BA DEMO R&D Activities on Advanced Tritium Breeders in EU

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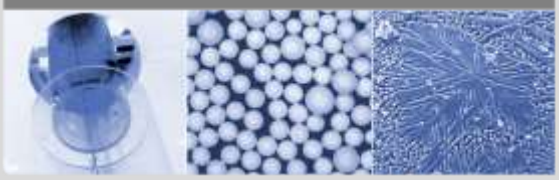
INSTITUTE FOR APPLIED MATERIALS - MATERIAL PROCESS TECHNOLOGY



D-T Fusion Power Plants

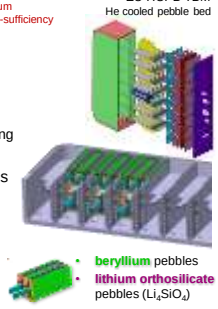
Plasma: $^{2}H + {}^{3}H \rightarrow {}^{4}He + n + Energy$

Blanket: $^{6}Li + n \rightarrow {}^{4}He + {}^{3}H + Energy$

tritium self-sufficiency

- Solid breeder concept
  - beryllium pebbles as neutron multiplier
  - lithium ceramic pebbles for tritium breeding
- Requirements for tritium breeder ceramics
  - high lithium density
  - low tritium inventory
  - low activation
  - high thermal + mech. resistance
  - economic production + recycling

EU HCPB TBM
He cooled pebble bed



- **beryllium** pebbles
- **lithium orthosilicate** pebbles (Li_4SiO_4)

Projects of the Broader Approach Activities

- **Broader Approach (BA) comprises 3 projects**

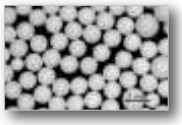
  In February 2007, Euratom and the Japan signed the BA agreement
  JA activities are funded by EU, EU activities by national governments

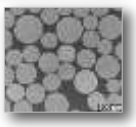
  - Eng. Validation and Eng. Design Activities for the International Fusion Materials Irradiation Facility (IFMIF/EVEDA)
  - Satellite Tokamak Programme Participation to upgrade of JT-60 Tokamak to JT-60SA and its exploitation
  - International Fusion Energy Research Center (IFERC)
    - DEMO Design and **DEMO R&D** coordination Center
    - Computational Simulation Center
    - ITER Remote Experimentation Center

T1 SiC/SiC Composite
T2 Tritium Technology
T3 Materials Engineering for DEMO Blanket
T4 Adv. Neutron Multiplier for DEMO Blanket
T5 Adv. Tritium Breeders for DEMO Blanket

R&D Tasks: Advanced Tritium Breeders

- Preparation of Equipment (JA)
- Production of advanced breeder pebbles
  - Production of lithium orthosilicate pebbles (EU)
  - Production of lithium metatitanate pebbles (JA)
- Characterization of the developed materials
  - Inspection of properties
  - Study on long-term stability (EU, 2013)
- Studies related to reprocessing and re-use (2013-2014)
  - Study on reprocessing
  - Minimization of impurities
  - Calculation of activation characteristics (EU)





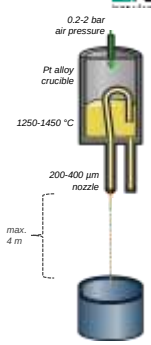
Production of Advanced Breeder Pebbles

KALOS (KArlsruhe Lithium OrthoSilicate) facility

- Melt-based process to achieve:
  - a controlled droplet generation
  - a high yield
  - a close process control
  - a high crush load
  - a low porosity

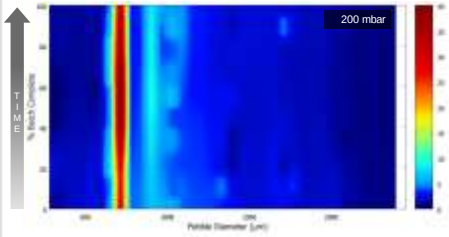
Process Characteristics

- Raw Materials
  - LiOH·H_2O, SiO_2 and TiO_2
    - Formation of Li_4SiO_4 (Li_2SiO_3) and Li_2TiO_3
- Process Features
  - droplet generation by jet breakup (Rayleigh instability)
  - 1 kg batch size
  - liquid nitrogen as cooling medium
    - quench method
    - spray method

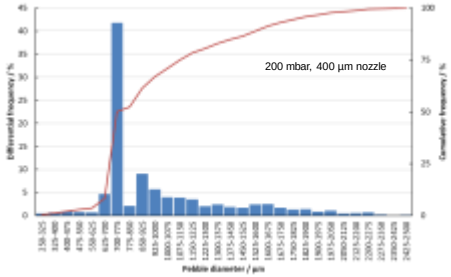


Pebble Size Distribution

- Effect of the operating pressure (400 µm nozzle)

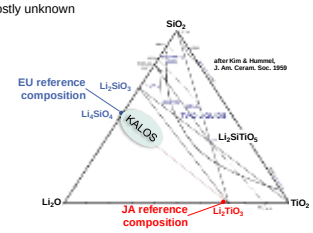


Pebble Size Distribution



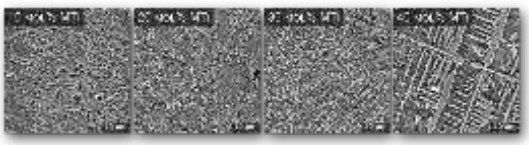
Ceramic Breeder Materials

- Modified breeder material: combination of Li_4SiO_4 & Li_2TiO_3
  - Fabrication of two- or three-phase breeder pebbles
    - up to 15 mol% Li_2SiO_3 and 40 mol% Li_2TiO_3
    - phase equilibria mostly unknown



Microstructure of Modified Breeder Ceramics

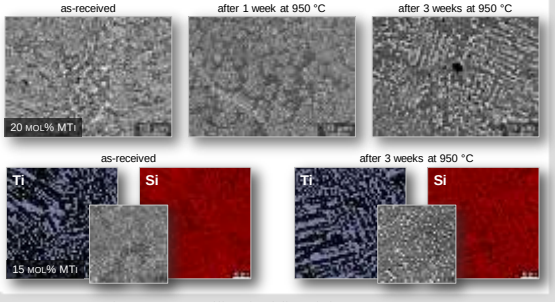
- Effect of Li_2TiO_3 content



- Li-orthosilicate and Li-metatitanate solidify dendritically
  - Between 20 and 30 mol% metatitanate a distinct change in crystallization behavior can be observed, as metatitanate dominates the crystallization

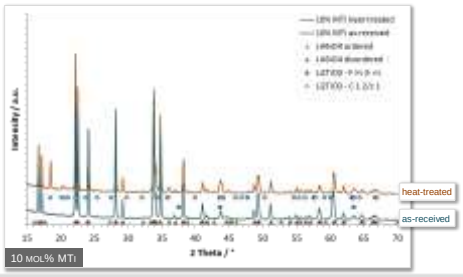
Microstructure of Modified Breeder Ceramics

- Effect of heat treatment



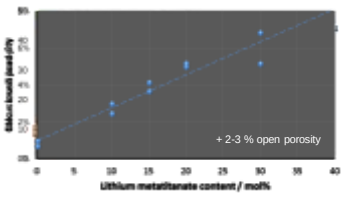
Phase Content of Modified Breeder Ceramic

- A disordered, cubic HT-phase of Li_2TiO_3 is initially received, which is easily transformed to the stable monoclinic phase



Crush Load and Density

- The addition of metatitanate has a strong effect on the crush load
  - A significant increase results beyond 10 mol% Li_2TiO_3



- The closed porosity increases with increasing Li_2TiO_3 content

Summary and Outlook

- The KALOS test facility is an experimental set-up
  - enhanced process control
  - variable chemical compositions
  - promising pebble quality
  - reproducibility has to be further increased
- Near-term activities
  - Study on long-term stability *(ongoing)*
  - Study on reprocessing and re-use *(2014)*
  - Further optimization of process and pebble properties
- Future activities *(outside BA DEMO)*
  - Neutron irradiation campaign of newly developed material
    - Effect of neutron irradiation (PIE)
    - Tritium retention/release
  - Scaling-up of production method

- Cooperation partners

GVT Gorialeb Versuchstechnik

JAEA Japan Atomic Energy Agency

IFERC International Fusion Energy Research Center

- Funding

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THANKS FOR LISTENING