Advanced Electrochemical Machining (ECM) for Tungsten Surface Micro-Structuring in Blanket Applications

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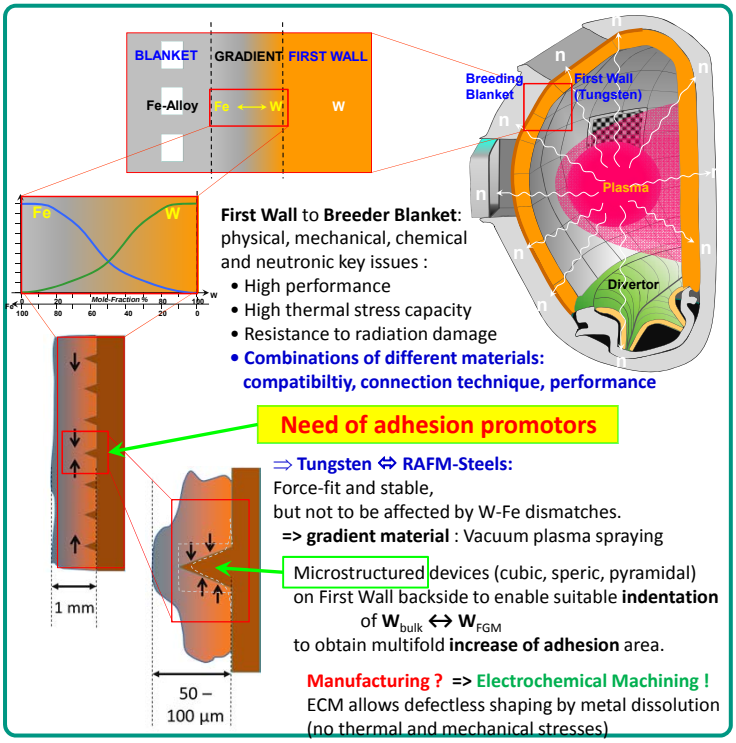
Motivation



First Wall to **Breeder Blanket**: physical, mechanical, chemical and neutronic key issues :

- High performance
- High thermal stress capacity
- Resistance to radiation damage
- **Combinations of different materials: compatibiltiy, connection technique, performance**

Need of adhesion promotors

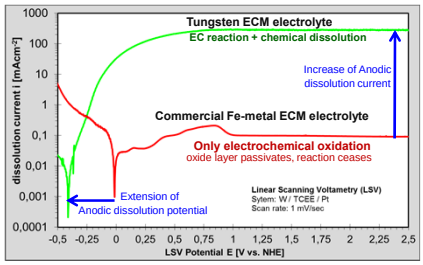
⇒ **Tungsten ⇔ RAFM-Steels:**
Force-fit and stable,
but not to be affected by W-Fe dismatches.
=> gradient material : Vacuum plasma spraying

Microstructured devices (cubic, speric, pyramidal) on First Wall backside to enable suitable **indentation** of W_{bulk} ↔ W_{FGM} to obtain multifold **increase of adhesion** area.

Manufacturing ? => Electrochemical Machining !
ECM allows defectless shaping by metal dissolution (no thermal and mechanical stresses)

Electrochemistry of tungsten

Electro-chemical investigation: tungsten dissolves in aqueous ECM electrolytes under formation of hydroxides, condensing to insulating oxides, ...
but which are sensitive to variation of chemical environment (pH, nucleophiles,...)



$W + 3\,H_2O \rightarrow WO_3 + 6\,H^+ + 6e^-$ $\quad WO_3 + 2\,OH^- \rightarrow WO_4^{2-} + H_2O$

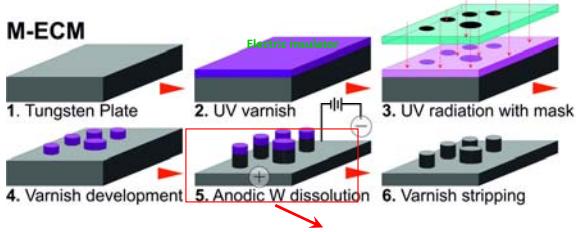
total ECM reaction: $W + 2\,H_2O + 2\,OH^- \rightarrow WO_4^{2-} + 6\,H^+ + 6e^-$

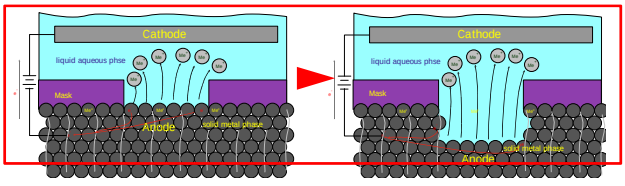
Regular aqueous ECM electrolytes (for Iron metals) are **not suitable** for tungsten.

Developped W-ECM solution increases Anodic reaction over several decades.

Effective and constant W-metal removal can take place in ECM if adopted e+c-reaction type by
- **two-component electrolyte**
- **electric pulse profiles**

ElectroChemical Machining (ECM) processes

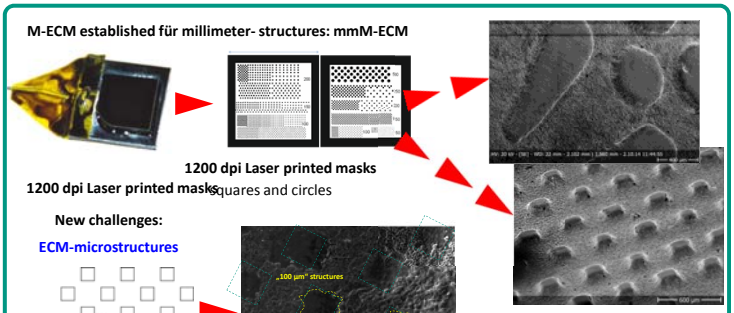




Mask-guided ECM (M-ECM): W-ablation by EC-dissolution of non-covered surface areas by a defined 2-dim resist mask => 3 dim shaping

Shaping of millimeter structures: mmM-ECM

M-ECM established für millimeter- structures: mmM-ECM



1200 dpi Laser printed masks squares and circles

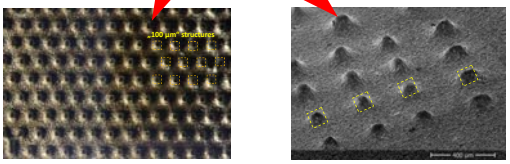
New challenges:

ECM-microstructures

3-dim shaping :
Tungsten surface with well-elaborate squares of 250 µm

Laserprinted mask, structuire size 100 µm: non-accurate imaging (edge rounding)...

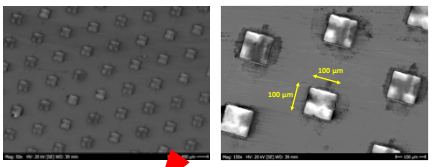
Adhesion structures: Micrometer-Dimensionin hair sizes



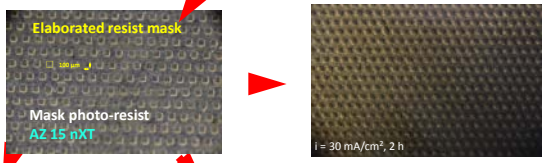
... Undefined shaping because of imagination-failures in micrometer-dimensions of printer mask

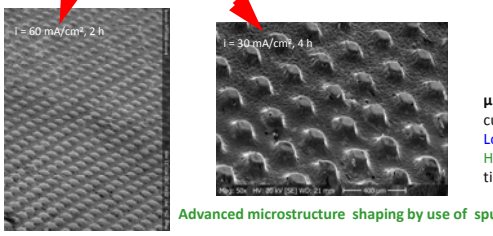
Minaturization into Microstructures: µM-ECM

Mircrostructure M-ECM masks
Lithographic masks for ECM-micrometer shaping:
only possible by microsystem manufacturing methods



Mask processing:
- UV-tansparent glass
- Metal sputtered (Cr).
- Eximer-Laser ablation





µM-ECM shaping Factor
current ***i*** and time ***t***:
Low currents ***i***: edge forming
High currents ***i***: round forming
time ***t***: deepness/height

Advanced microstructure shaping by use of sputtered mask

Conclusion

The results of our investigations show that M-ECM can be develllopped into microstructure dimensions

- **Standard two component electrolyte (TCEE) was used and conditions adopted to µm shaping**
- **W surfaces in strongly different geometrical features were successfully elaborated by specifically adapted suitable parameters**
- **High frequency pulse currents of 10^3 Hz are essential accuracy especially in C- ECM.**
- **1st Milestone: Squares of 100 µm in required geometry imaged into tungsten bulk.**
- **Further investigations: structure size 50 µm, required edge rounding**

Acknowledgment

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