Research With Explosives at the University of Adelaide

Thomas de Prinse

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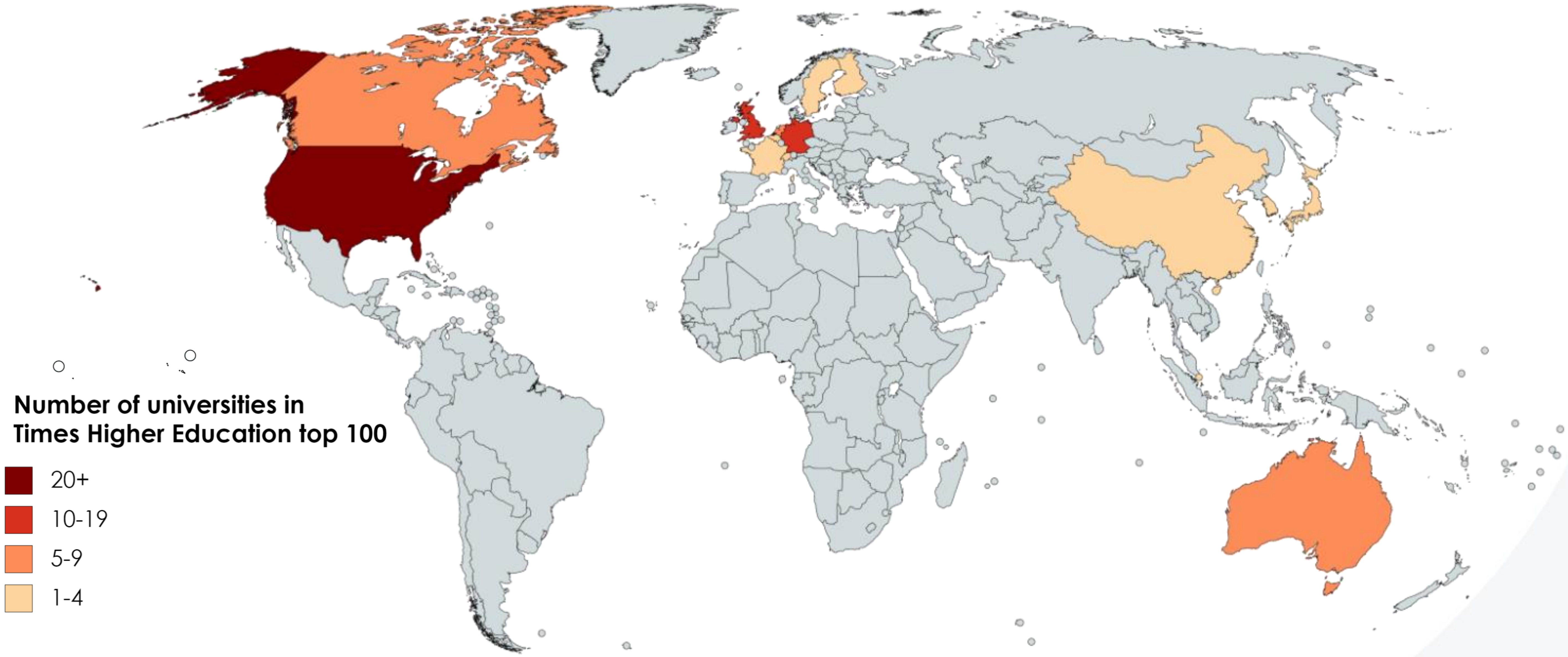
make history.

Why Partner With a University?



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My Research Group

- Prescott Environmental Luminescence Laboratory (PELL) within the Institute of Photonics and Advanced Sensing (IPAS) at the University of Adelaide
- Led by Professor Nigel A. Spooner
- Use optical fluorescence sensing to solve problems in mining, space and defence

Prototype using fluorescence for on-belt detection of fluorine levels in coal

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Obtaining Explosive Samples

- My PhD project was funded by Defence to look at fluorescence detection of explosives for standoff optical sensing. A 2 year project with a post doc

  (Grand Challenge, Counter Improvised Threats – CIT-186)

- Obtained a Permit to Purchase explosives (to acquire samples from DSTG) and a Licence to Store explosives in 2020
  - Maximum quantity of 2 grams total
  - Took us at least 12 months of paperwork
  - Obtained the first samples 2 months after the project was completed

- The delay was mostly because I had to personally write all the safety documents from scratch (no real prior precedent)
  - The documentation had to actually be good

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Licencing Process Involvement

- DSTG
  - Reviewed documentation, suggested changes, provided expertise and needed legitimacy
  - Provided ‘Explosive Safety Awareness Course’ for all lab users in 2019 (and myself in 2020, 2021)
  - Provided explosive samples (covered importation, transport licences)
  - Ran through laser process with us on first day, signed off proficiency documentation for the University
- University of Adelaide HSW Team
  - Thoroughly reviewed documentation
  - Undertook lab inspections
  - Handled communications with the regulatory body (SafeworkSA)
  - Involved top levels of faculty (head of school, executive Dean)
- SafeworkSA
  - Provided Permit and Storage Licence, undertook lab inspections
  - Translated some of the legal documentation for us (from 1936…)

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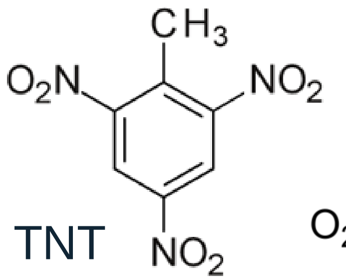
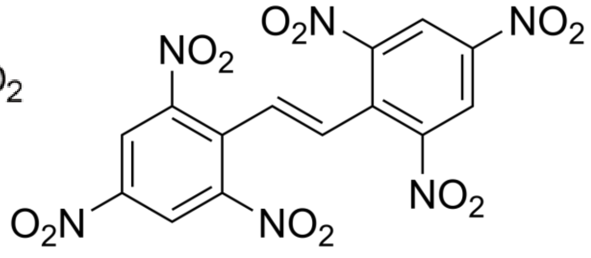
Current Explosive Storage

- Currently have 100 mg of 12 different secondary explosives in the University lab
- Stored in our optics lab, but permit is for the whole science + engineering faculty

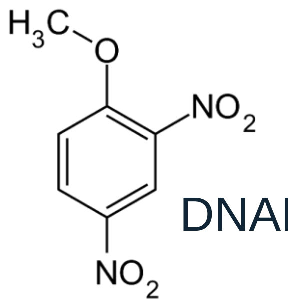
Nitroaromatics



TNT

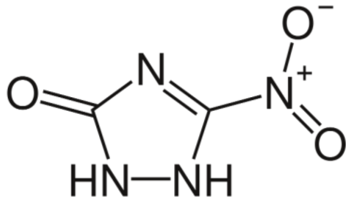


HNS

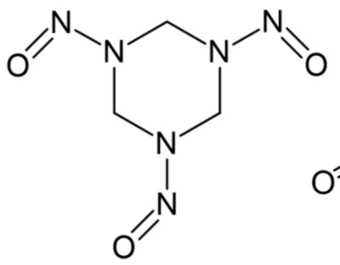


DNAN

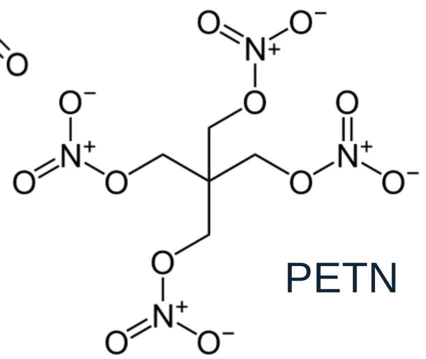
Other Secondary Explosives



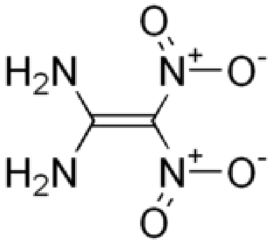
NTO



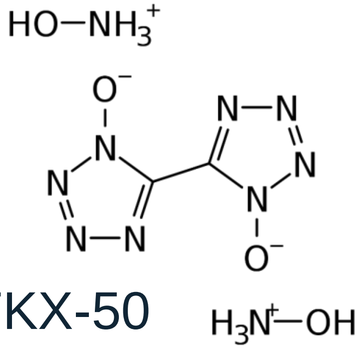
R-Salt



PETN



FOX-7

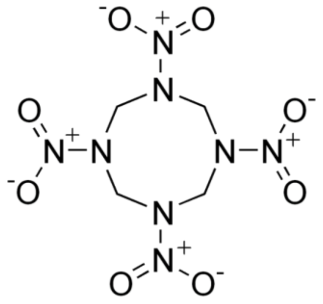


TKX-50

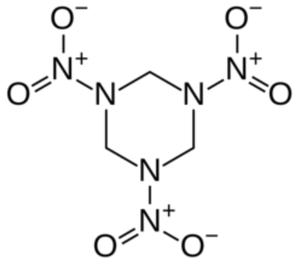
NH_4NO_3

AN

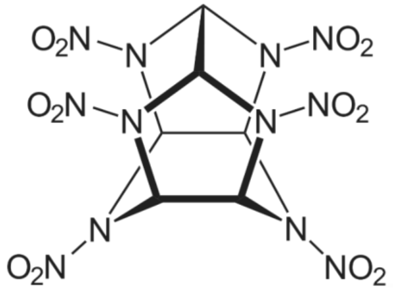
Nitramines



HMX



RDX



CL-20

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Project Ideas using <1 Gram Licence

- Optical detection methods
  - Laser detection
  - IR reflectance/hyperspectral
  - Terahertz
- Chemical sensing techniques
- Thermal decomposition (TGA)
- Mass spectrometry/Isotope tracing studies
- Crystallography (XRD, PXRD)
- Morphology, particle size
  - SEM/TEM imaging
- Synthesis of novel compounds
- Environmental decontamination

My Projects Using Small Quantities of Explosives

1. Stability of explosives under pulsed laser excitation (DSTG Internship)

2. Fluorescence detection for standoff detection of explosives (PhD Project)

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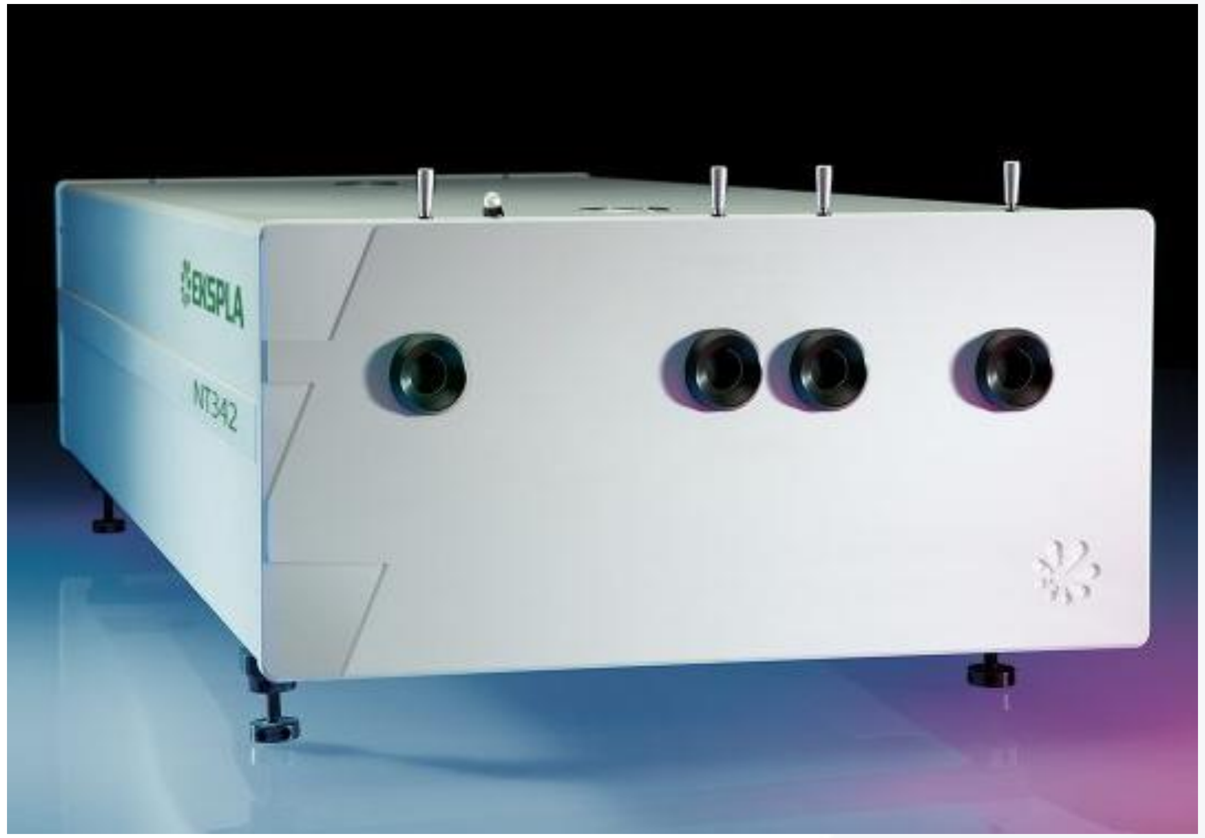
Project 1 - Laser Stability of Explosives

- Can we quantify laser safety thresholds?
    - Does a degraded surface change initiation risk?
    - Are events more likely at the start, or after a delay time?
    - What role does laser wavelength play?
    - Do different classes of explosive respond the same to a laser?
    - Can the laser stability or sensitivity of an explosive be predicted from its other properties?
- Low repetition rate (10 Hz) laser, can vary wavelength from 210nm to ~2600 nm while other settings remain the same
- Nanosecond pulses with ~40 mJ/pulse (Megawatt peak power)
    - About 1/10th the intensity needed to directly initiate explosives by laser pulse alone



de Prinse, T., Armitt, D., Rogers, B. & Spooner, N. A. **"Stability of explosives under continued laser pulse exposure"**. *Science and Technology of Energetic Materials* Vol. 83, p65-70 (2022).

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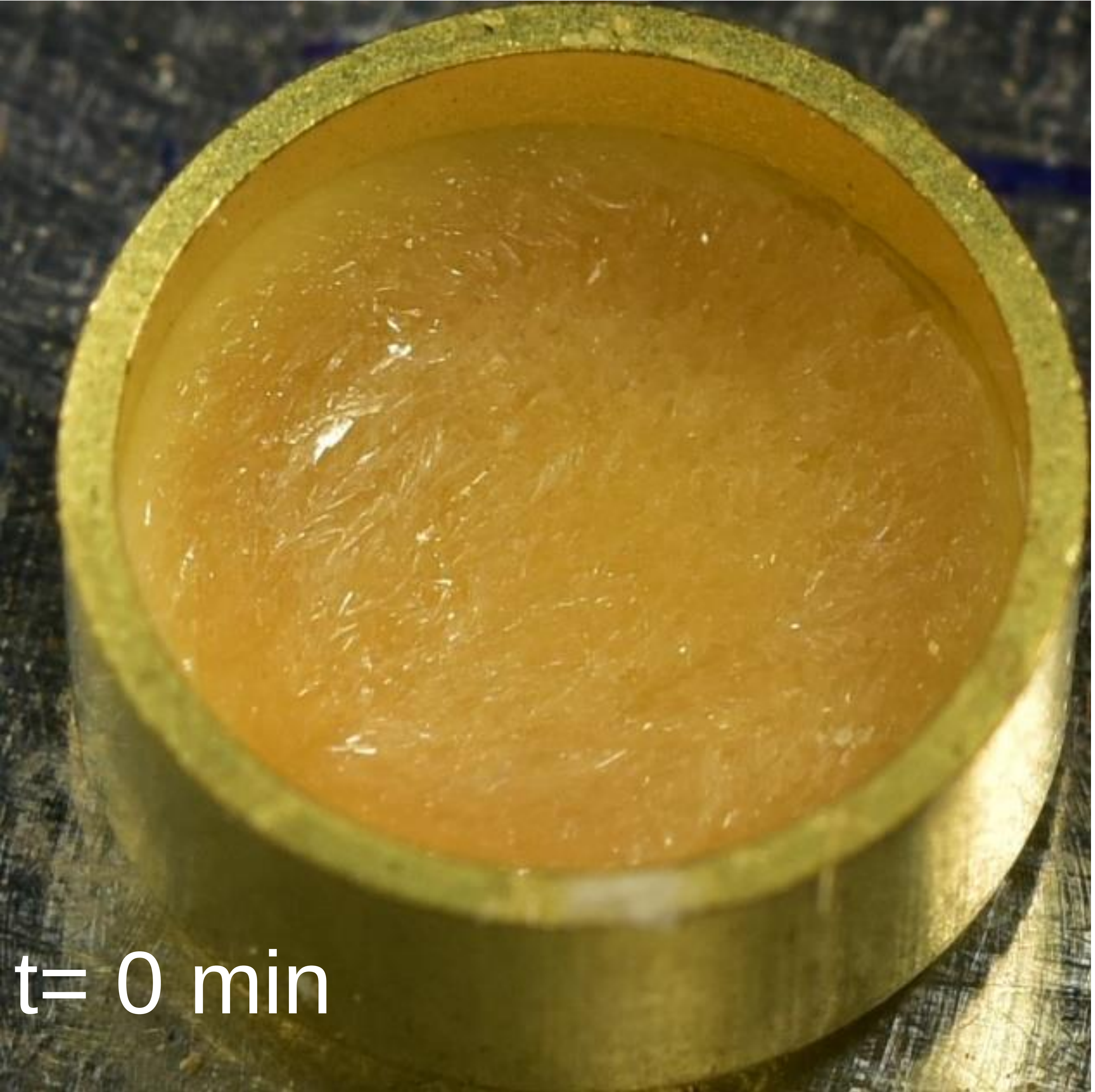
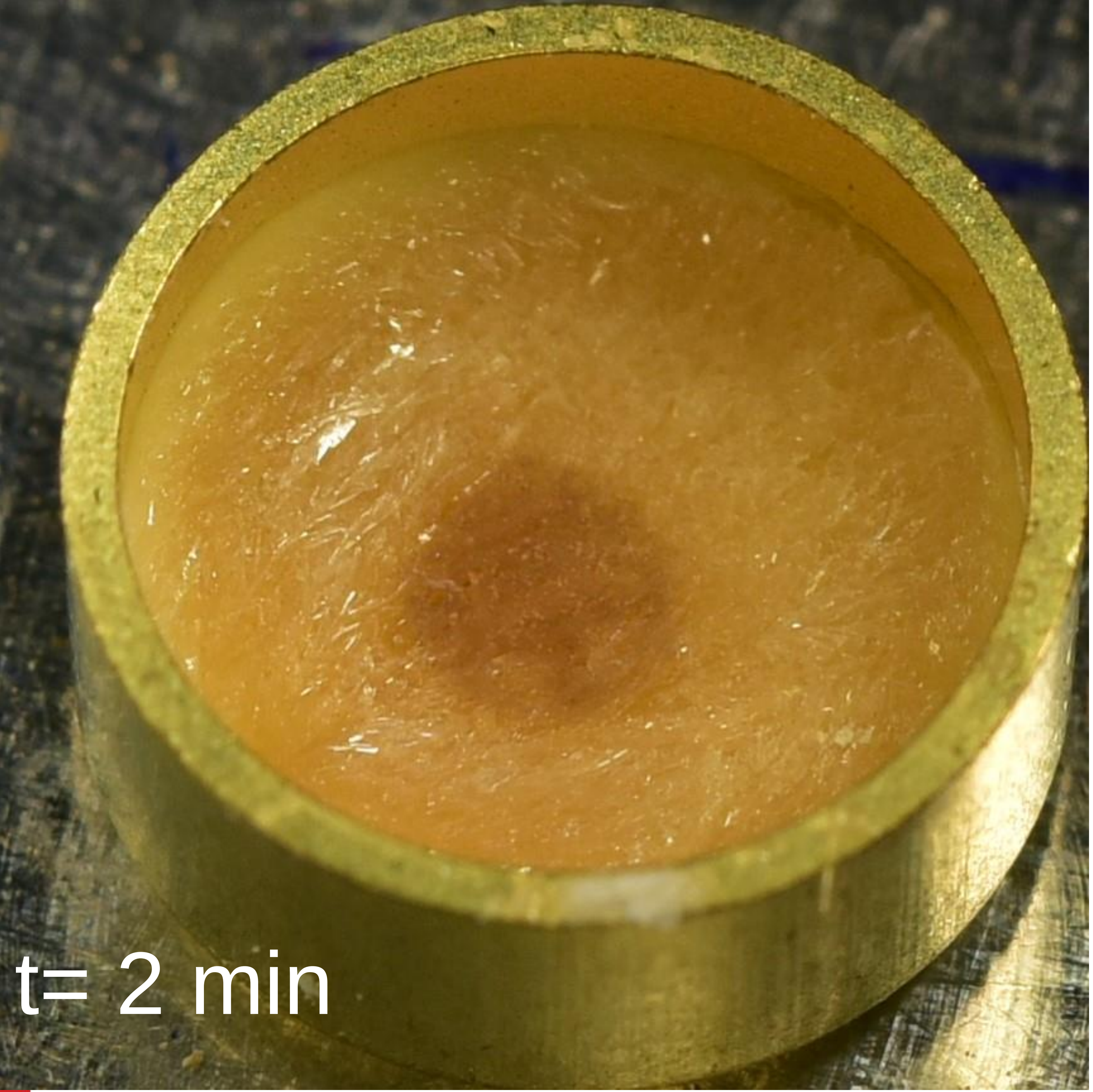
420 nm, 6 mJ





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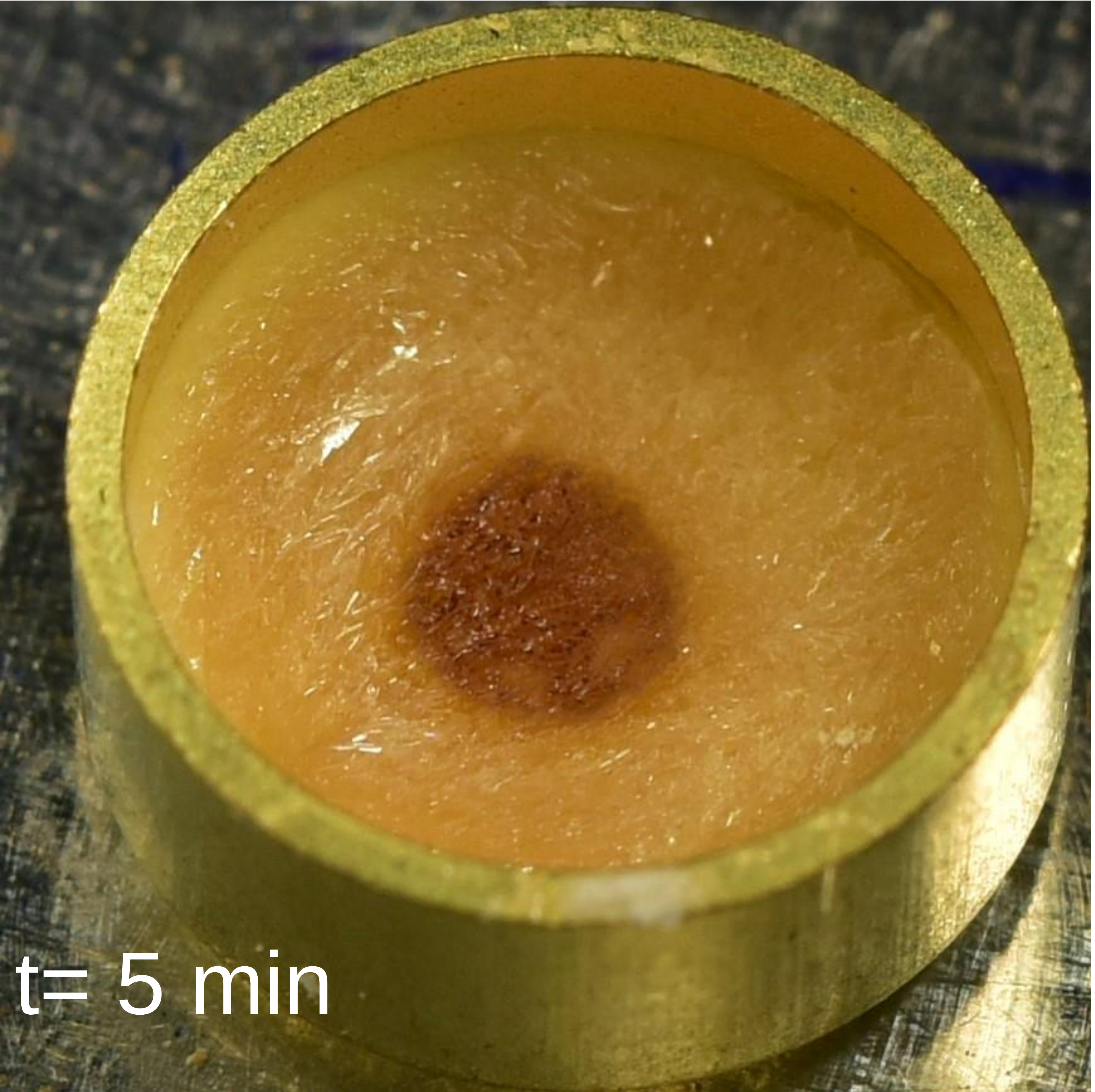

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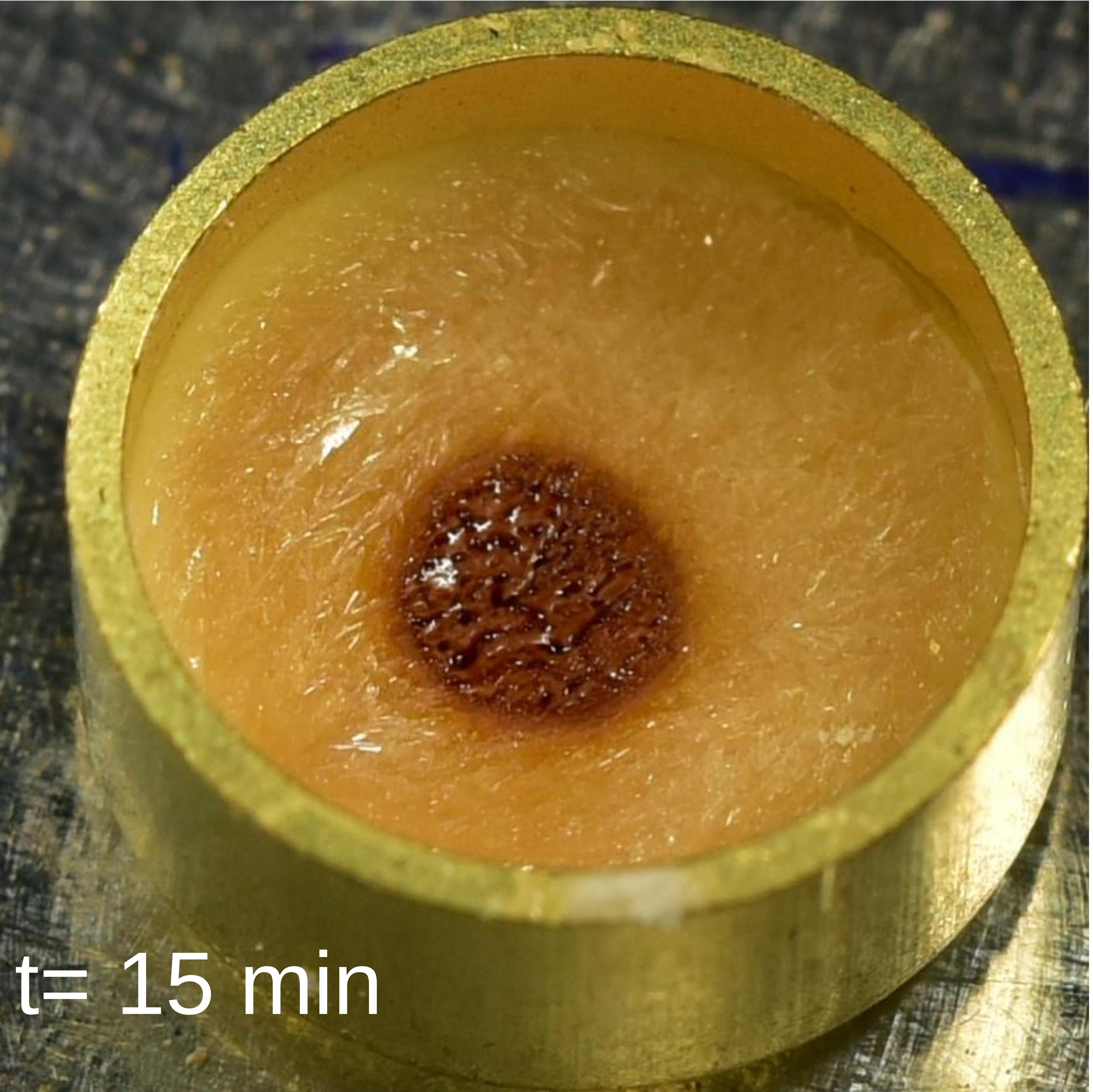

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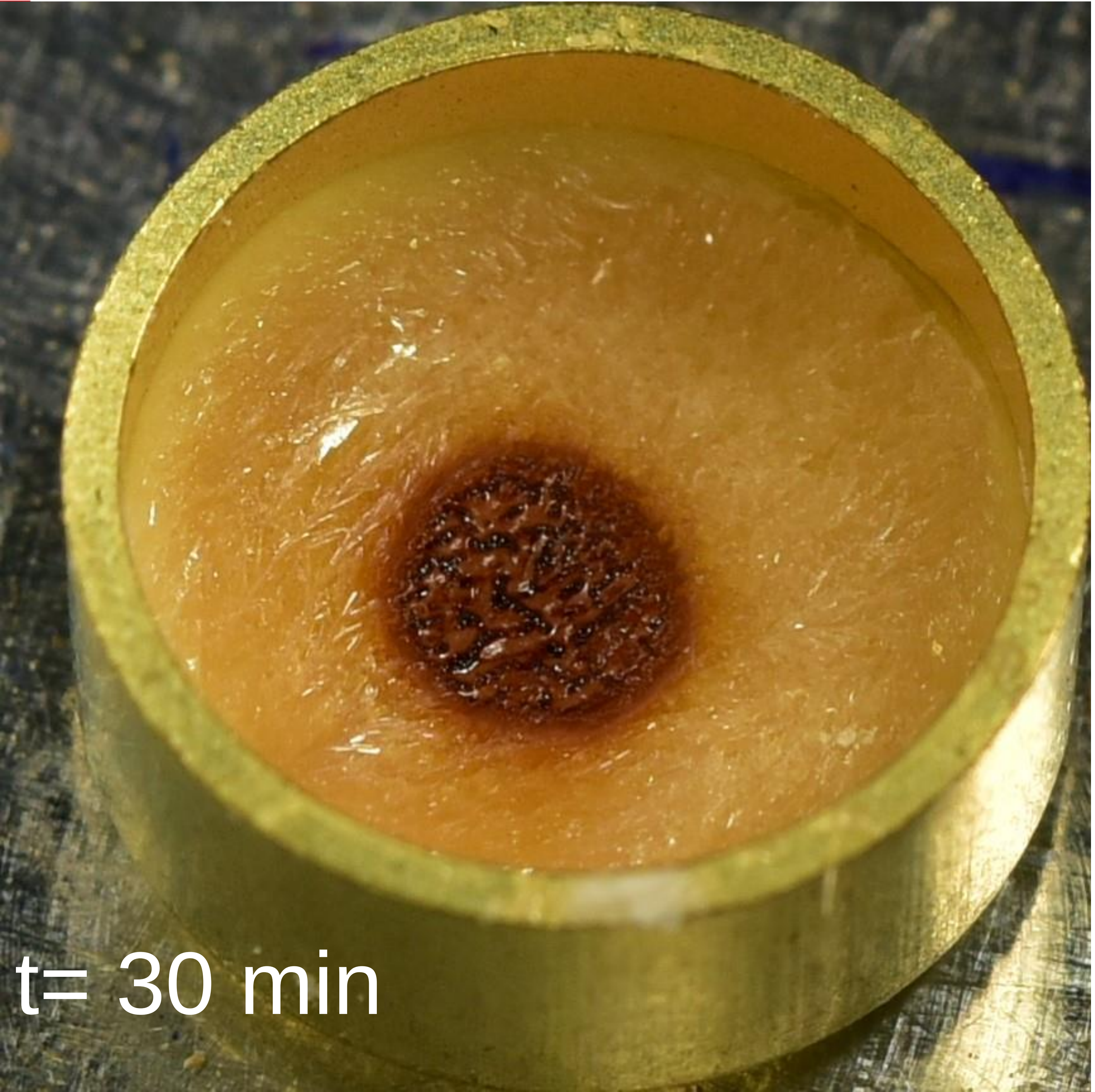

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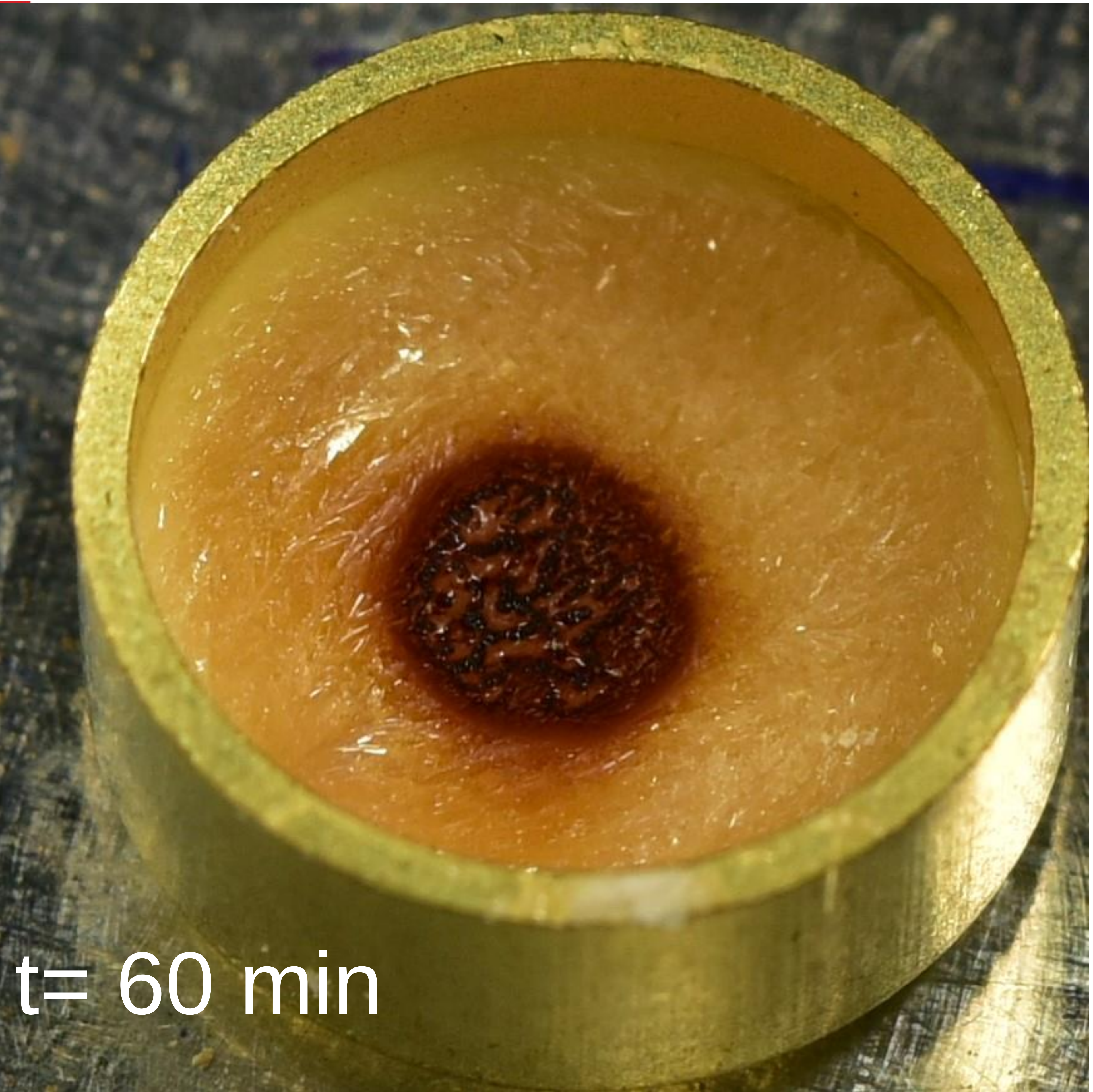

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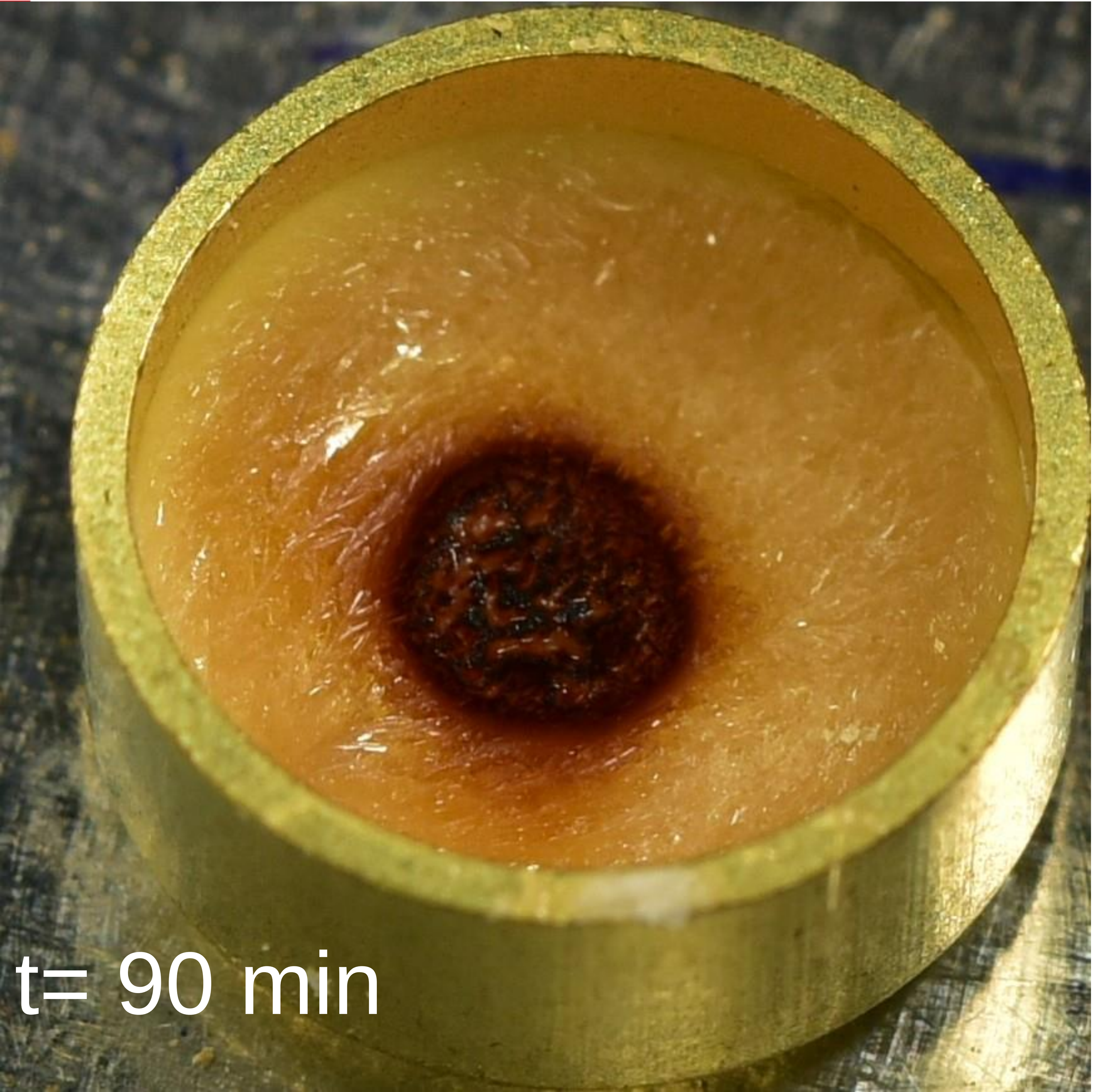

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532 nm, 6 mJ

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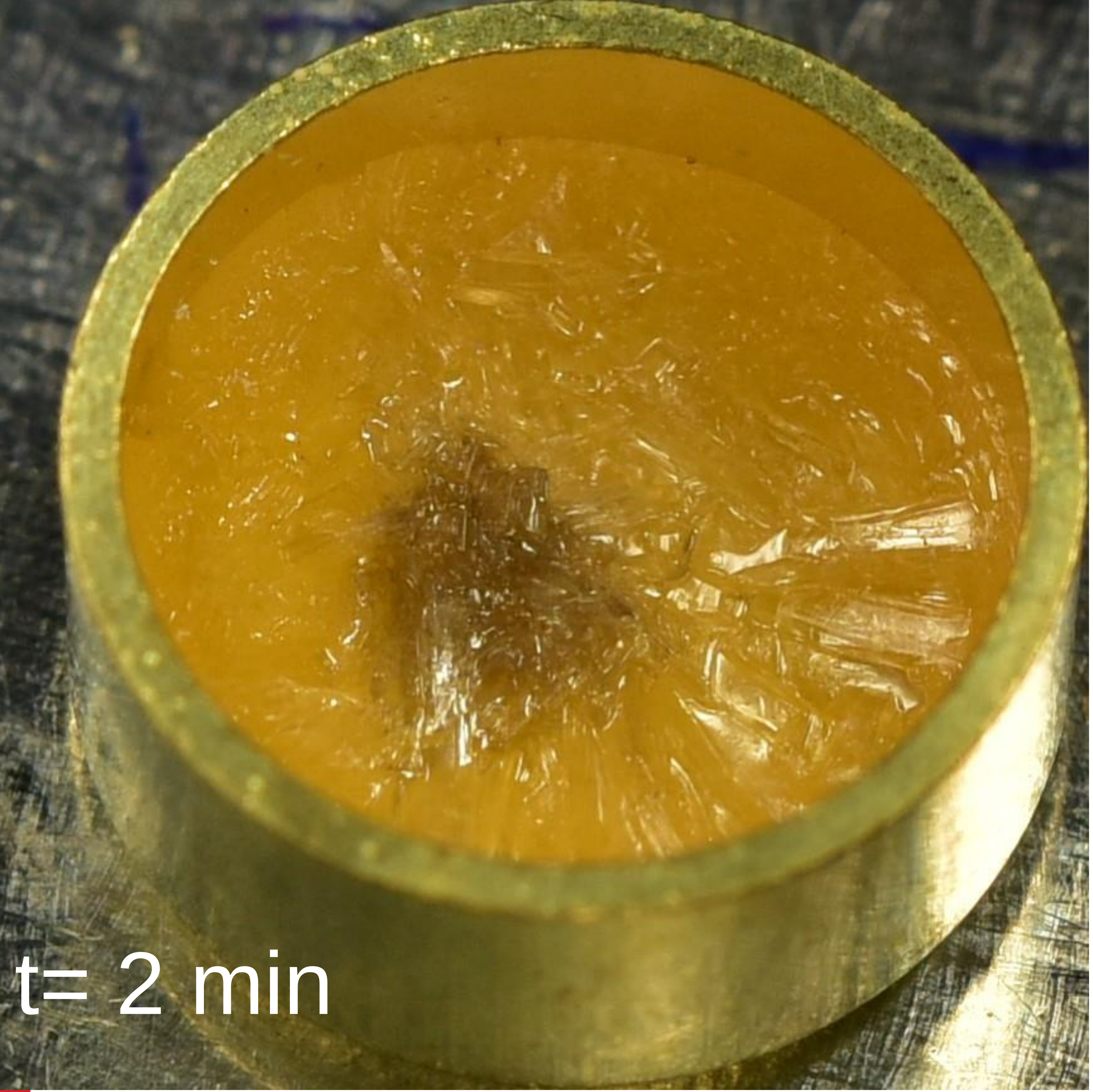
532 nm, 6 mJ



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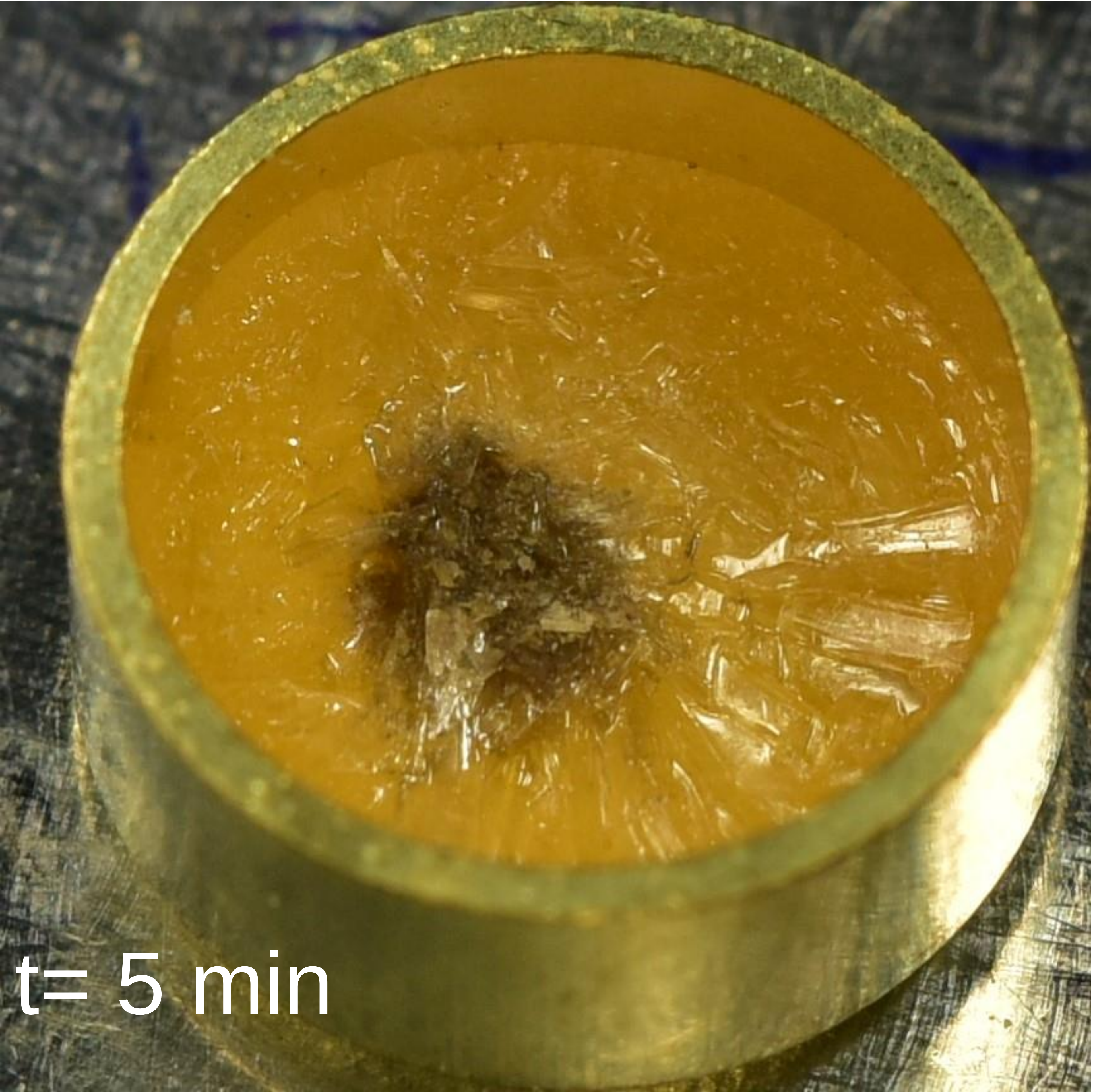
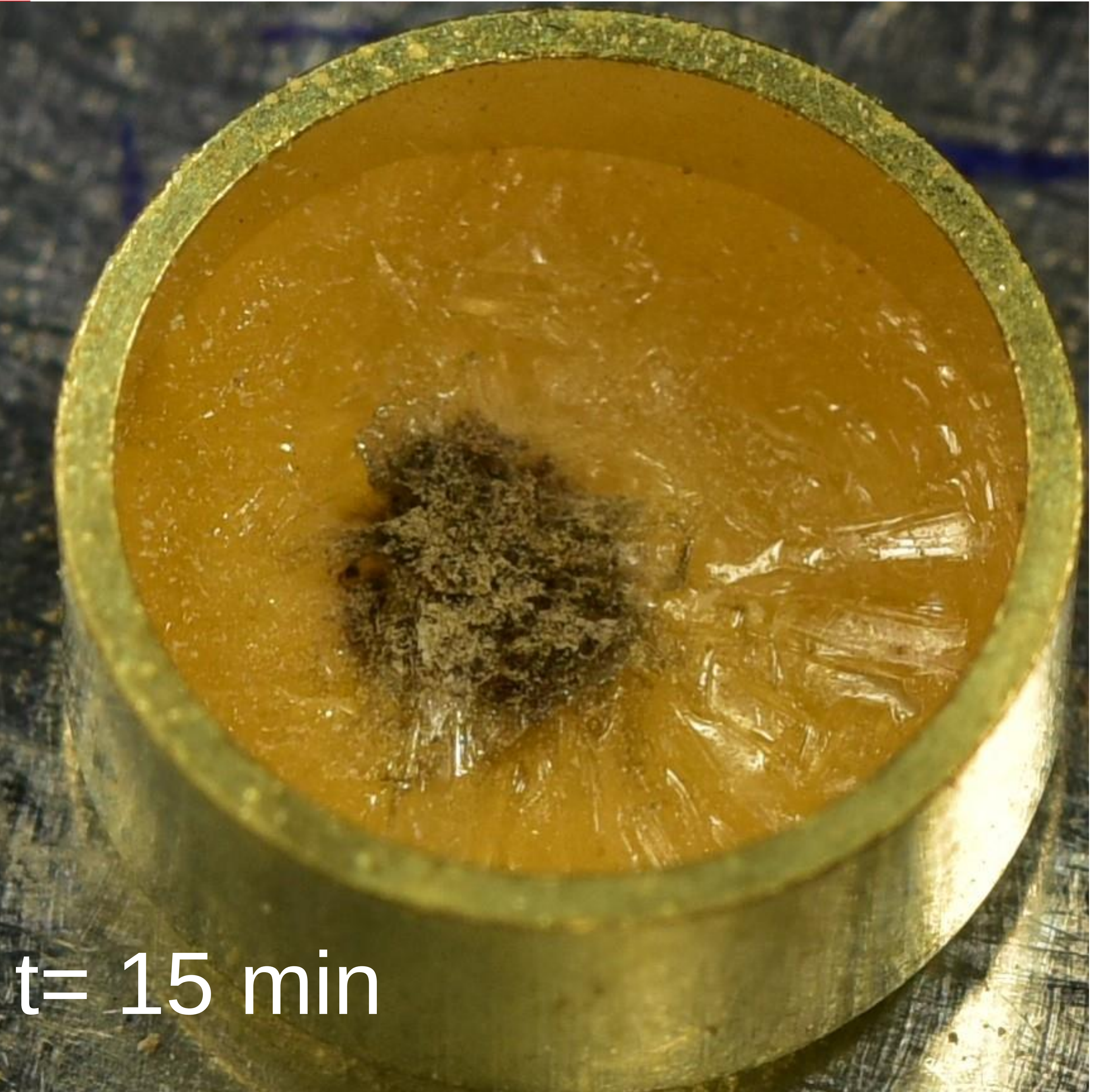
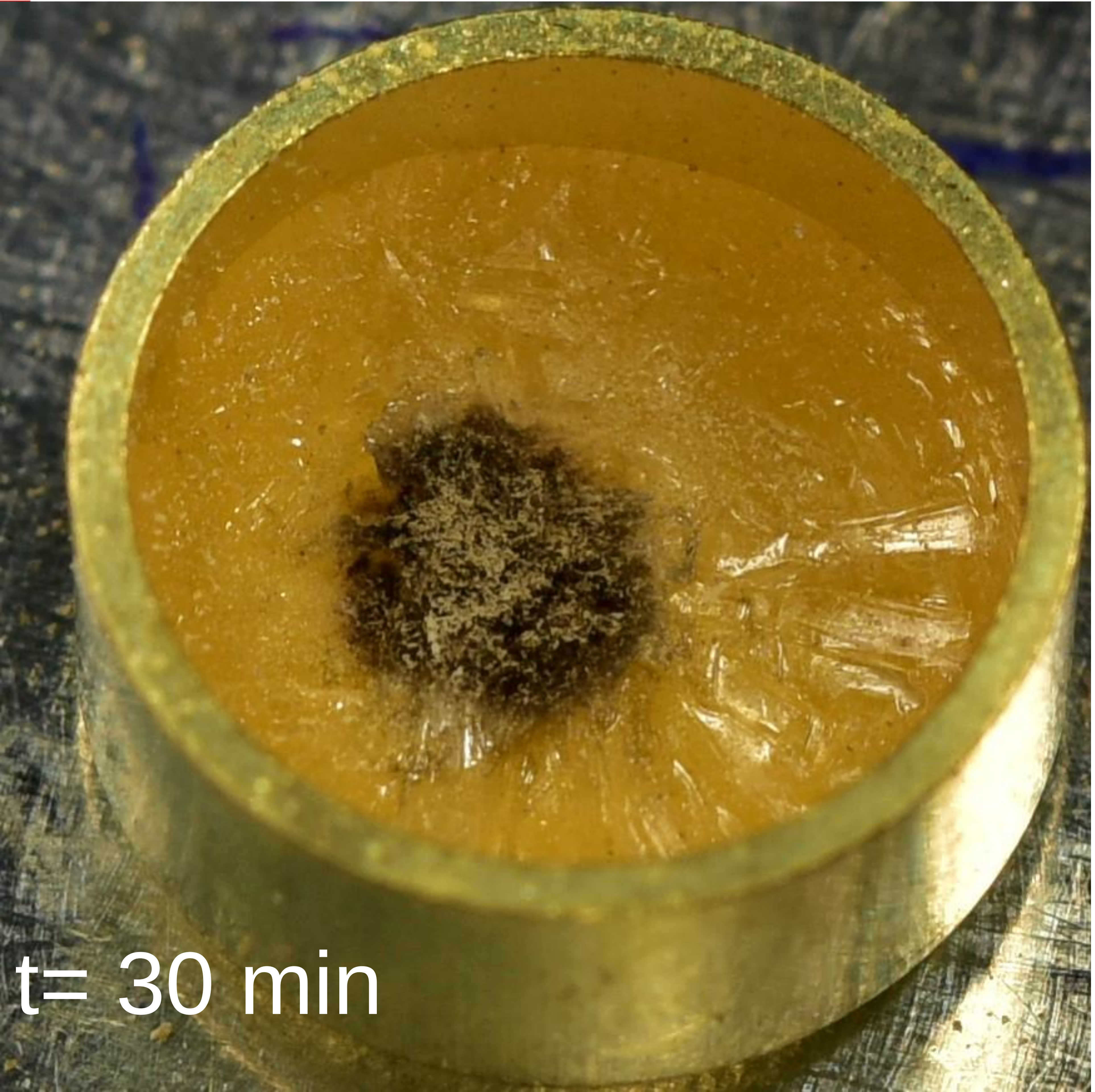
532 nm, 6 mJ



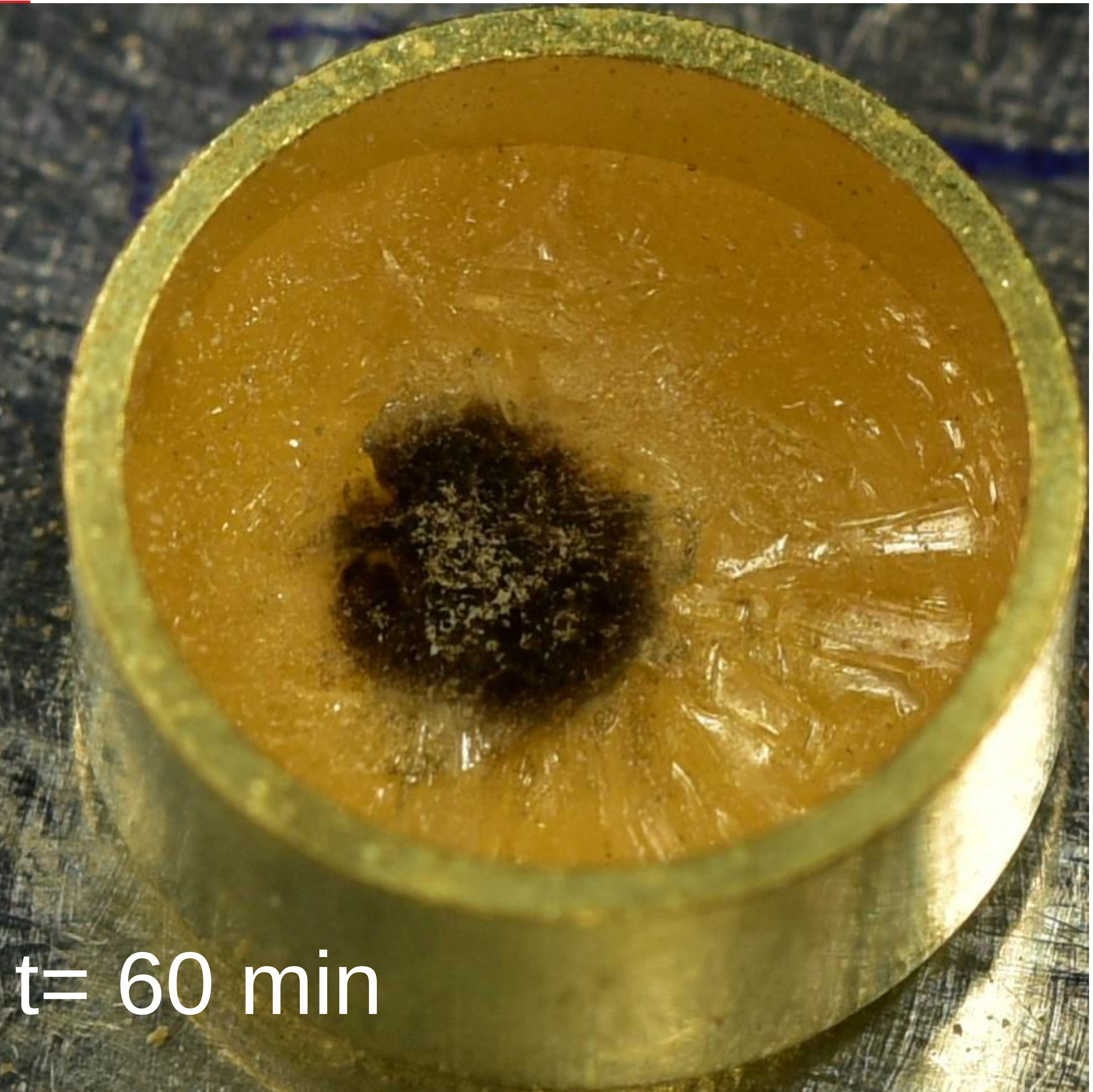
532 nm, 6 mJ



532 nm, 6 mJ



532 nm, 6 mJ



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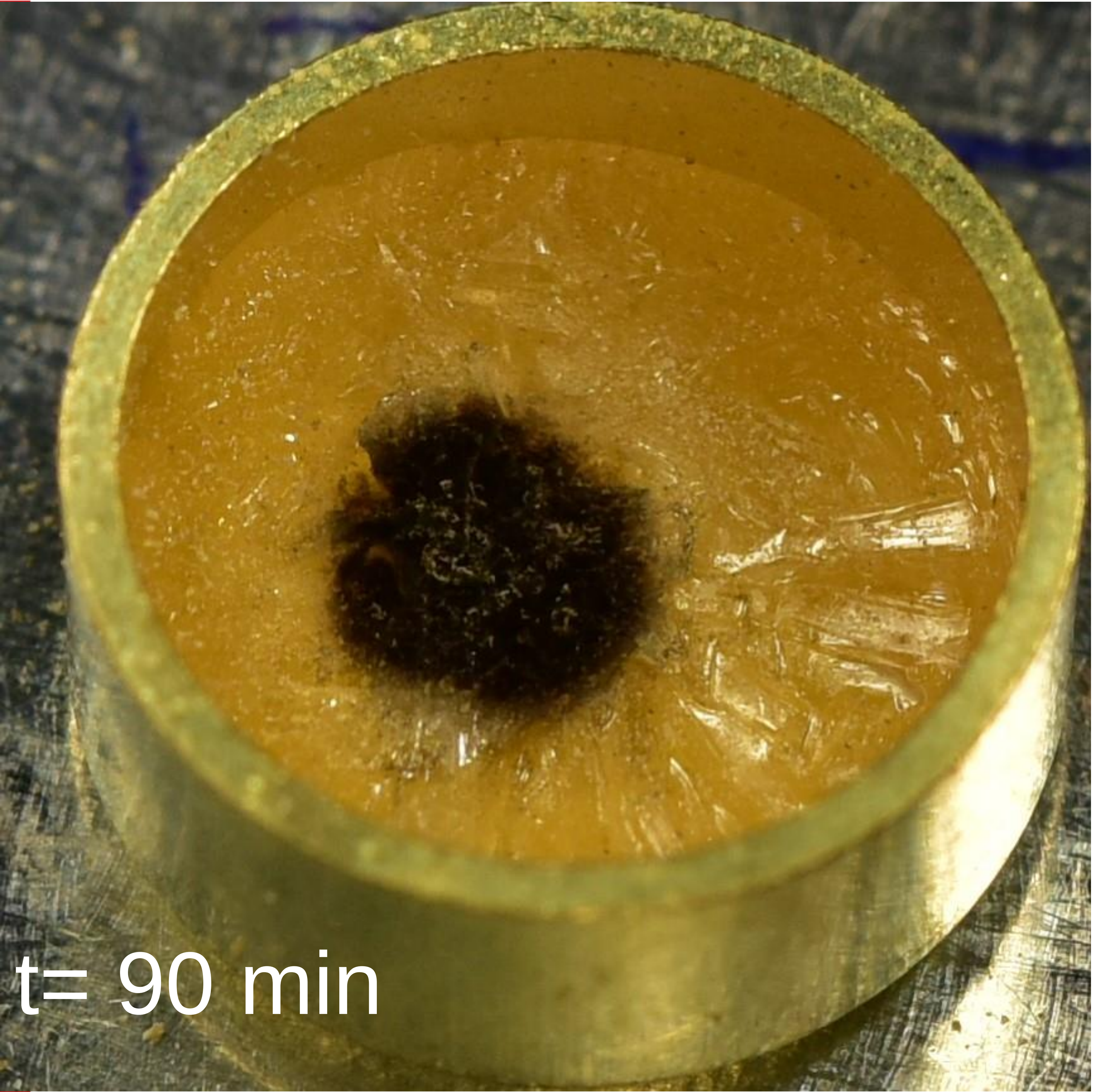
532 nm, 6 mJ



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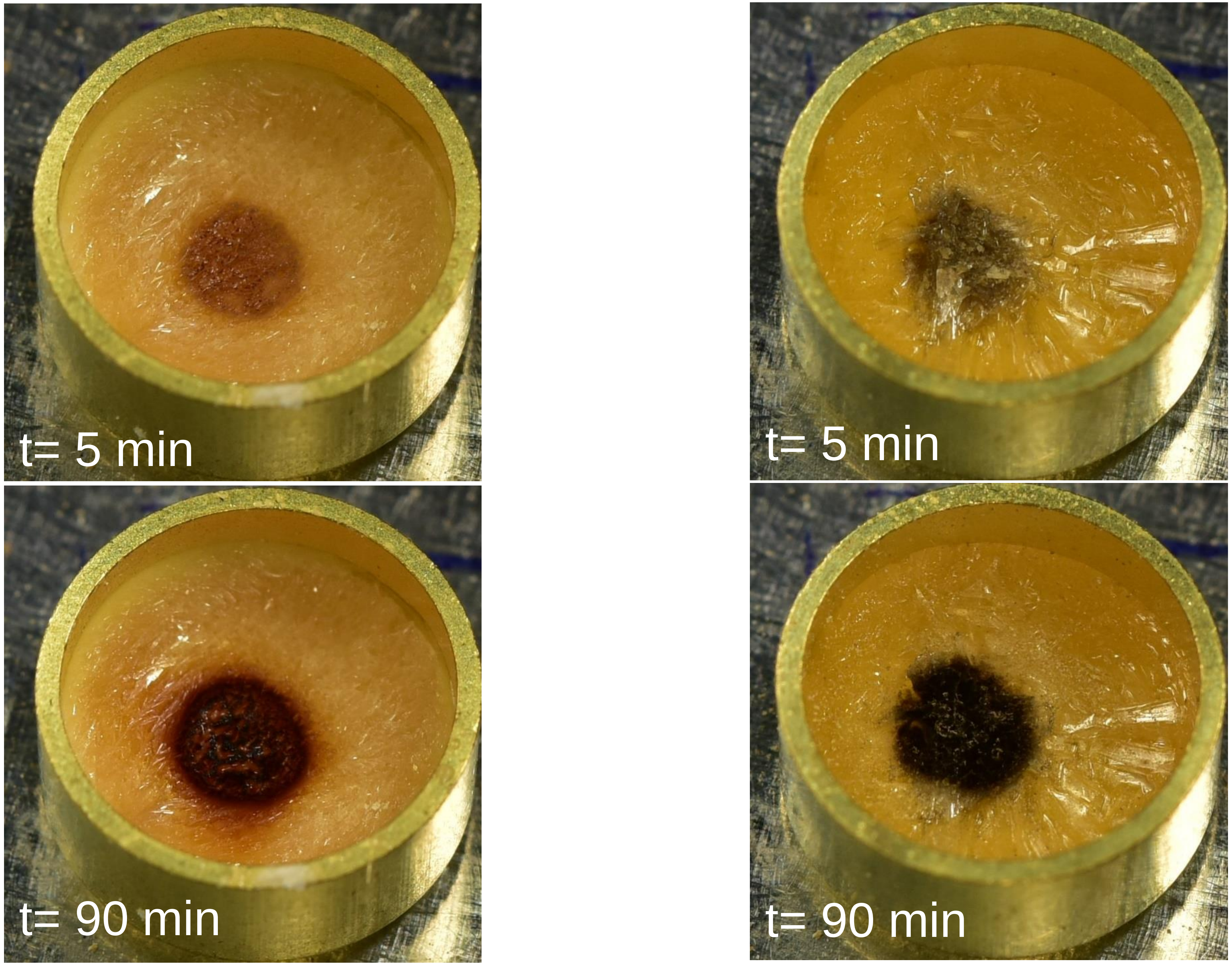
420 nm, 6 mJ | 532 nm, 6 mJ



Clearly a different reaction occurring

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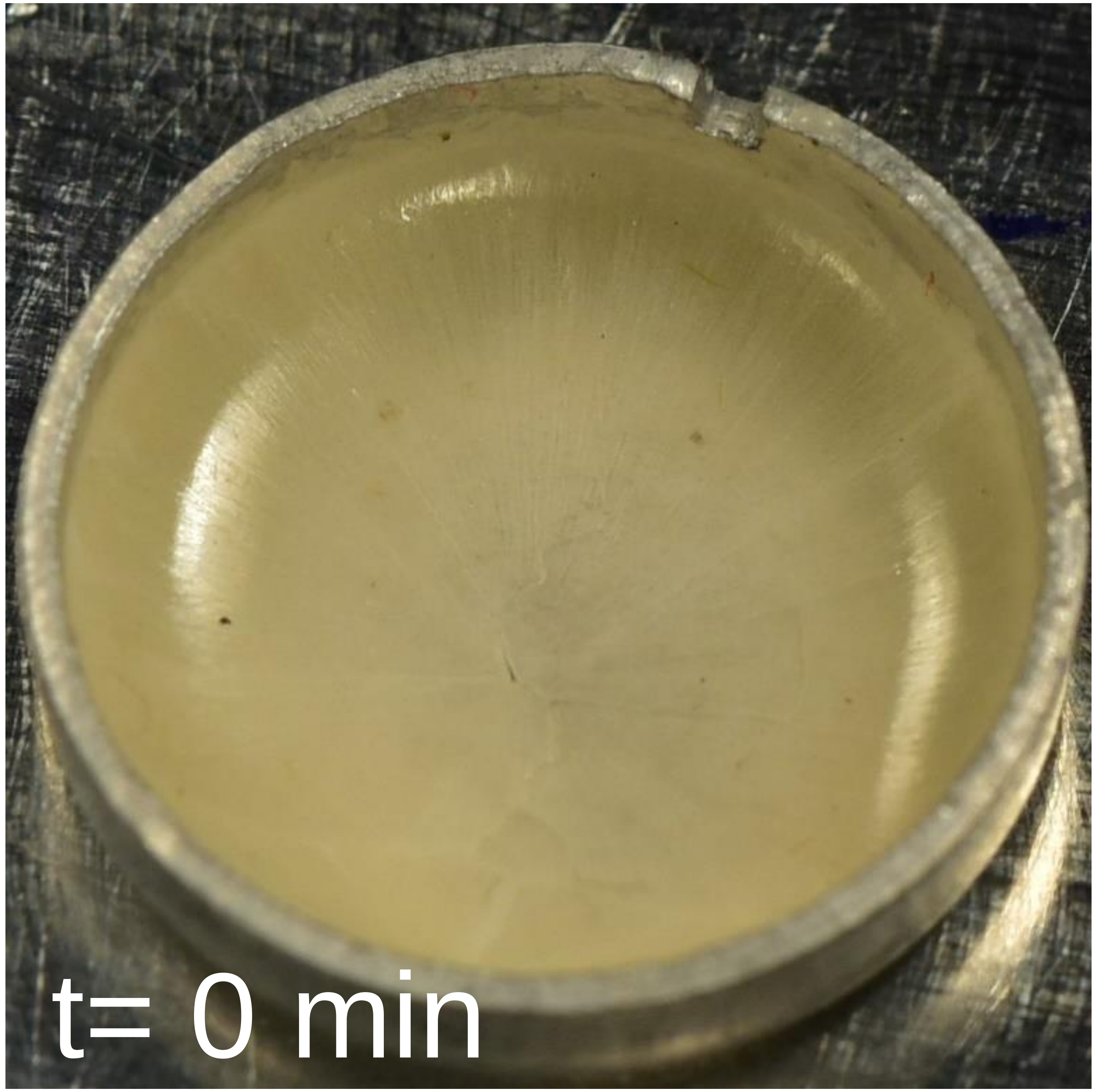
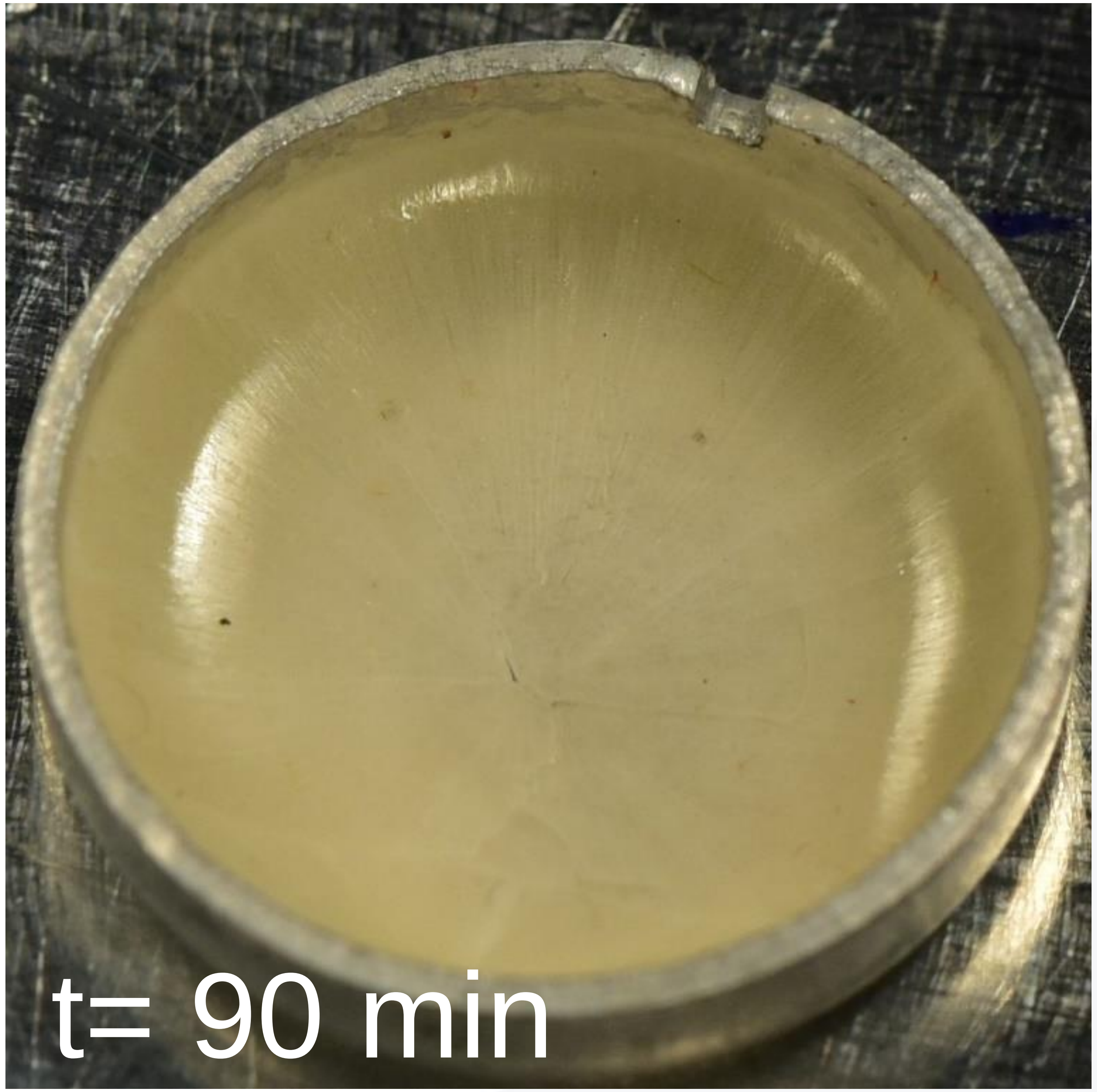
ETN - 785 nm Excitation, 12 mJ





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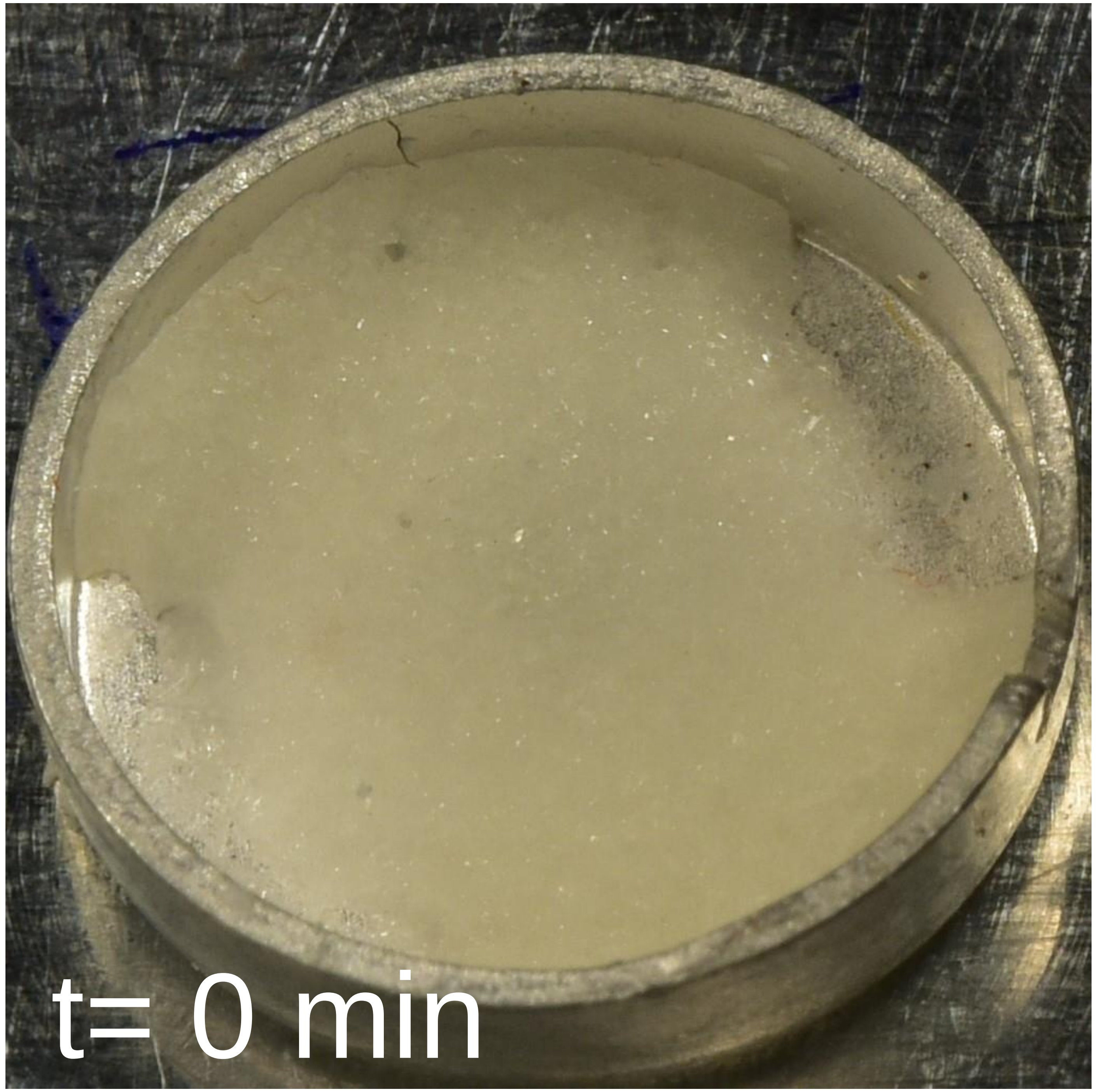
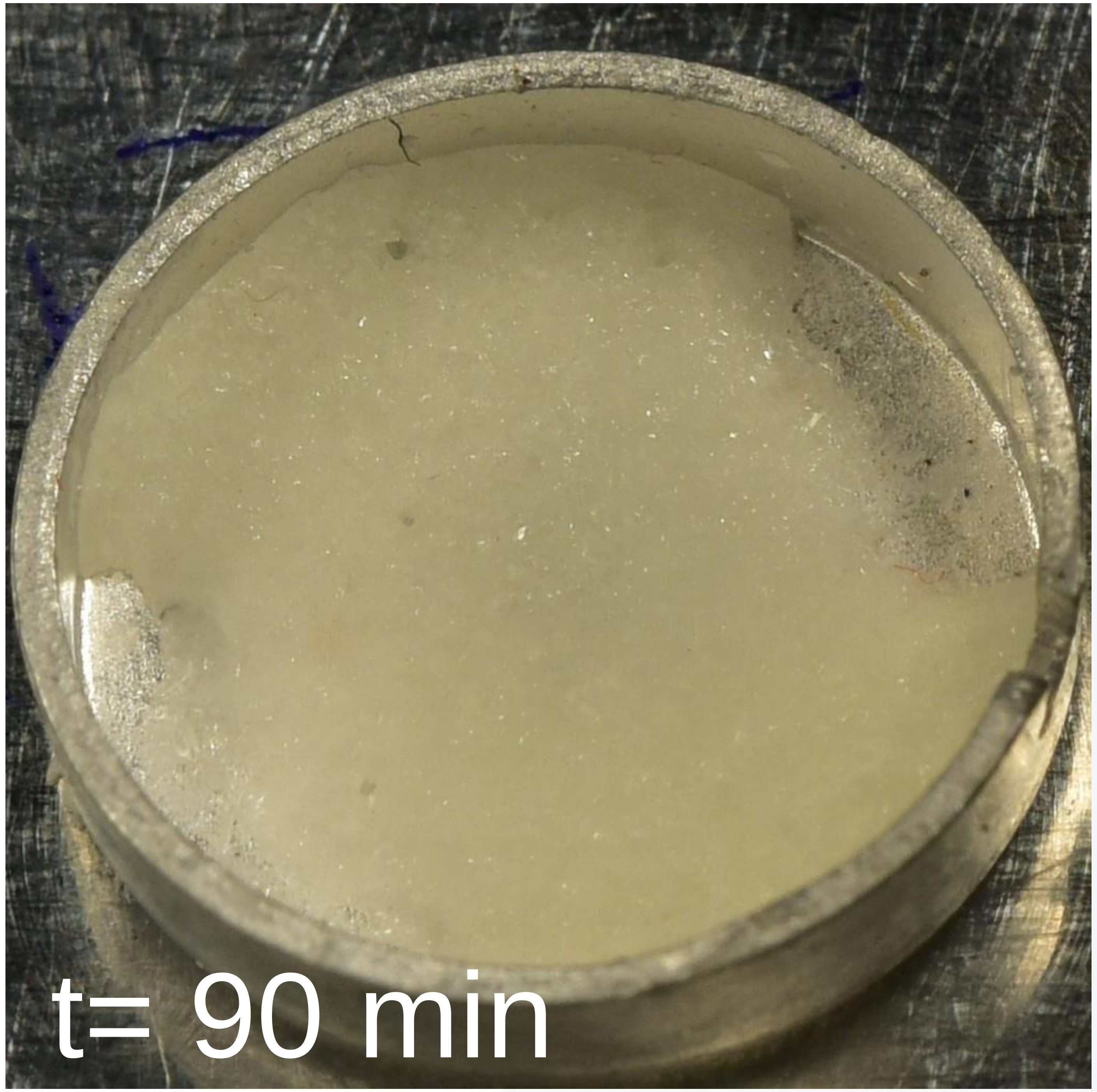
ETN - 1064 nm Excitation, 12 mJ





Project 2 - Fluorescence Analysis

- My PhD was expanding and calibrating a custom fluorescence measurement system
- The system uses tunable lasers to deliver high intensity pulses that can scan across a very wide range (deep UV to mid IR), looking to excite previously unseen fluorescence processes
- The high intensity creates opportunities for more novel fluorescence pathways (like upconversion)

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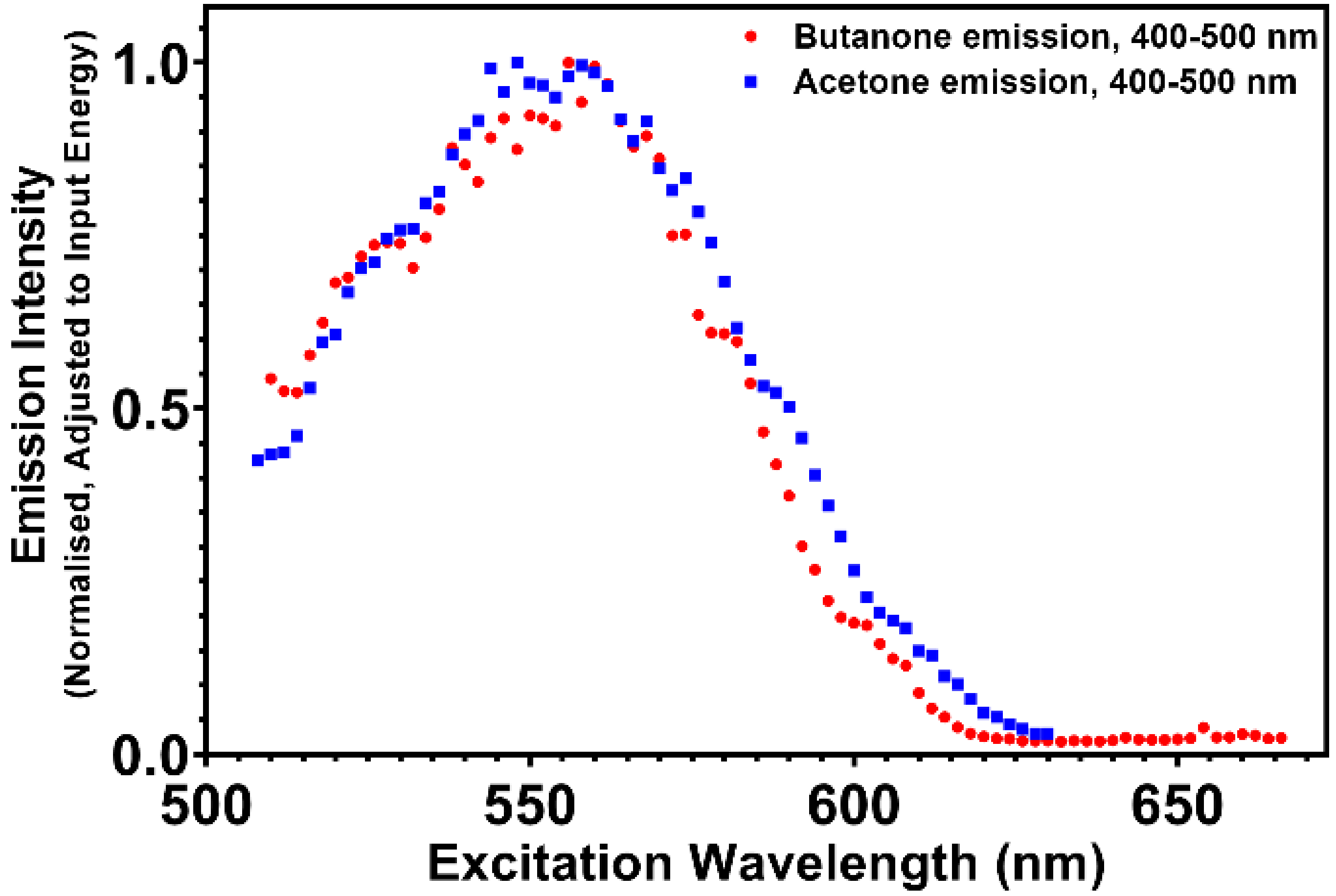
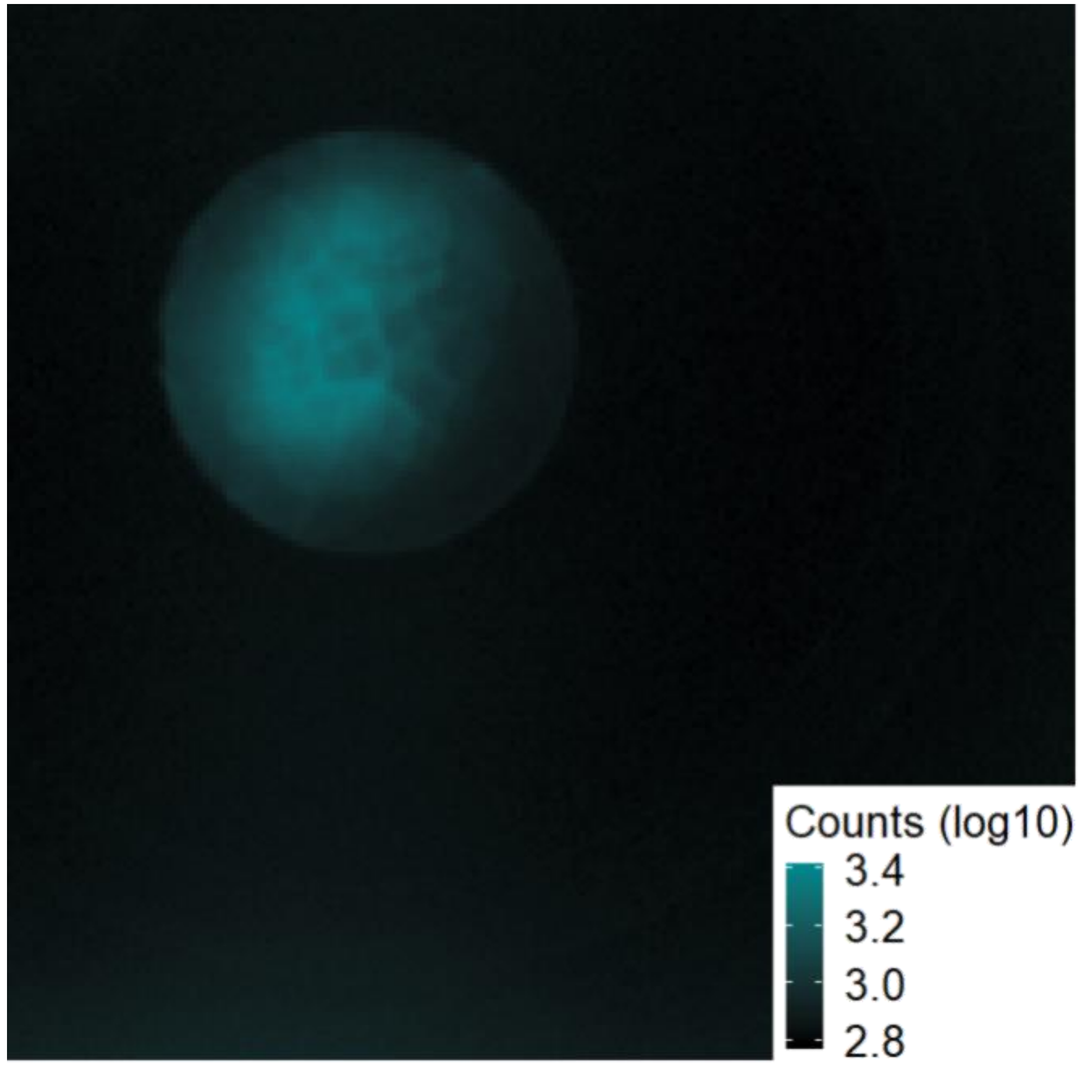
Anti-Stokes Fluorescence

- Frozen acetone (-100 ºC) was excited with green light, with blue light detected





EMCCD image of acetone through the temperature stage window. Excitation at 532 nm, imaging through two 498 nm short pass filters. The optical window is 1 inch in diameter.

de Prinse, T., Klantsataya, E., Tsiminis, G., Payten, T., Moffatt, J., Kee, T. W. & Spooner, N. A. **"Multiphoton Phosphorescence of Simple Ketones by Visible-light Excitation and Its Consideration for Active Sensing in Space"**. *Journal of Fluorescence* Vol. 32, p1051-1057 (2022).

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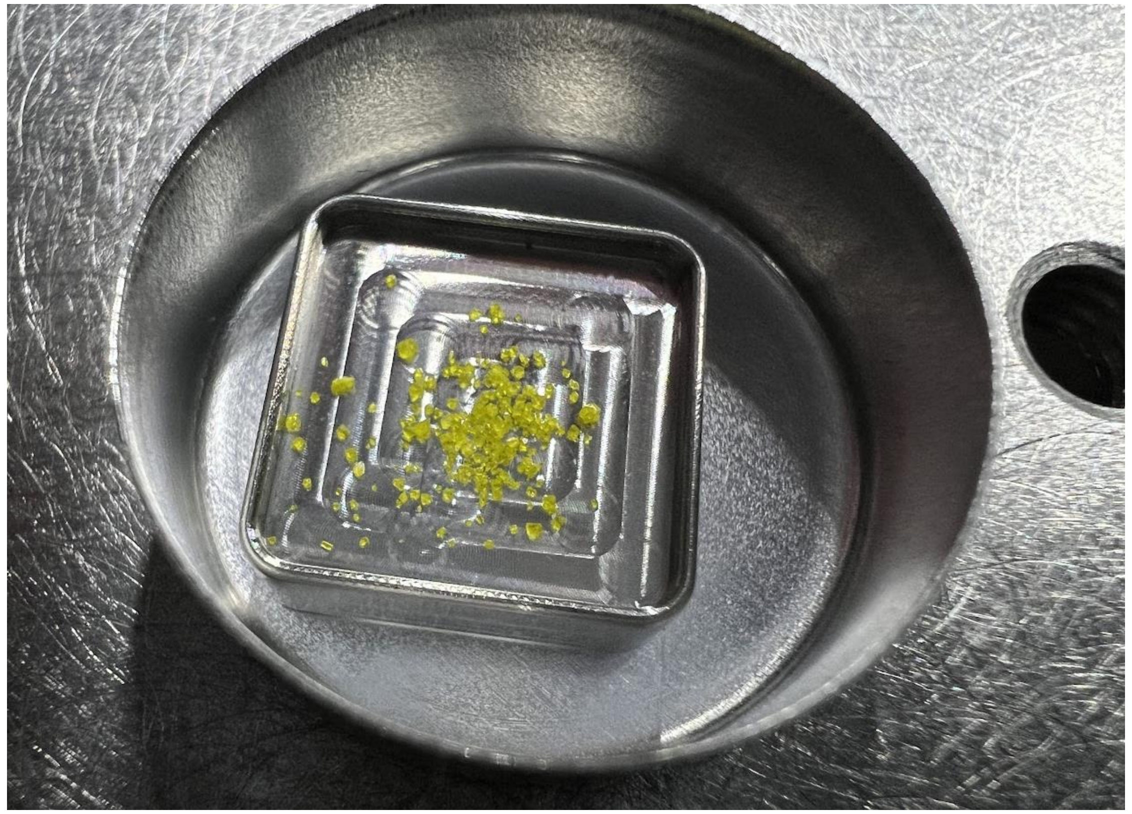
Project 2 - Fluorescence Analysis of Explosives

- Some fairly contentious claims of fluorescence from conventional explosives in the literature
- Have not found anything to back those claims up, still trying to completely disprove some
- More novel explosives, such as TKX-50, do potentially show some emission



2 mg FOX-7 for analysis

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Unsolved Explosive Issues

- Disposal, no company will take explosives or ‘explosives’
  - “Any concentration of explosive counts as an explosive”
  - Reliant on the good will of DSTG to take back samples, but this is not ideal for them
- Proficiency and training, especially legacy
  - The standard University model is that I train someone, who then trains someone in 2 years, who then trains someone…..
  - I have done the ‘Explosive Safety Awareness Course’ at DST Edinburgh, they are potentially modifying it to make it more applicable to external people in energetic materials
  - Ideally there would be more of a stricter training requirement at Adelaide Uni, but it can be hard to rely on external courses and write them into documentation

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An Open Question:

Should it be as difficult for a University to acquire a 2 gram explosive permit for secondary explosives?

- Obviously access to explosives has to be restricted but…
- Currently the University acquires the two general explosive permits, meant for kilogram quantities
  - I had to submit blast radius maps for the proposed 2 grams explosives
  - MFS was involved, campus security
- Are there any real risks of explosion, or are they a legitimate security risk?
- What's the rest of the world doing? The same or different?

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Suggestions for Removing Perceived Barriers?

- Permit to purchase must be under an individual’s name, not an organisation, but only 1 person per organisation can be awarded one
  - The University don’t like this
  - 2020 – I was on it
  - 2021 – The head of school was on it
  - 2022 – The executive dean was on it
- For <5 grams secondary explosives, is there need for a Storage Licence? Could it be covered just by the Permit to Purchase?
  - Storage licence in general is for quantities exceeding 3 kg, but it was deemed necessary in our case
  - Is potentially very discouraging for Universities
  - Universities have other specific purchasing permits (THC analogues, restricted carcinogens, SSAN) but they don’t have an associated storage licence

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Conclusions

The University of Adelaide can now store 2 grams of explosives for research

- Can do a lot of potential research projects with milligrams of material!
- Several unsolved issues still remain, such as disposal of <<1% explosives in flammable waste
- Perhaps the University of Adelaide can set an Australian precedence for academic explosives research??

Laser stability experiments on 50 mg/100 mg samples

- Some explosives are much more easily degraded than others by laser light and are a possible initiation risk
- Laser wavelength does play a role, clearly triggering different degradation mechanisms
- Predictions are currently just guesses unless experiments are run

Fluorescence detection of explosives on 2 mg samples

- No readily detectable fluorescence from solid conventional explosives
- Novel high-nitrogen explosives are a promising future target

Acknowledgements

Academic Supervisors

- Professor Nigel A. Spooner
- Professor Tak W. Kee
- Dr Elizaveta Klantsataya

DSTG

- Dr David Armitt
- Craig Wall
- Dr Ben Rogers

Fluorescence Team

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- Dr Jillian Moffatt
- Dr Tom Payten
- Dr Genevieve Dennison
- Thomas Slattery
- Lewis Teixeira

University of Adelaide Support

- Jessica Gilson
- Dr Mailys Stirling

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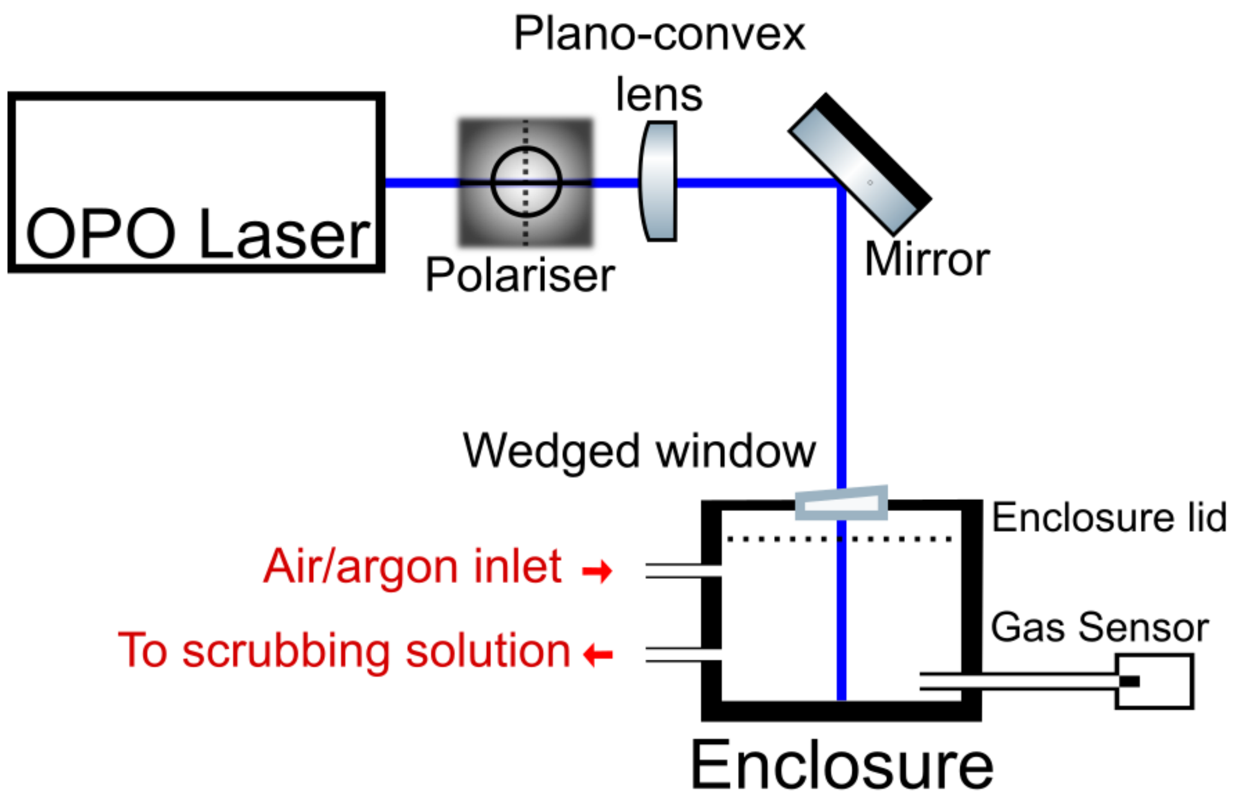
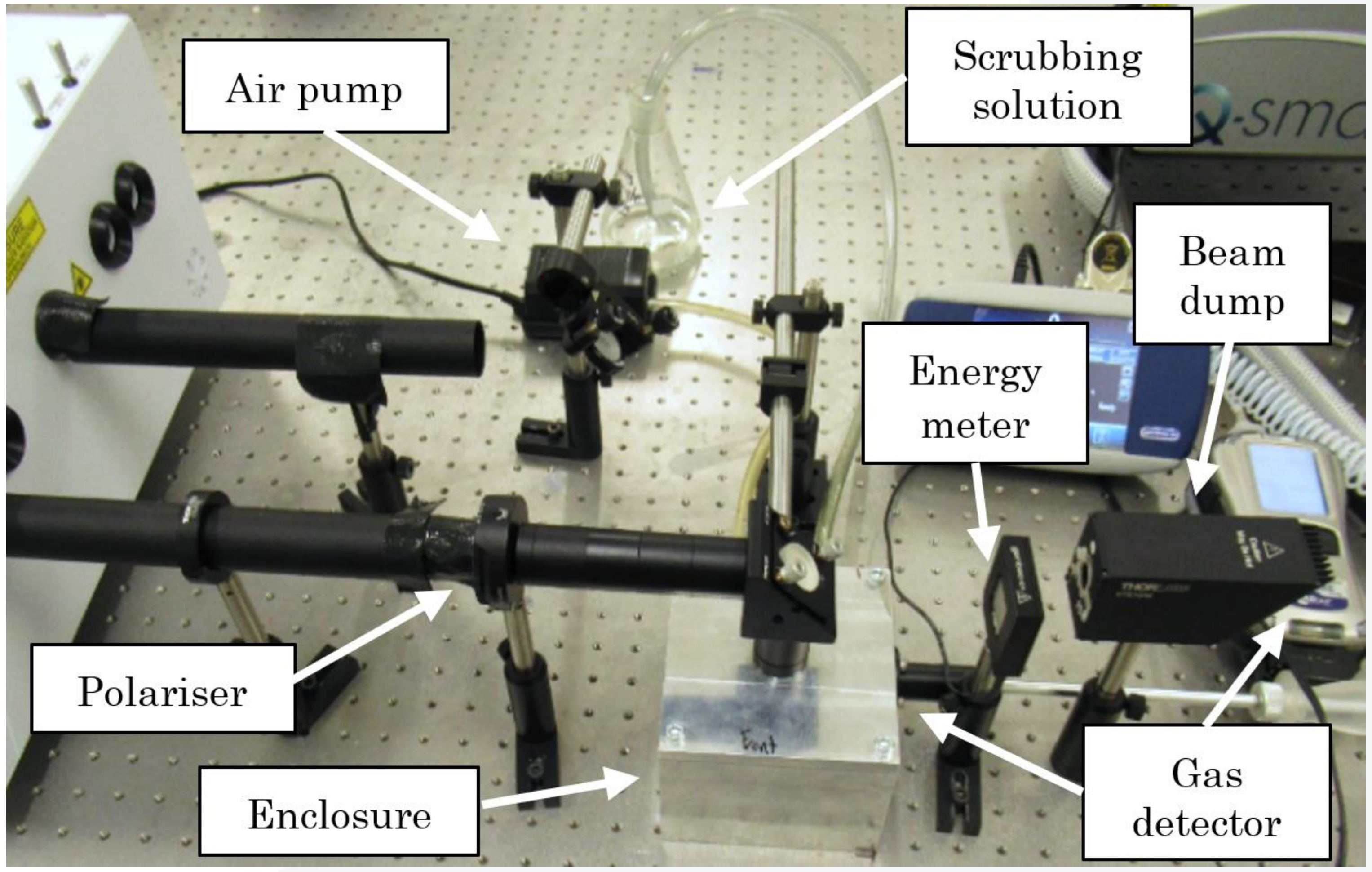
Enclosure design

- Experiment relied on a specialist sample stage that can be safely and easily used
- Experiment was run in a laser lab, not an explosive area, so the explosive hazards had to be well mitigated
- Gas sensor used to measure CO/NO/NO_2 release as initiation/ignition indicator
- Sample stage should still allow for sample to explode or deflagrate with minimal risk
- Individual disks were weighed out and heated in an oven, melting the samples (100 mg TNT, 50 mg ETN)





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