Evaluation of rotating electrode Electrical Discharge Machining (EDM) on molybdenum

In view of producing RF cavities

Plan.

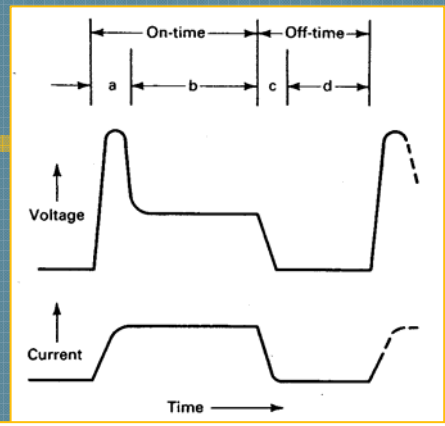
- Intro.
- Technique EDM with rotating electrode.
- Results
  - Surface morphology.
  - Surface analysis.
  - Metrology.
- Concerns.
- Possible ways for improvement.

- Collaboration with the *Laboratoire NMP* of *Ecole d'Ingénieurs de Genève* (*EIG*). R. Demellayer.

- First step, feasibility study: machining of 3 cavities on a pure Mo block by EDM with a rotating Copper electrode.

EDM

- Types of EDM:
  - Wire, die-sink, milling, rotating electrode.
- Parameters
  - Pulse on-time, off-time, current, open circuit voltage, work piece polarity, dielectric medium, electrode material, electrode speed…
- Well known procedures for conventional and less conventional materials, but poor knowledge for Mo as workpiece.
- Typical EDMS surface:
  - Topography: Cratered surface. Crater size and roughness depend on spark energy.
  - Metallurgical and Chemical effects on the affected layer (in conventional materials and methods <0.13 mm for roughing settings, < 0.01 mm for finishing settings)
    - Recast layer. Experiences a rapid quench, in tension, solidification micro-cracks
    - Heat affected zone. Also in tension
- Surface crack prediction maps:



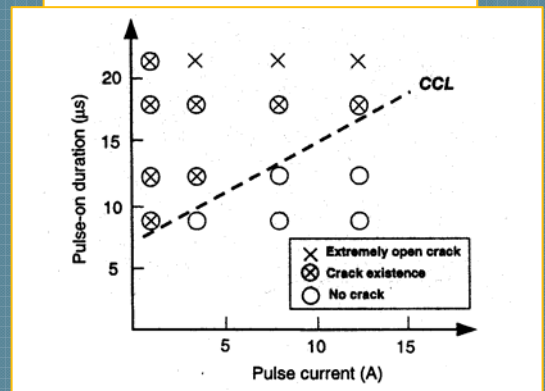


Fig. 10. The type of crack and the location of critical crack line (CCL) under different EDM conditions.

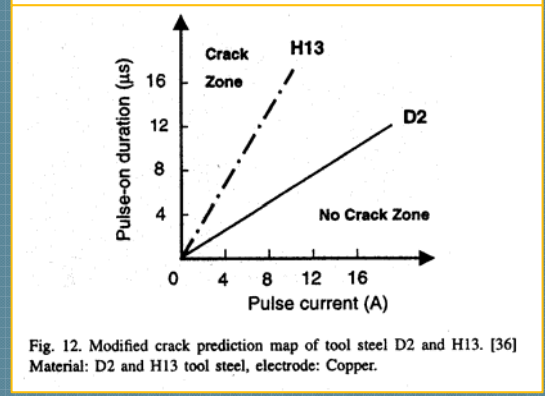
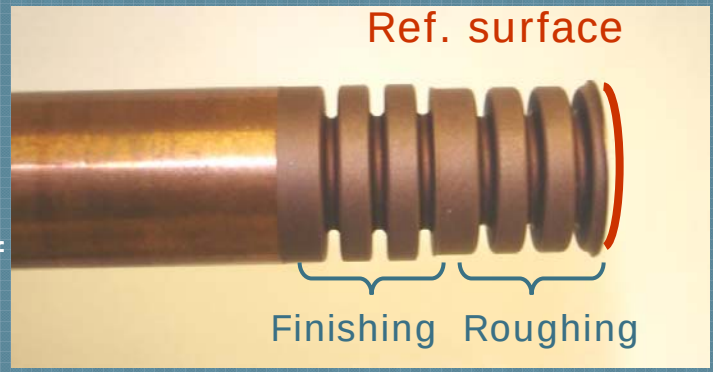


Fig. 12. Modified crack prediction map of tool steel D2 and H13. [36] Material: D2 and H13 tool steel, electrode: Copper.

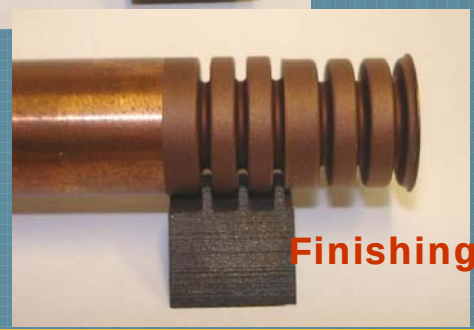
Lee et all. 2004

Technique EDM with rotating electrode.

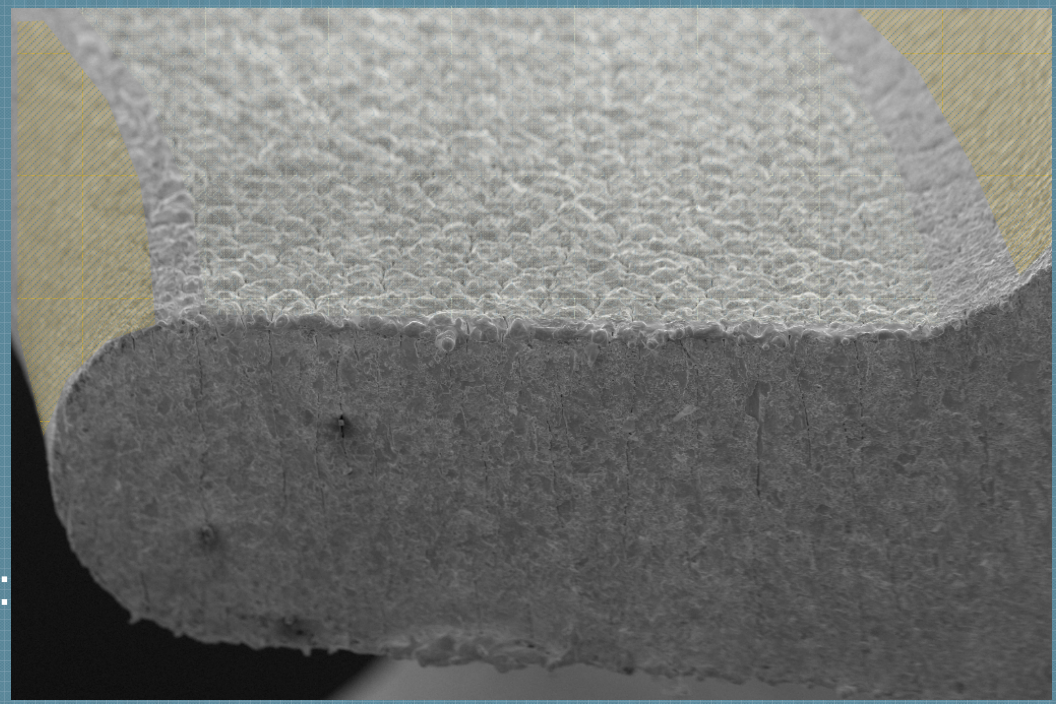
- Fabrication of a high precision electrode.
  - From a copper bar.
  - By conventional wire EDM in water, the work piece is rotating.
  - Two regions within the same electrode: for roughing and for finishing.
  - Positioning reference surface: flat end of the electrode.
  - One Cu electrode per Mo piece.
  - Machining time: 24 h.



- Fabrication of the piece.
  - From a pure molybdenum bar.
  - By special EDM process with a **rotating electrode**, in oil.
  - Roughing and finishing runs.
  - One Cu electrode is consumed by piece. Erosion of the Cu is 20% that of the Mo piece.
  - Machining time: 24 h.



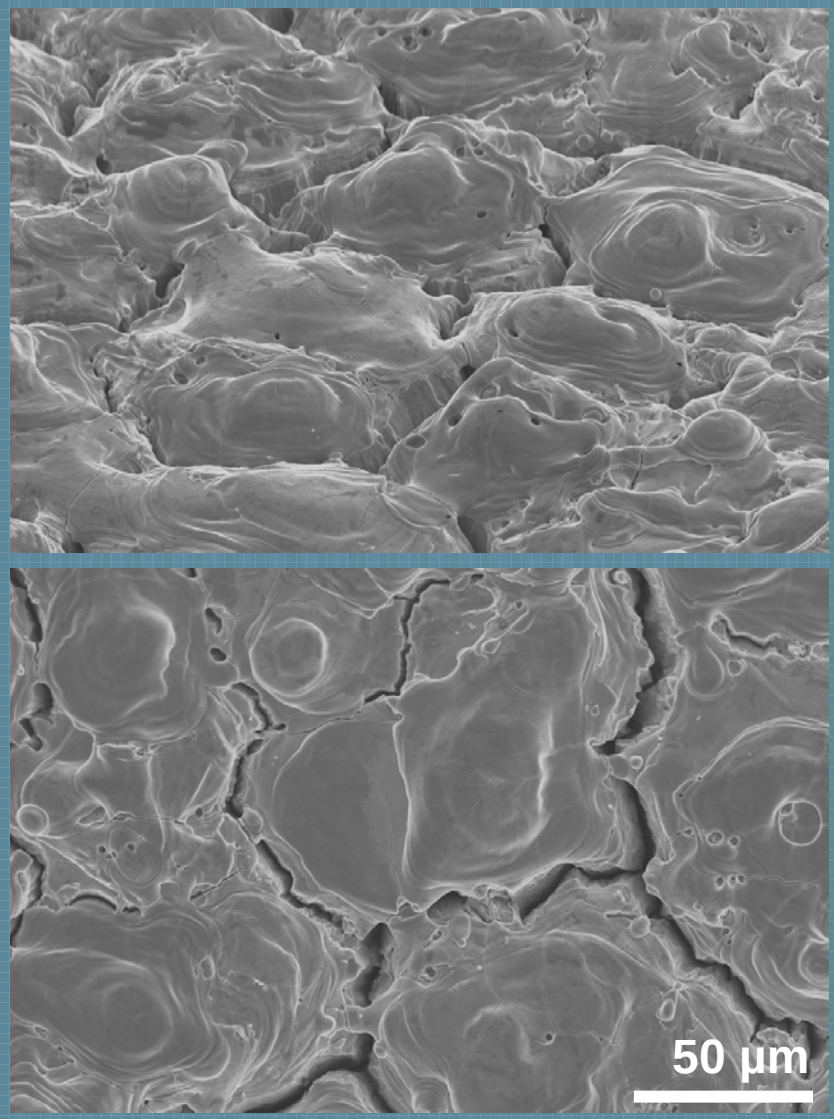
Results: Surface Morphology.



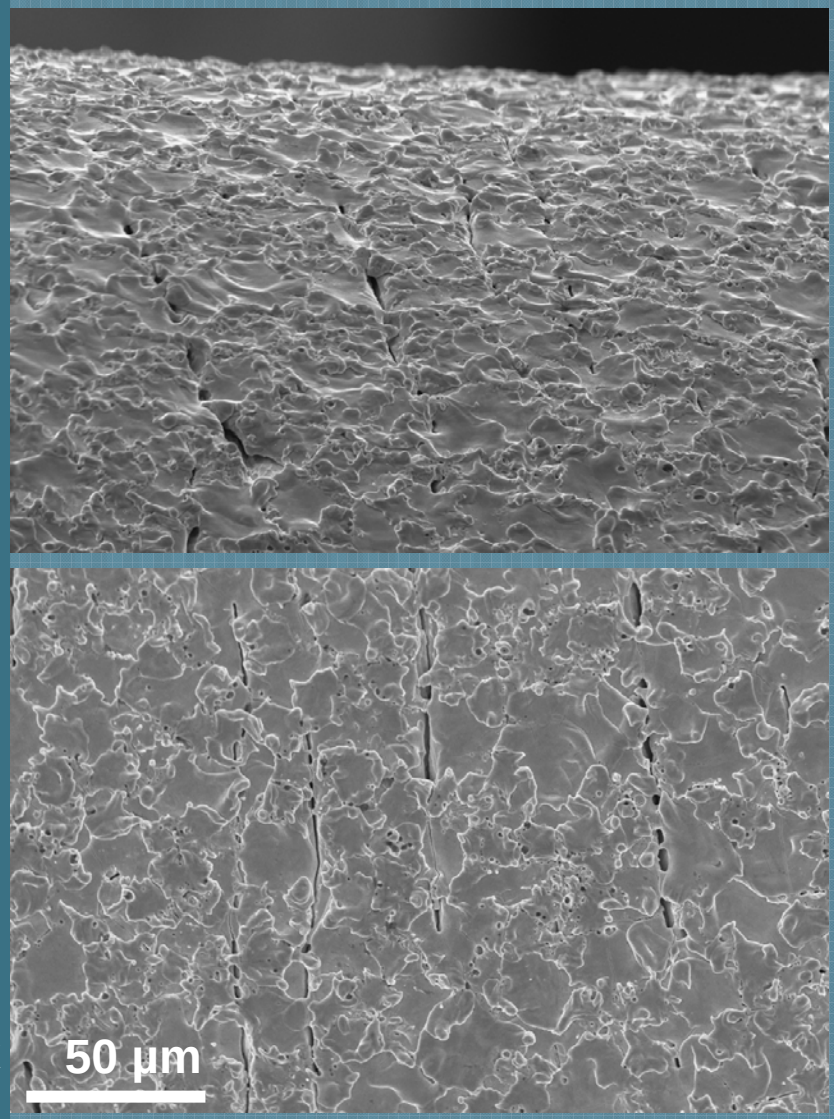
- Network of cracks.
- Two different regions:
  - Iris sides
    - Surface normal to the axis.
    - Surface that last longer exposed to the electrode.
  - Iris tips and cylindrical part of the cavity
    - Surface parallel to the axis.
    - Surface freshly exposed to the electrode.

Results: Surface Morphology.

- Iris sides:
  - Network of cracks, mesh size 50-100 µm. (grain size 1-5 µm; original powder particle size 2-10 µm)
  - Severe cracks.
  - “Ice cream-like” features on top of islands.
  - Rougher morphology that any other machined surface seen so far.

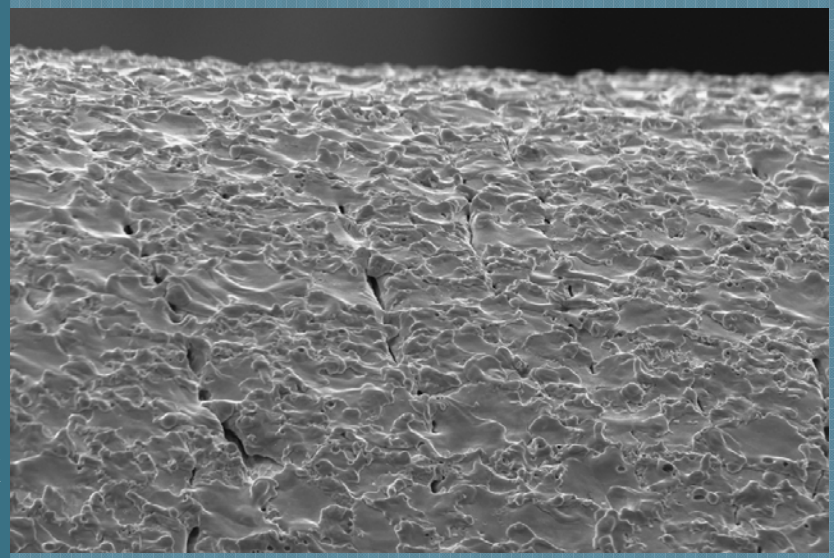


Results: Surface Morphology.

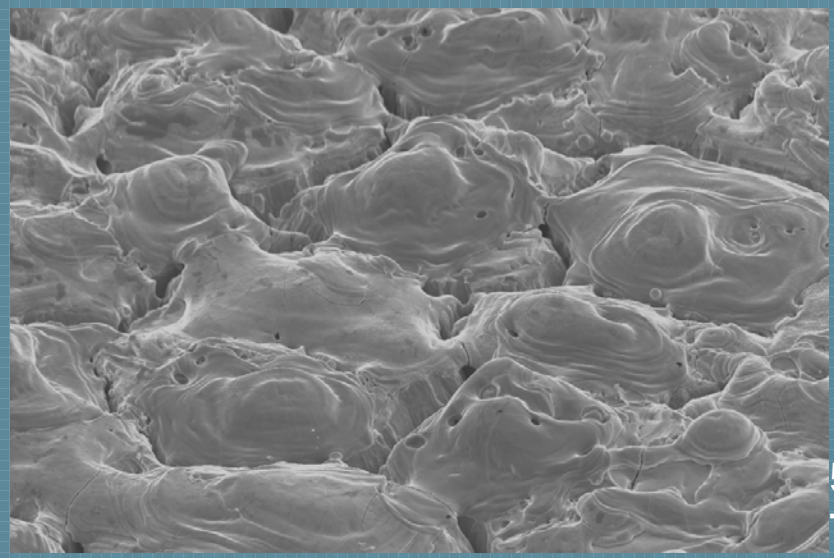


- Iris tip:
  - Cracks are straight and parallel to structure axis.
  - Less severe cracks
  - Typical EDM crater morphology.

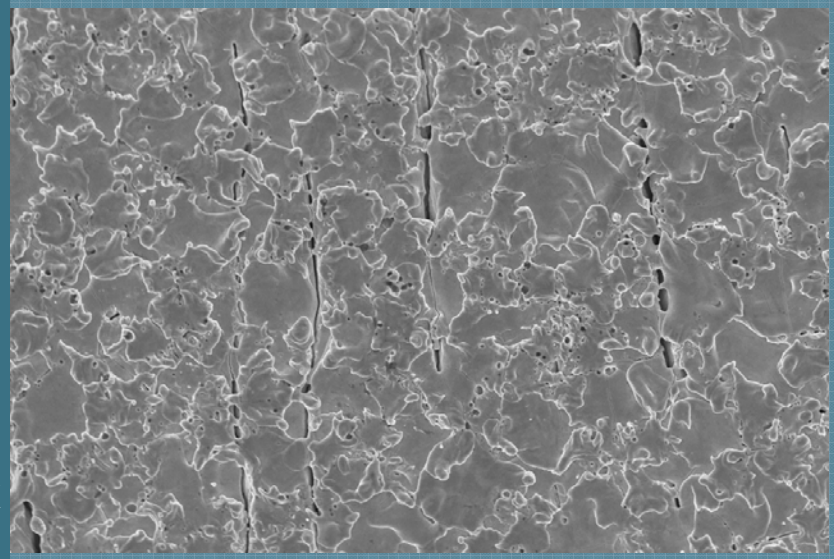
Results: Surface Morphology.



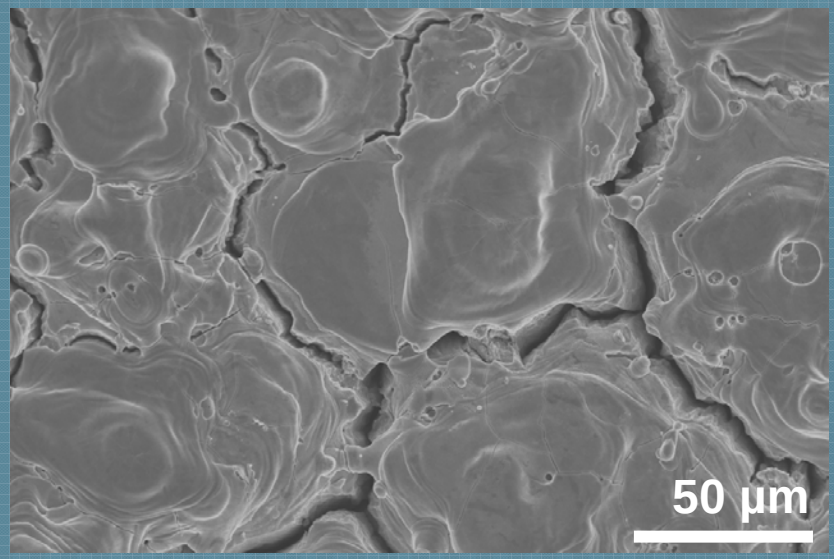
500x
Tilt 60º



500x
Tilt 60

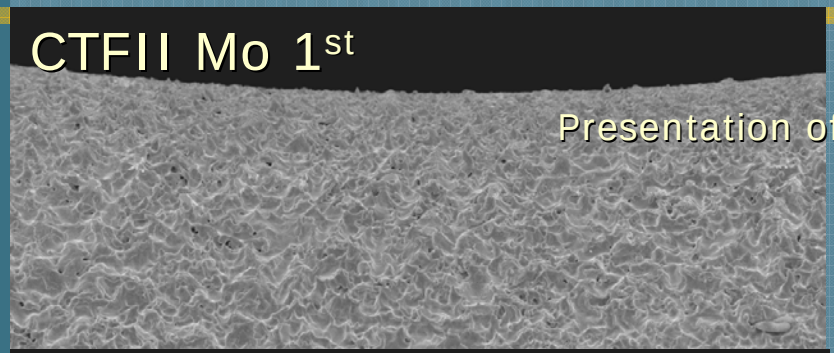


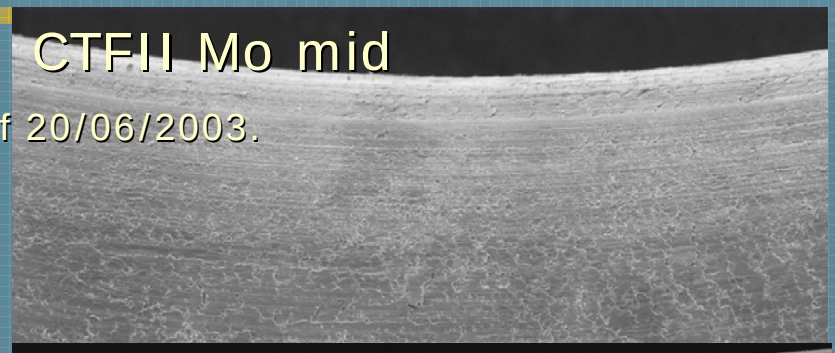
500x

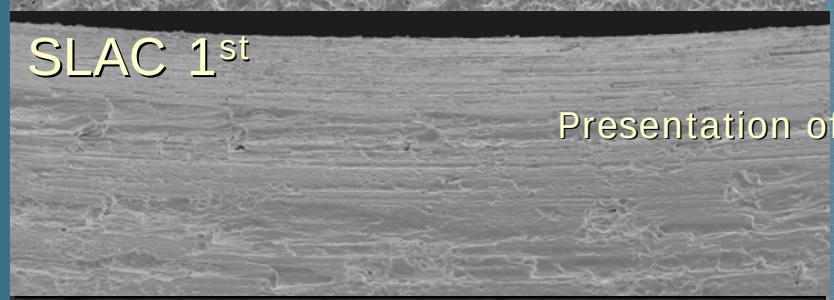


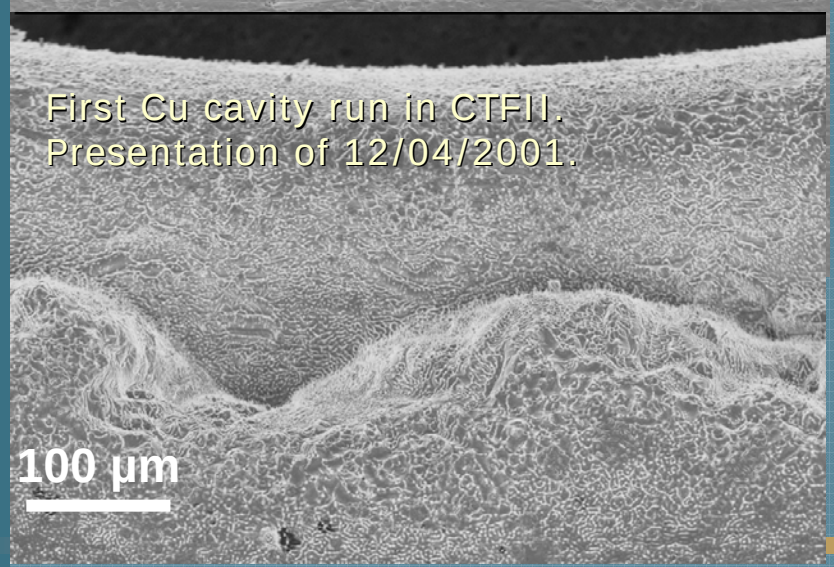
500x

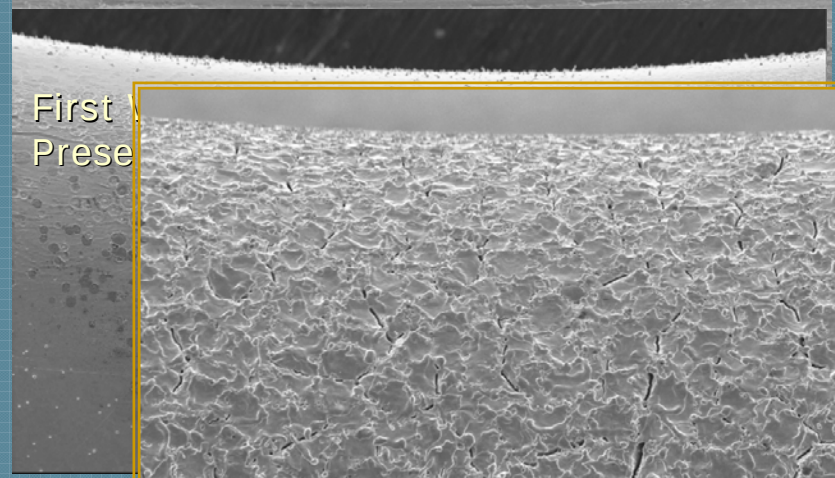
Comparison of iris tip surface morphology with historical records.





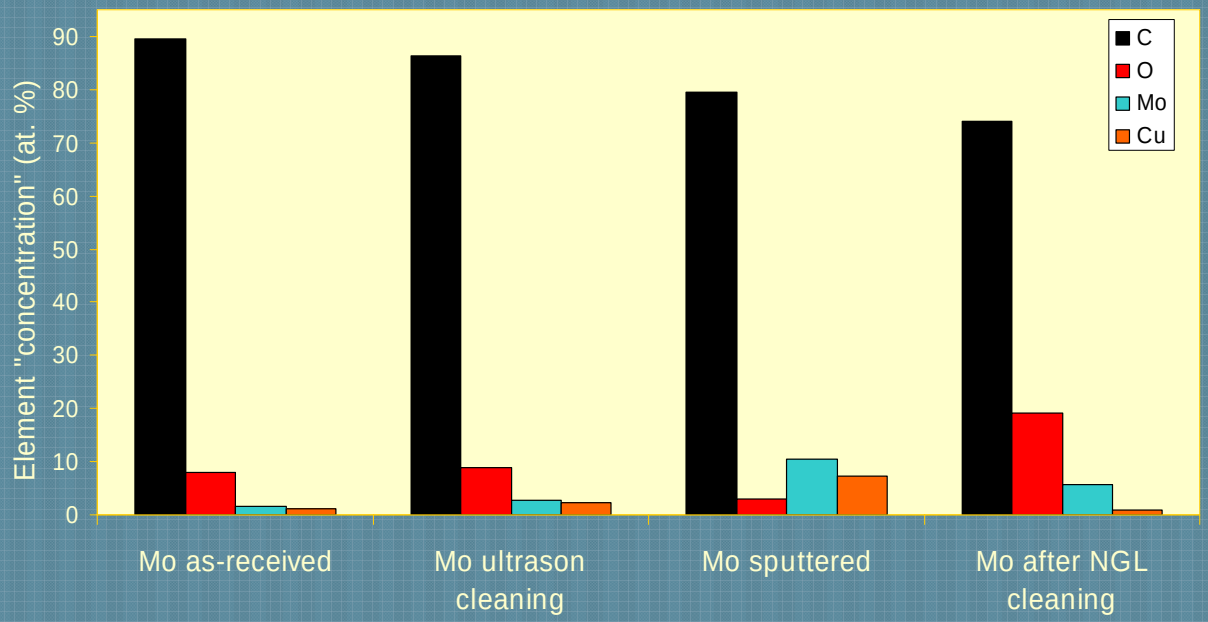






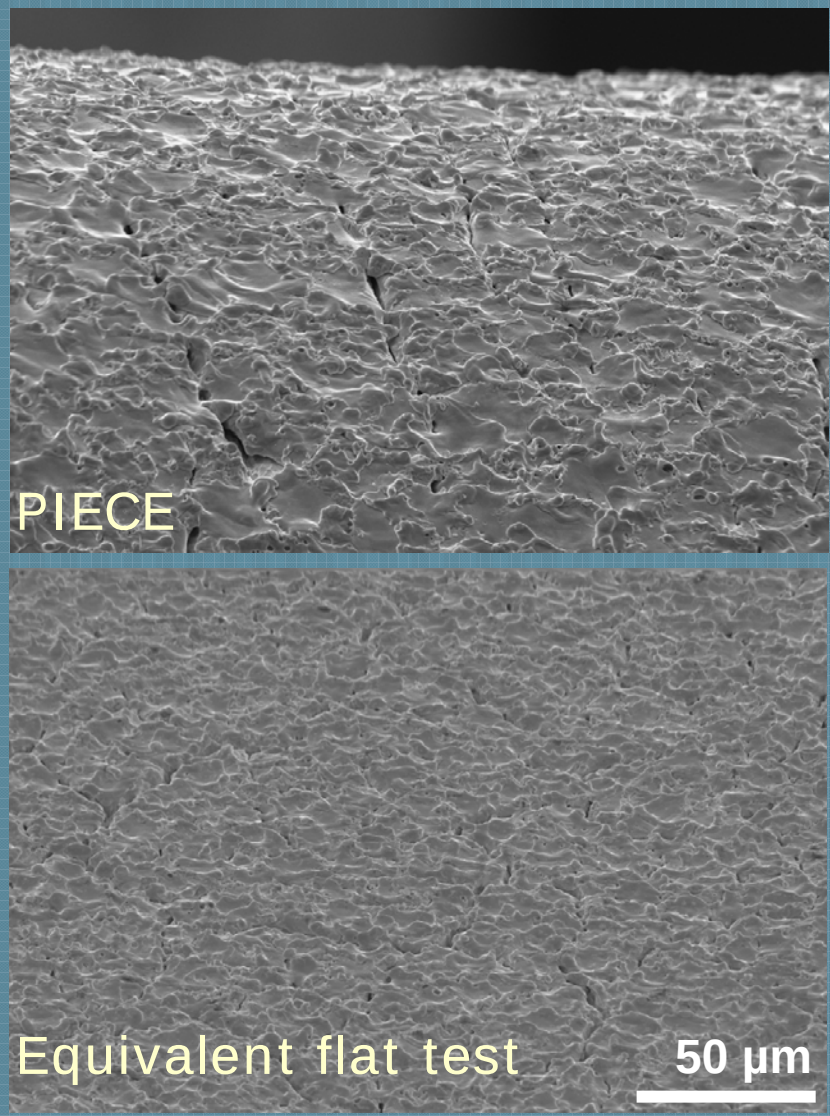
Results: Surface Analysis. (J. Gavillet TS/MME)

- XPS analyses as received and after cleaning steps.
  (Original aspect was bright, became dark after NGL cleaning)
- Thick carbonaceous layer not removed by standard cleaning methods.
- No carbide layer (Mo_2C or MoC)
- Some Cu transfer from electrode.



Results: Metrology.

- Roughness in equivalent flat test surface. At EIG Ra=0.4 µm.
- Roughness and dimensions at CERN: Pending.
- Optimizing dimensional tolerances was not a target at that stage. Electrode machining can be further optimized and number of finishing runs increased.



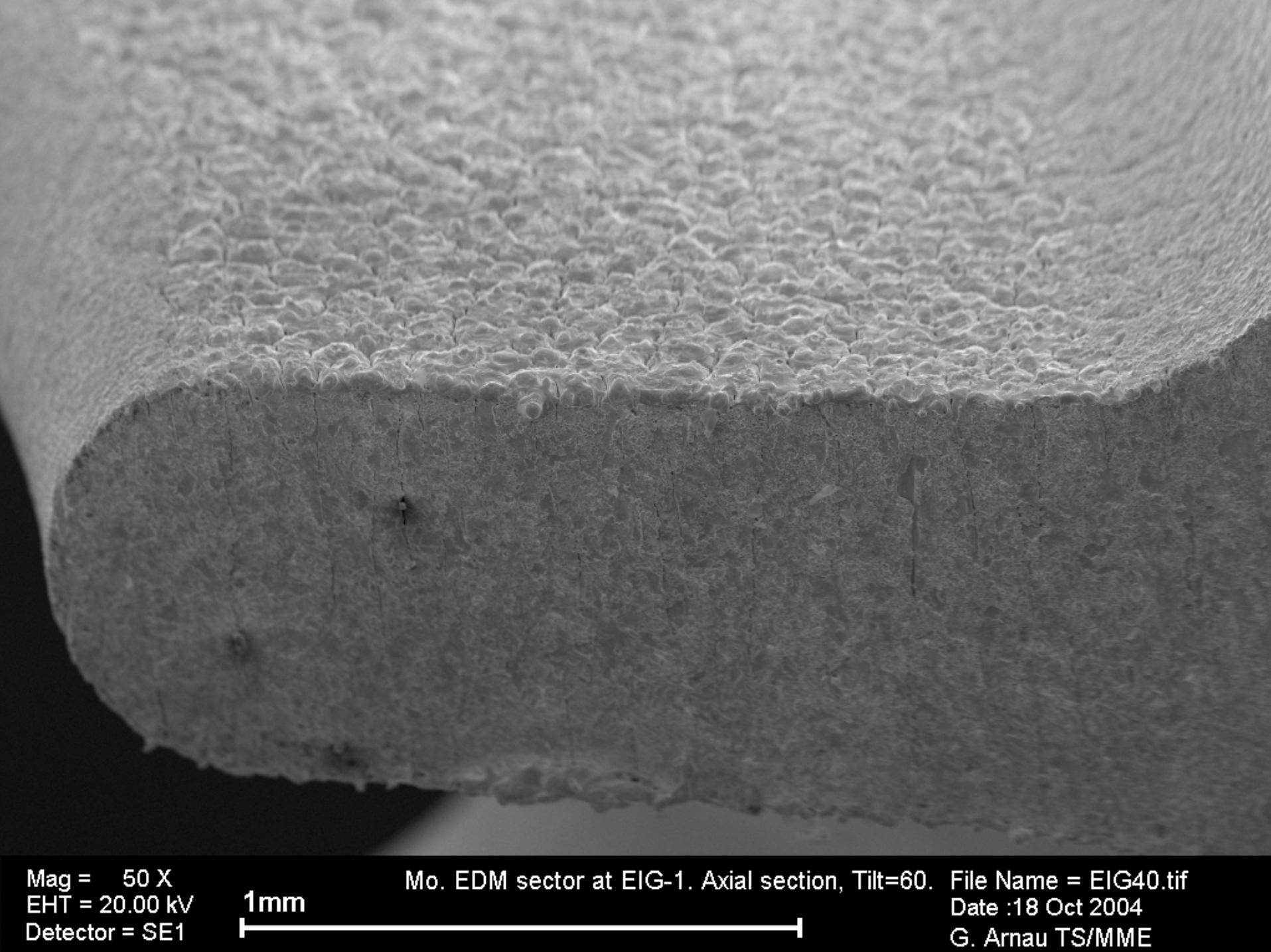
Concerns.

- Cracks and craters.
  - Mechanical weakness.
  - Electric field concentrators.
  - Retention of contamination: virtual leaks for UHV.
- Carbon contamination.
  - Degassing under service discharges.
- Dimensions.
- Mo versus Hybrid bimetallic.

Possible ways for improvement.

- These are first results produced. Far from optimized conditions.
- Use different pulse generator for more respect of the surface integrity (Charmilles development to cope with similar problems in EDM of WC-Co materials)
- Use different dielectric.
- Use Mo electrode.
- Add a 3rd finishing run (3rd region in the electrode).
- Optimize machining of electrode.
- End by an in situ electro-polishing (replace dielectric by electrolyte and use electrode as static electro-polishing electrode)
- Explore post treatments (better adapted cleanings, laser re-melting, acid etching, reverse sputtering,...)

- Possibility of institutional founding for joint projects: CTI-EIG-CERN-Charmilles.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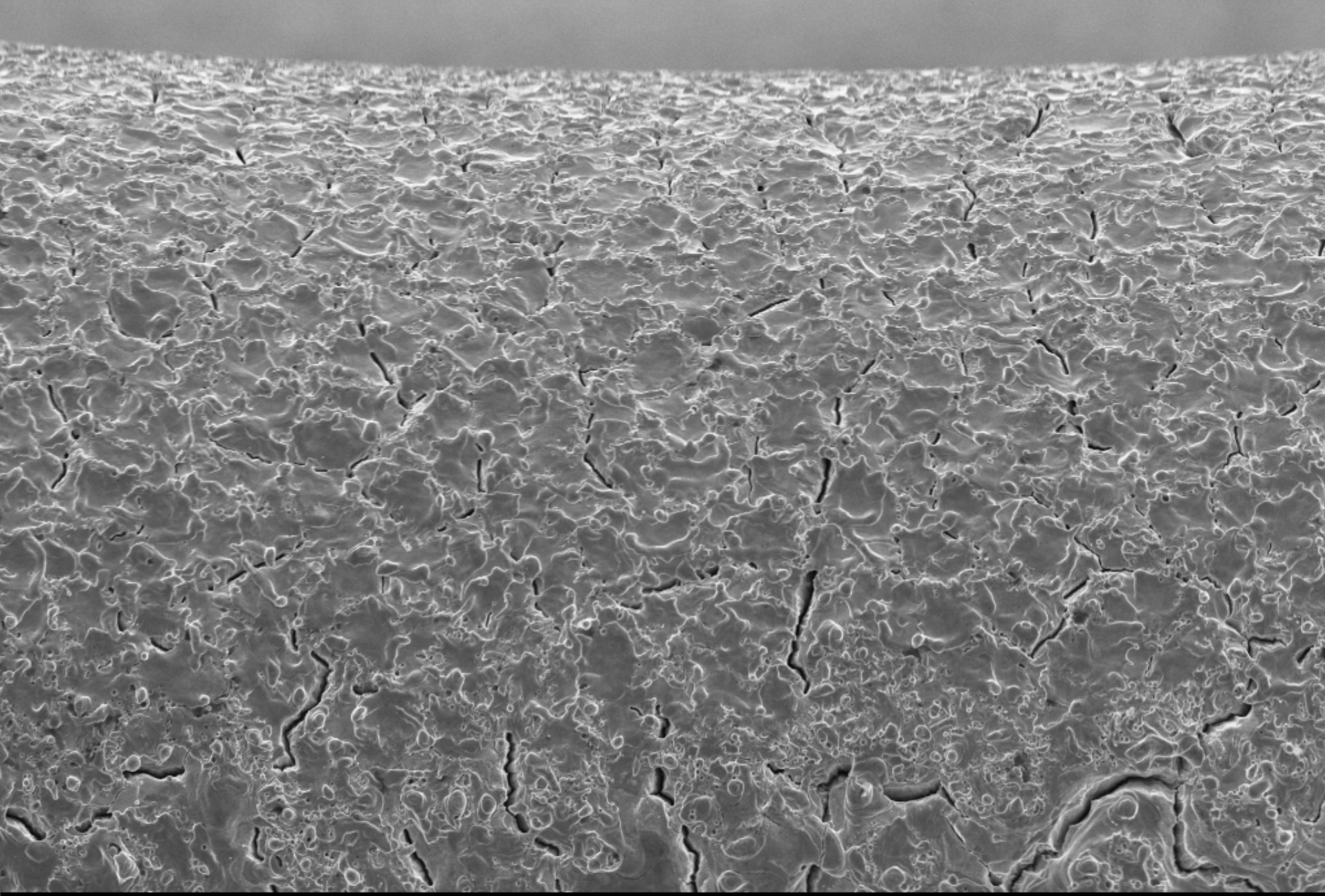
Date :18 Oct 2004
G. Arnau TS/MME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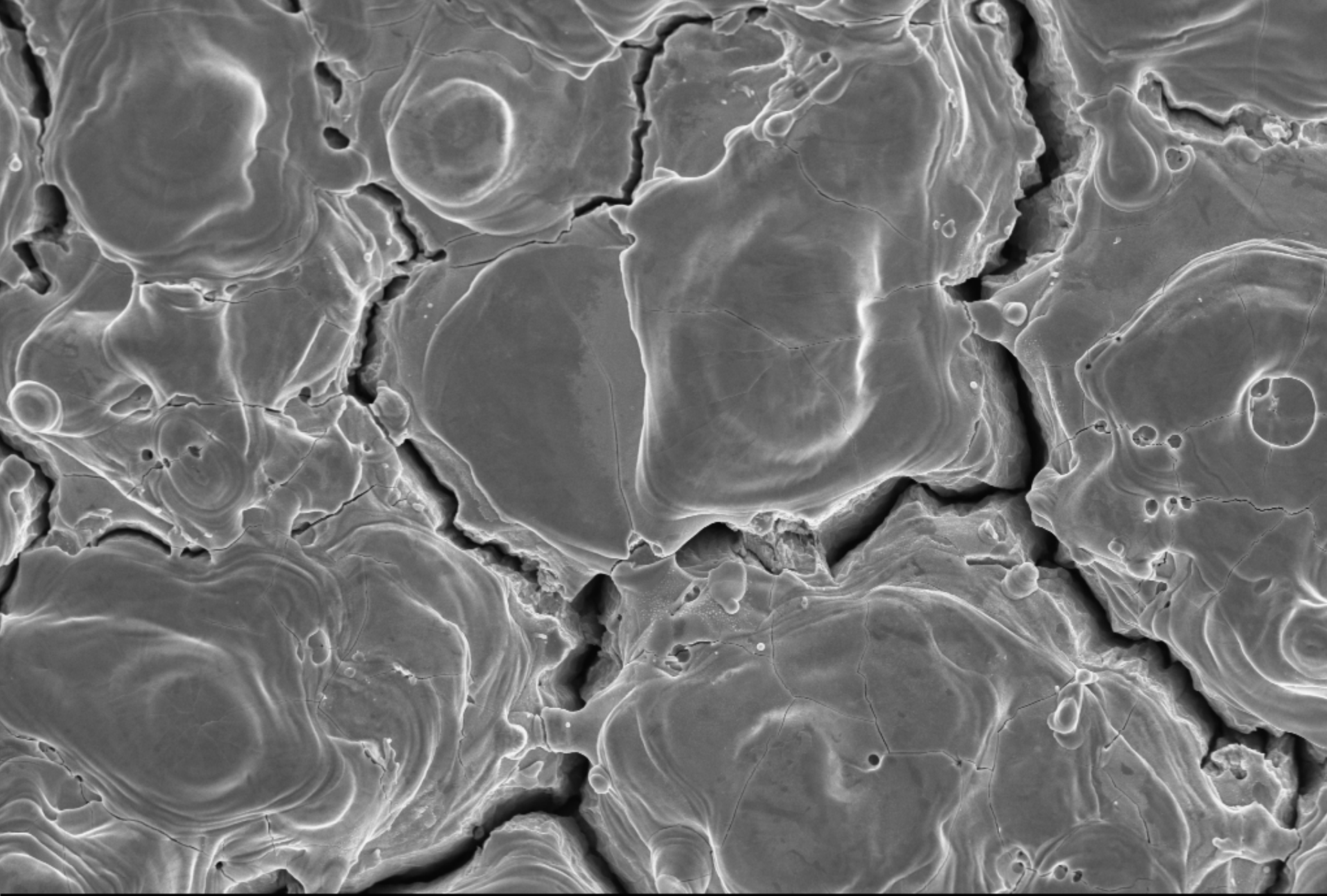
G. Arnau TS/MME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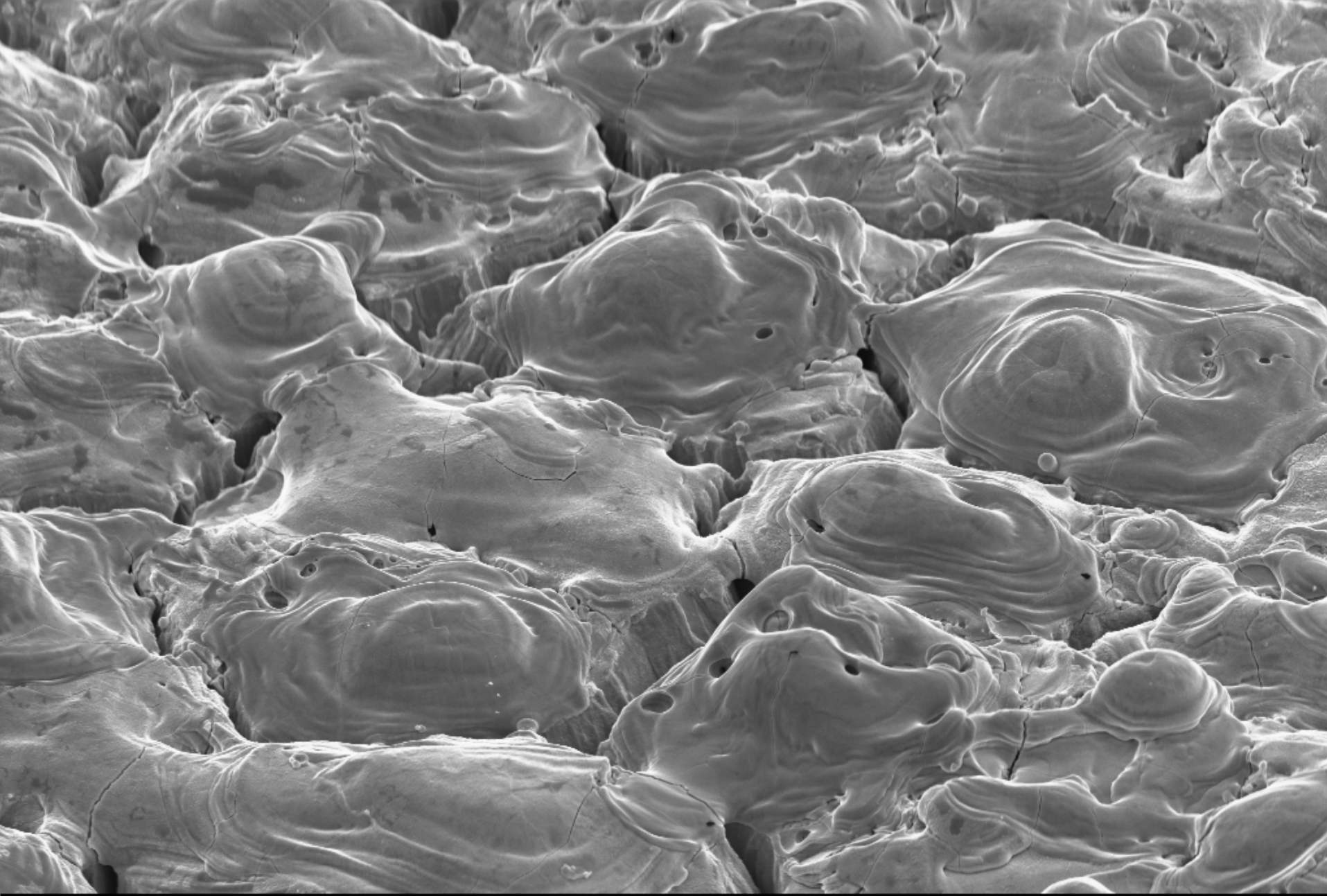
G. Arnau TS/MME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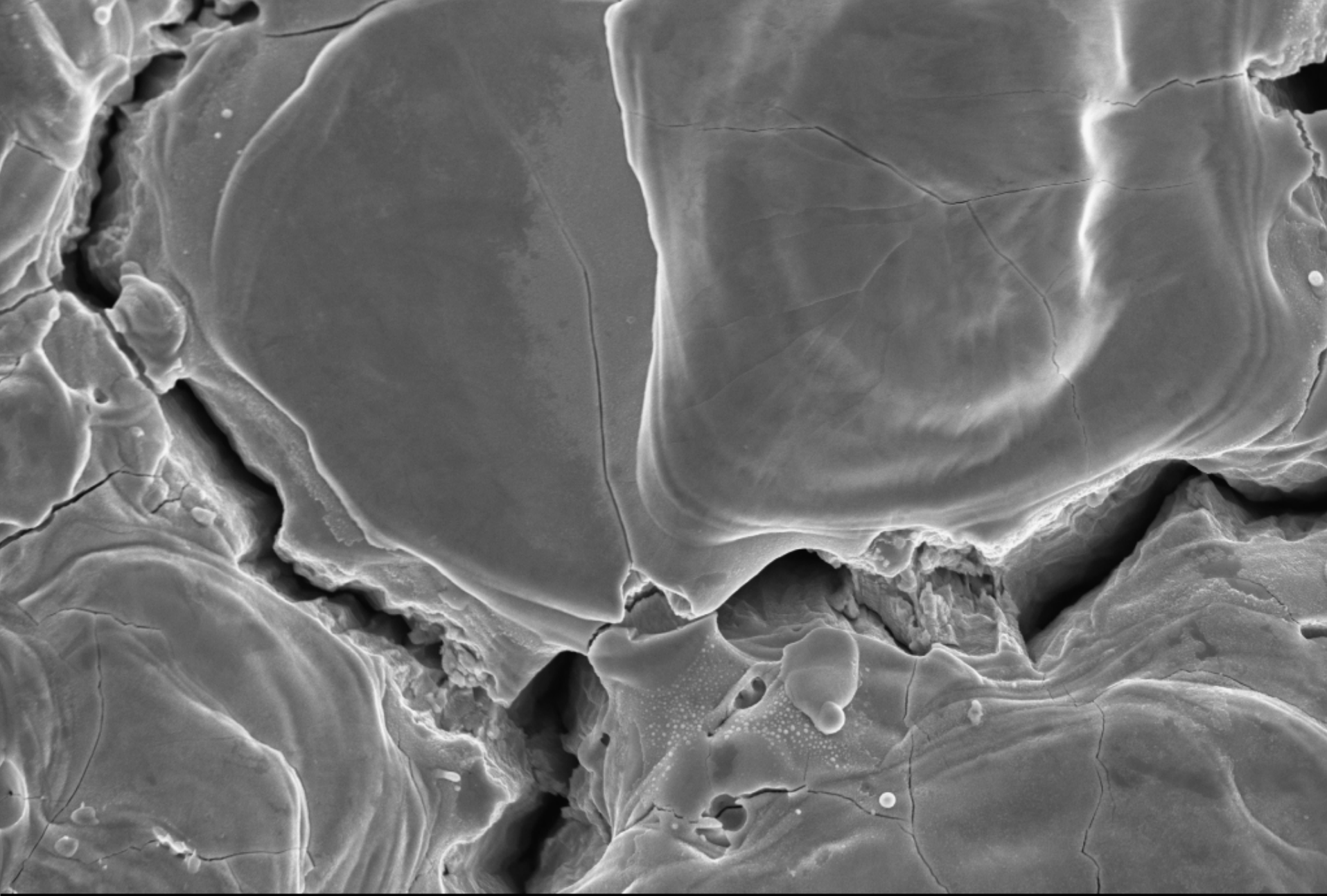
G. Arnau TS/MME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Mo. EDM sector at EIG-1. Iris flat side.
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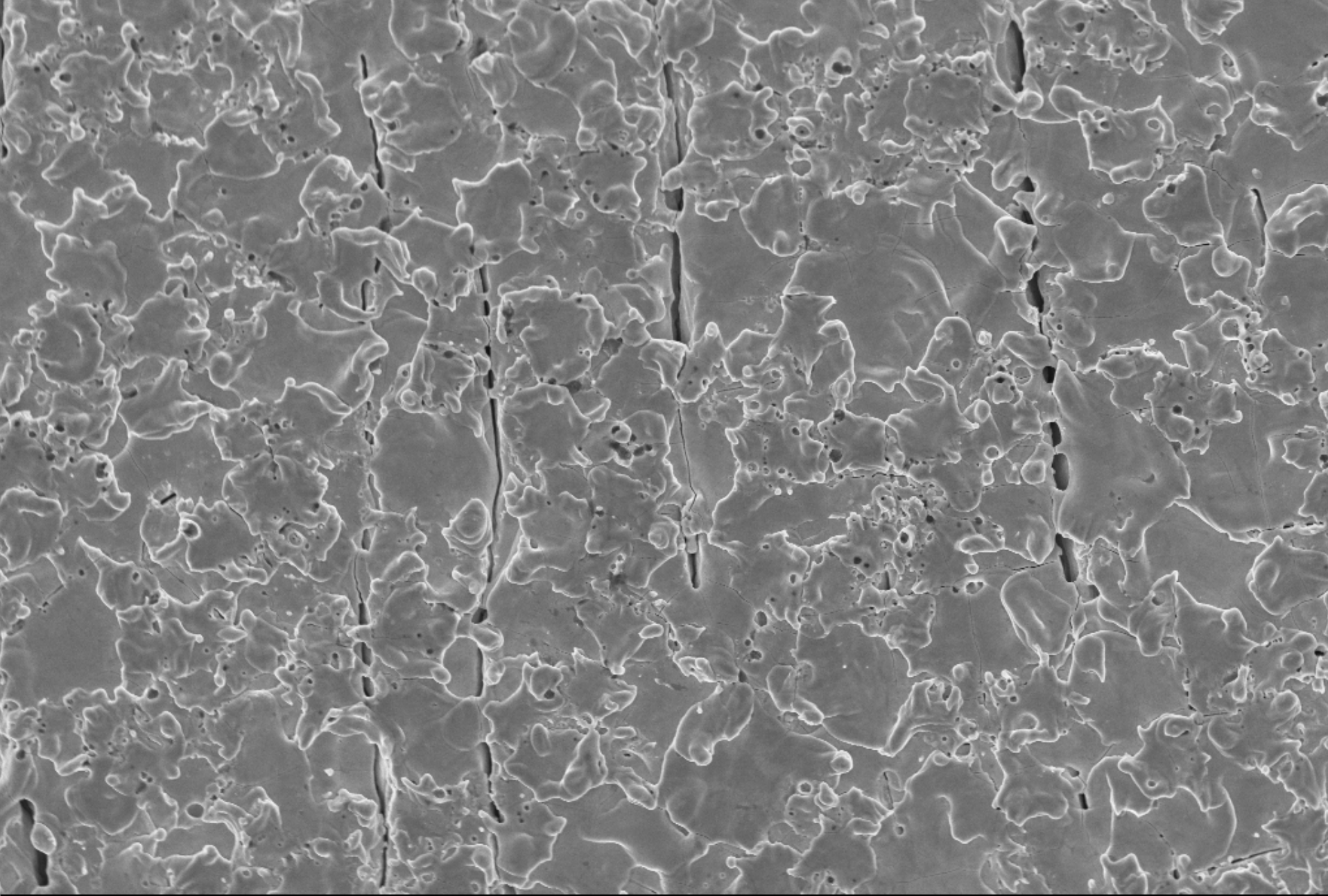
Date :17 Oct 2004
G. Arnau TS/MME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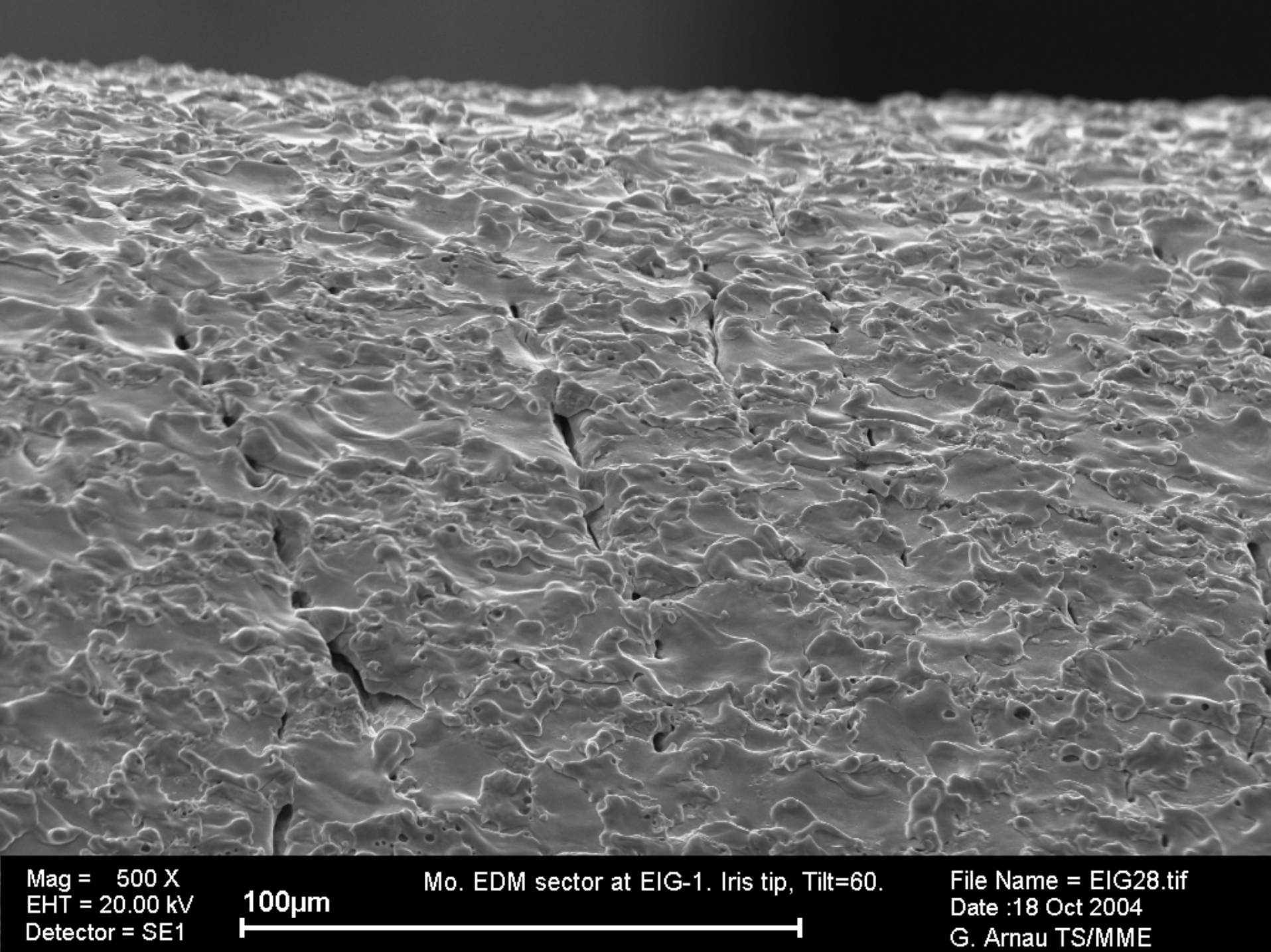
Date :17 Oct 2004
G. Arnau TS/MME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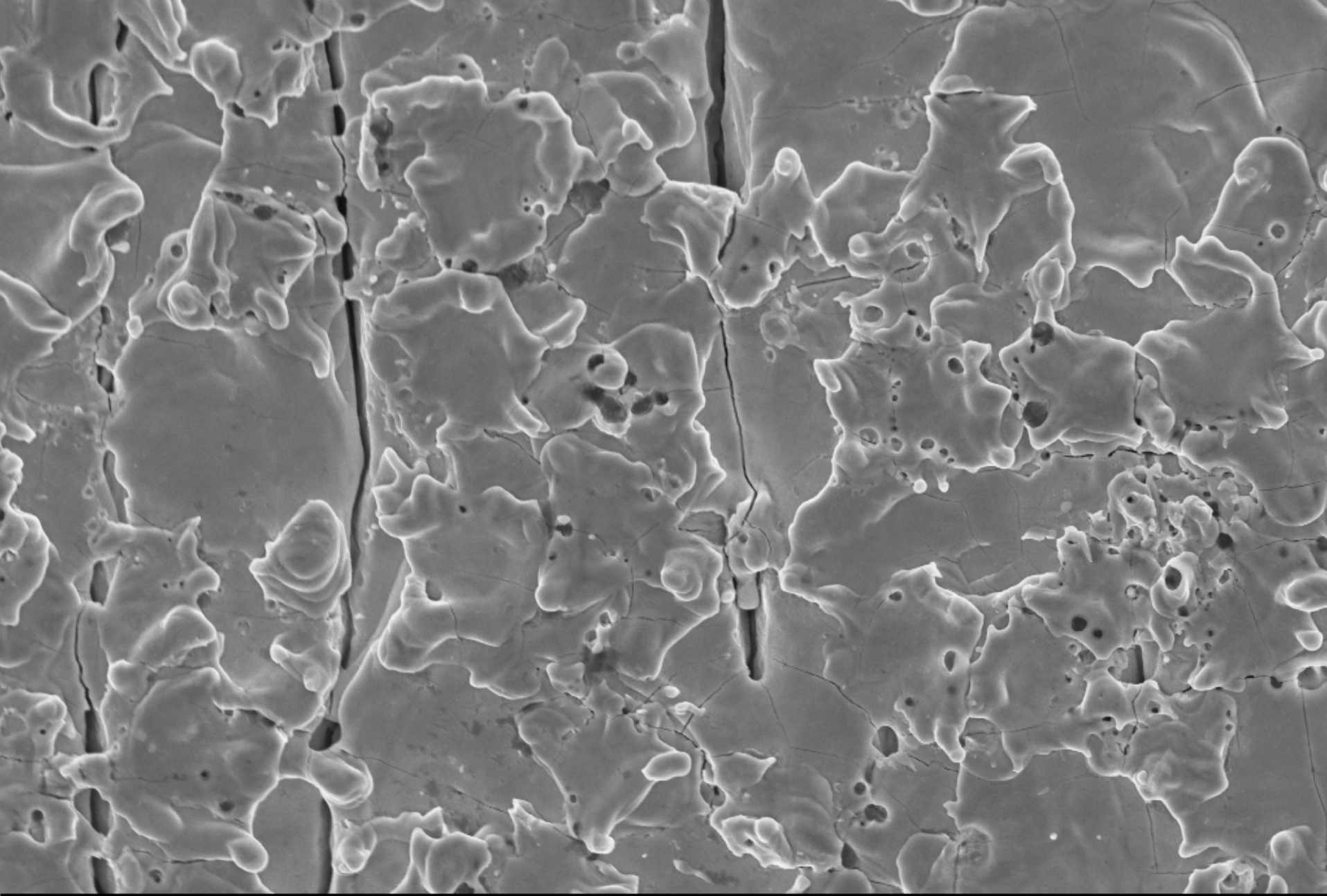
G. Arnau TS/MME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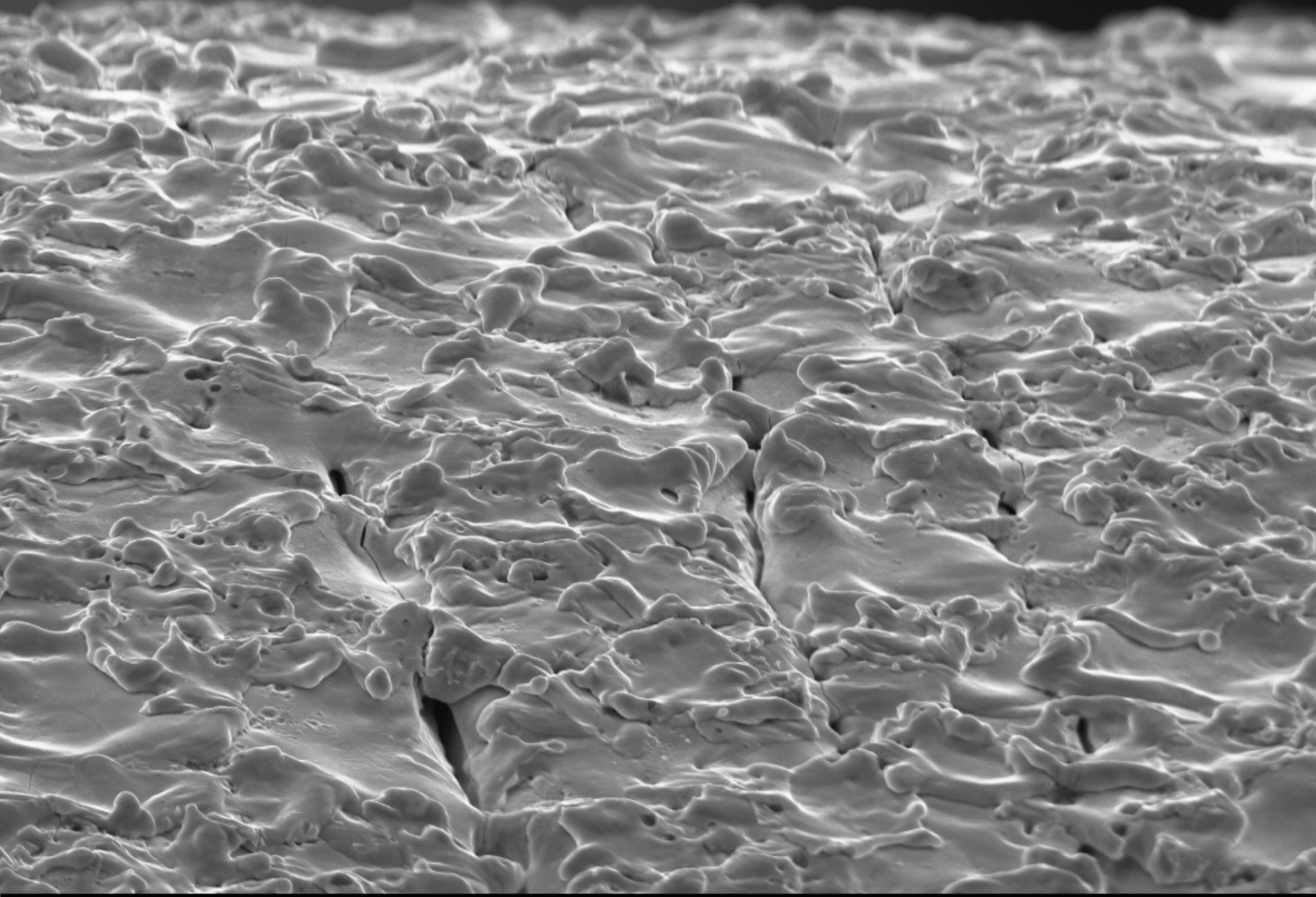
G. Arnau TS/MME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G. Arnau TS/MME