**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 neutron key issues:
- High performance
- High thermal stress capacity
- Resistance to radiation damage
- Combinations of different materials: compatibility, connection technique, performance

**Need of adhesion promoters**

- **Tungsten ≠ RAFM-Steels:**
  - Force-fit and stable, but not to be affected by W-Fe mismatches.
- **gradient material:** Vacuum plasma spraying

Microstructured devices (cubic, spicic, pyramidal) on First Wall backside to enable suitable indentation of WECM to obtain multifold increase of adhesion area.

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

### Shaping of millimeter structures: mmM-ECM

**M-ECM established for millimeter-structures: mmM-ECM**

1200 dpi Laser printed masks

- New challenges:
  - ECM microstructures
  - Laserprinted mask, structure size 100 μm: non-accurate imaging (edge rounding)...

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

### Minaturization into Microstructures: μM-ECM

**Microstructure M-ECM masks**

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

### 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, nucleophile, ...)

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

Developed W-ECM solutions increase Anodic reaction over several decades.

**Effective and constant W-metal removal can take place in ECM if adopted electrolyte type by**

- two-component electrolyte
- Electric pulse profiles

**ECM reaction + chemical dissolution**

**First Wall + Neutron Blanket + 3-D Divertor**

### ElectroChemical Machining (ECM) processes

1. **Tungsten Plate**
2. **UV varnish**
3. **UV radiation with mask**
4. **Varnish development**
5. **Anodic W-dissolution**
6. **Varnish stripping**

**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**

### Conclusion

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

- Standard two component electrolyte (TCEl) 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 10³ 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

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