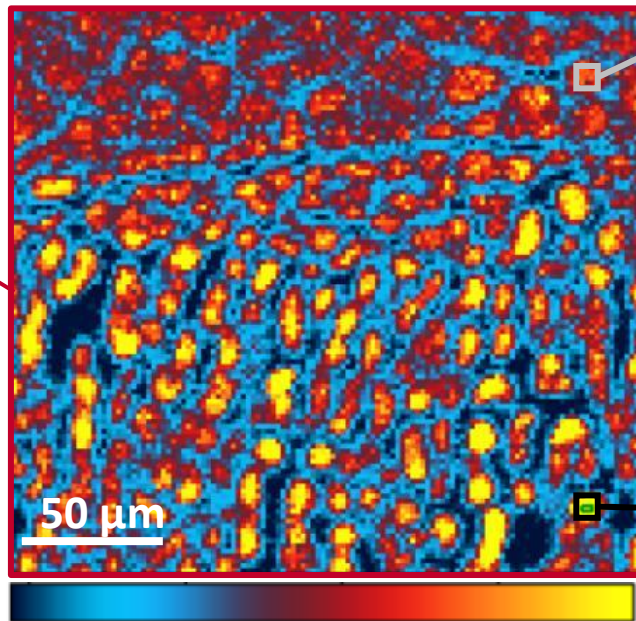
Fit of the RBS-data:  
carbon and oxygen dominate the thin  
film, nitrogen measurable.

# IBA of irradiated Tm MP targets

Tm MP film, 500  $\mu\text{g}/\text{cm}^2$ , on 25  $\mu\text{m}$  Ti foil



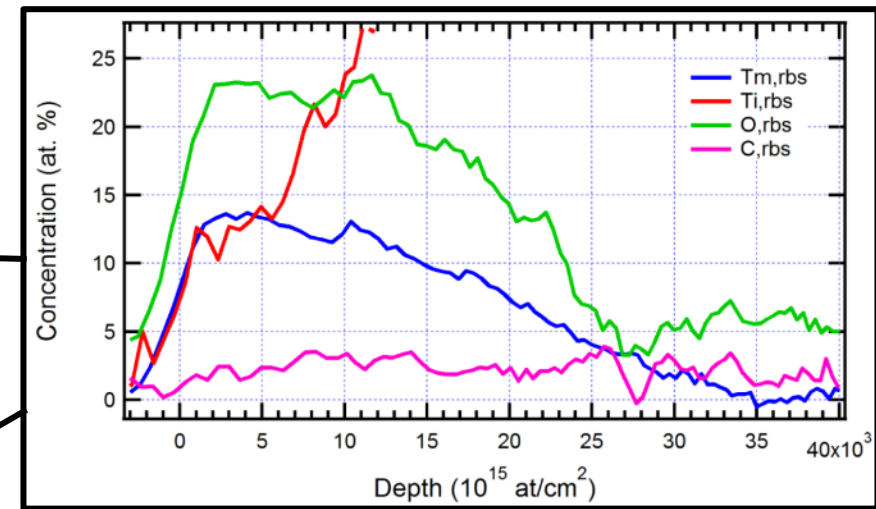
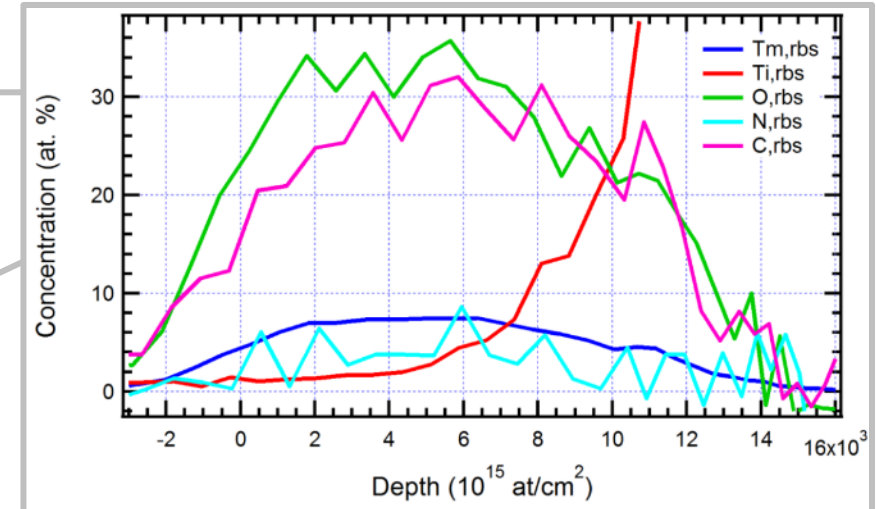
fresh Tm MP film



Tm-L intensity (a.u.)

irradiated Tm MP film

preliminary data

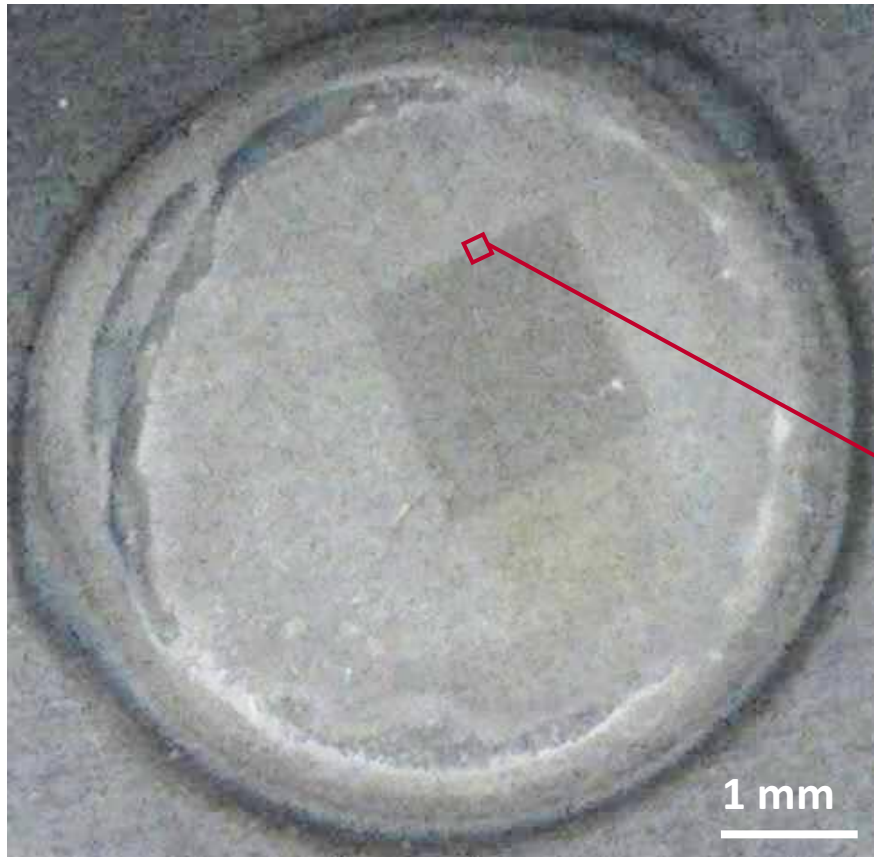


The  $^{169}\text{Tm}$  target after the bombardment with the  $^{35}\text{Cl}$  beam dose of  $2 \times 10^{14}$  ions/ $\text{cm}^2$

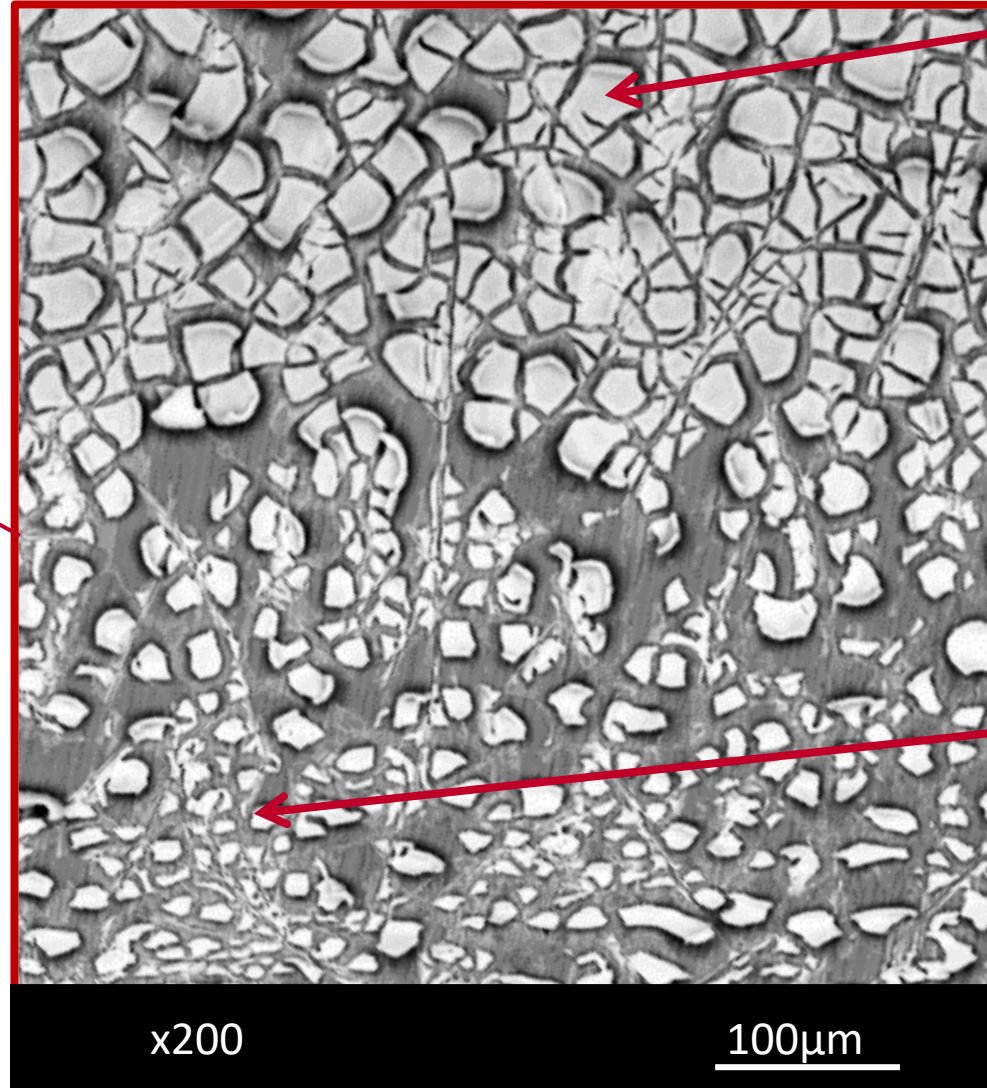
# SEM of irradiated Tm MP targets

preliminary data

Tm MP film, 500  $\mu\text{g}/\text{cm}^2$ , on 25  $\mu\text{m}$  Ti foil



The  $^{169}\text{Tm}$  target after the bombardment with the  $^{35}\text{Cl}$  beam dose of  $2 \times 10^{14}$  ions/ $\text{cm}^2$



fresh Tm MP film

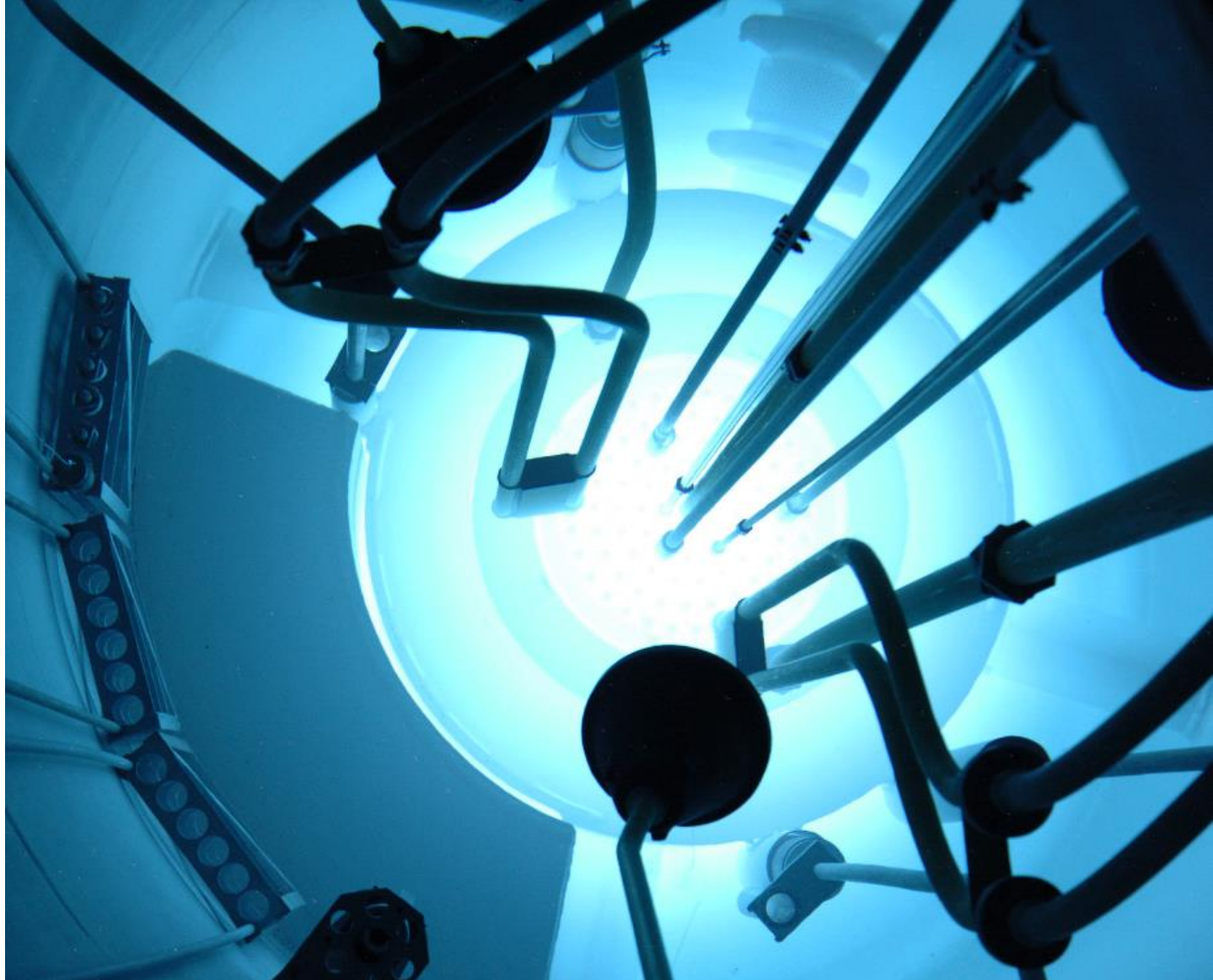
irradiated Tm MP film

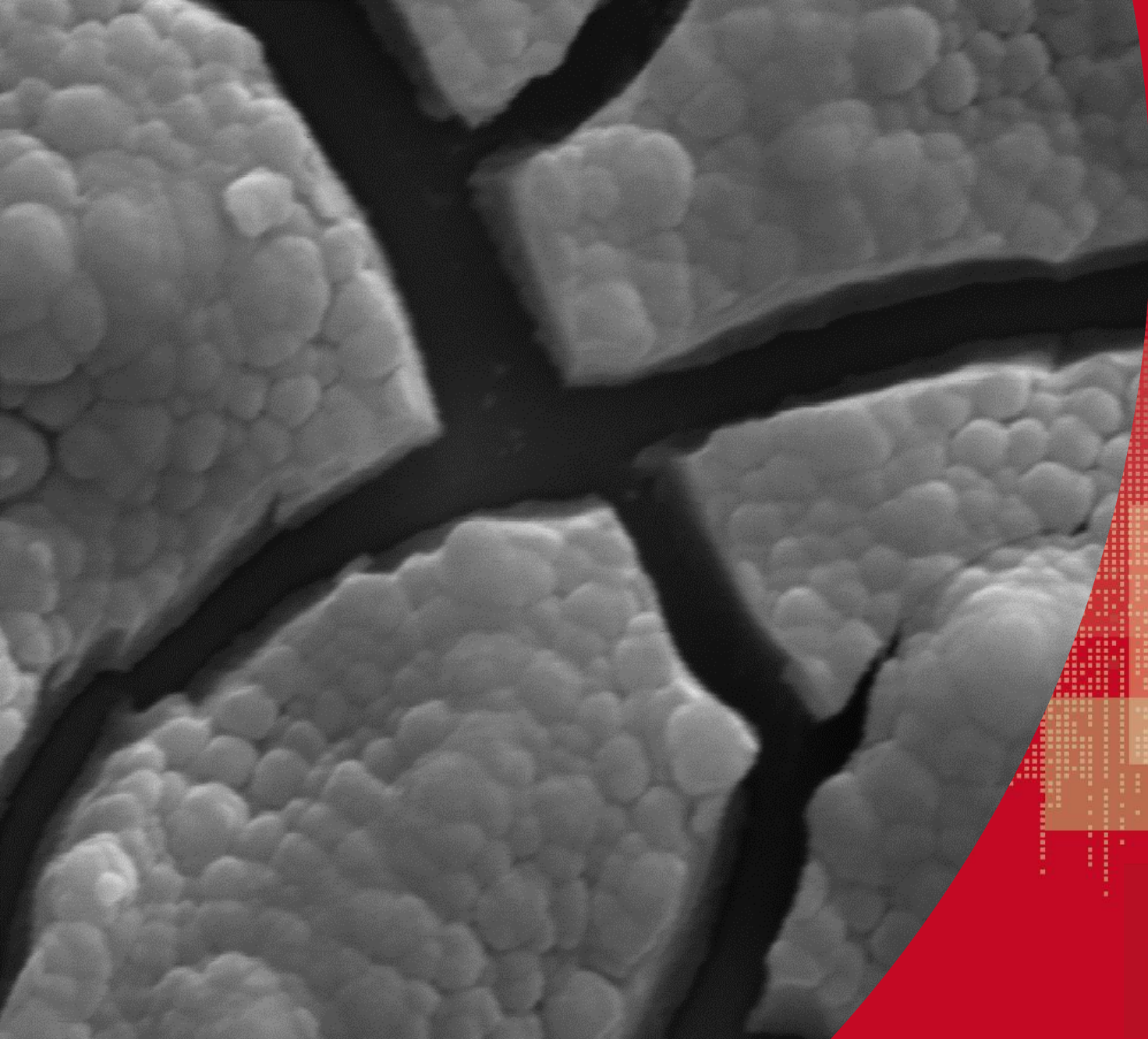
# SUMMARY

- Molecular Plating produces not only oxides and hydroxides, but also carbon compounds.
- The carbon compounds are a mixture of formates and carbonates.
- Irradiation leads to the loss of carbon compounds in the MP thin films and the formation of an unidentified oxidic compound.
- The thin films are compacted by irradiation, meaning that the newly formed chemical compound likely has a higher density.

# ACKNOWLEDGEMENTS

Electrical and precision mechanics workshops of the research reactor TRIGA Mainz.





**Thank you very much  
for your attention!  
Questions?**