Karlsruhe Institute of Technology

HELMHOLTZ ASSOCIATION

LIMTECH Alliance *and HEMCP: Helmholtz Energy Materials Characterization Platform*

Institut für Neutronenphysik und Reaktortechnik
Anlagenentwicklung, Systemdynamik und Sicherheit

Development of an Alkali Metal Thermal to Electric Converter (AMTEC)

N. Díez de los Ríos, A. Onea, W. Hering, J. L. Palacios, P. Moster, R. Stieglitz

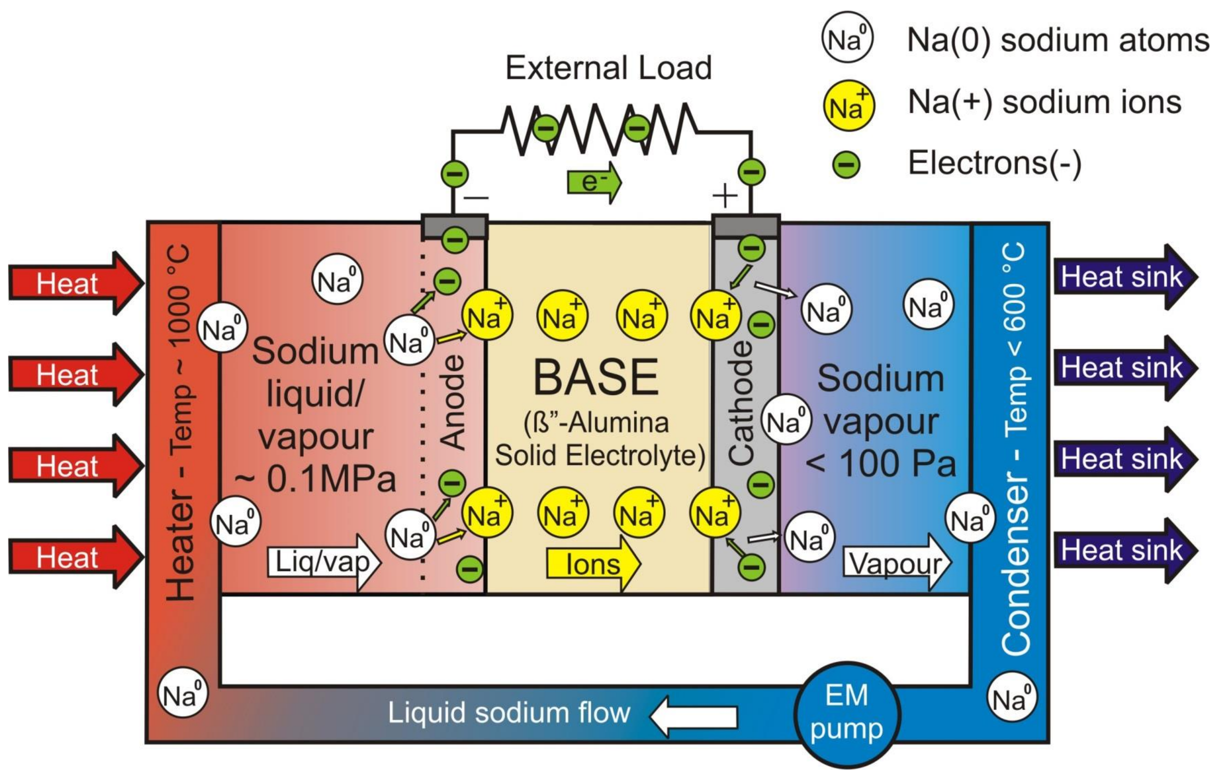
HEMCP AMTEC CENTER

AMTEC operating principle

- Direct conversion of thermal energy into electricity
- Key component: β''-Alumina Solid Electrolyte (BASE)
- Key process: Na-ionization (Δp across BASE)

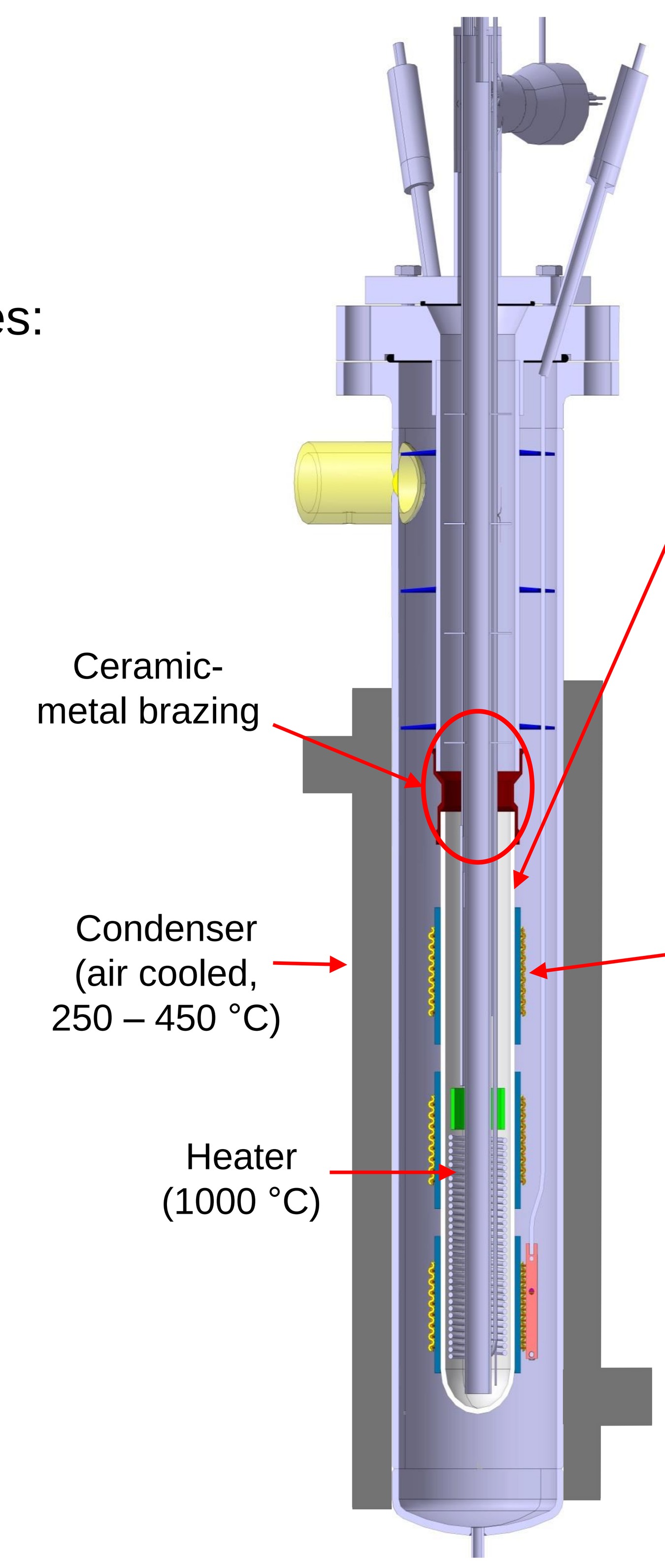
$$Na \rightarrow Na^{+} + e^{-}$$

- Recombination of Na^+ and e^- only at 3-phase boundaries: BASE – electrodes – Na
- Na condensation
- Na return line: electromagnetic pump



Operating principle of AMTEC

AMTEC test cell



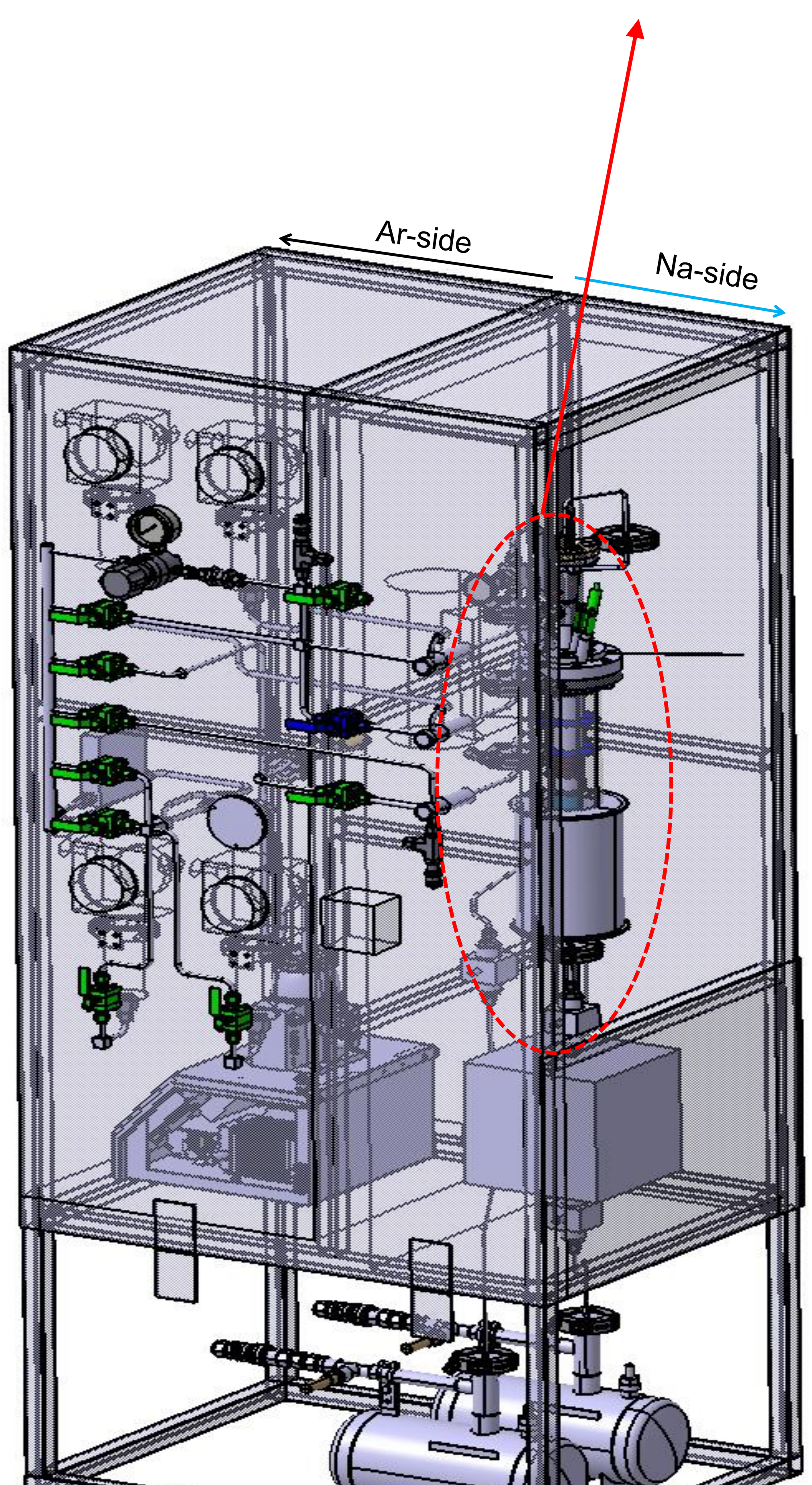
Open issues

- Cell efficiency (η_{theo} ~ 45 %)
- Contribution to power degradation:
  - BASE degradation ~ 60 – 70 %
  - Electrode degradation ~ 20 %

Variable	AMTEC @ INR
V	0.4 – 1.2 V
I	0.5 – 1.5 A/cm²
P	0.5 – 1.5 W/cm²
$\eta_{present}$	~ 20 %
T_{Na}	600 – 1000 °C
p_{Na}	10 Pa – 0.1 MPa

AMTEC TEst FAcility (ATEFA)

- At present under construction
- Control Na-flow
  → adjustment Ar properties (p_{Ar} & $\dot{m}_{Ar}$)
- Safety aspects:
  - Contained in an thermally isolated metallic box
  - Na-side separated from Ar-side
  - Emergency Na evacuation: delivery in both tanks



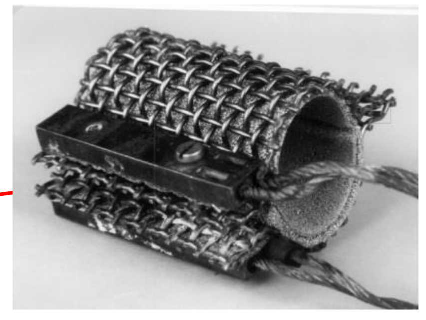
Requirements for:

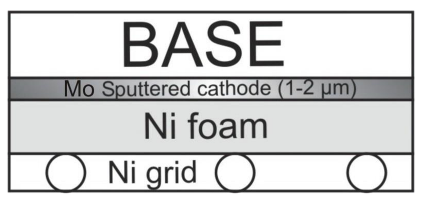
(+) fulfilled
(-) improvable

BASE (ß''-Alumina Solid Electrolyte)

- High ionic conductivity (0.38 1/Ωcm at 400 °C) (+)
- Negligible electron conductivity (1.1 × 10^{-4} 1/Ωcm at 650 °C) (+)
- Chemical stability in operation (-)

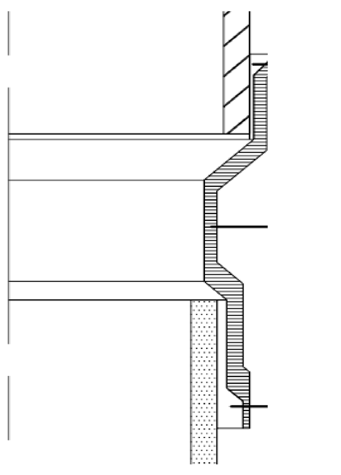
Electrode (Cathode) and current collector





- High electronic conductivity / low resistance (-)
- Large amount of contact points to the BASE (+)
  → recombination rate of sodium ions in sodium vapor
- Good sodium vapor transport (-)
- Stability at high temperatures (grain growth) (-)

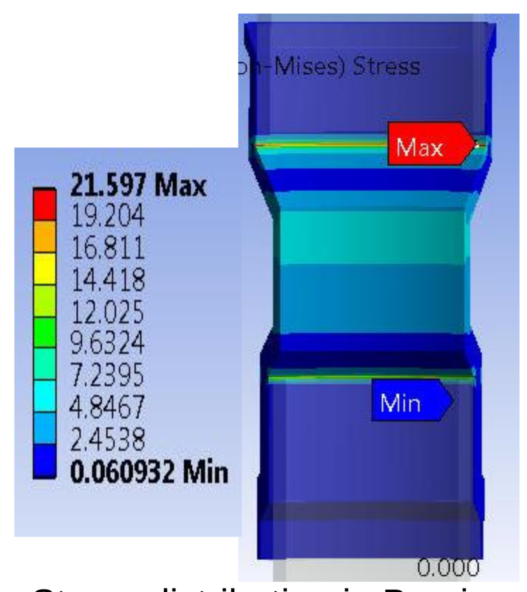
Ceramic to metal joining



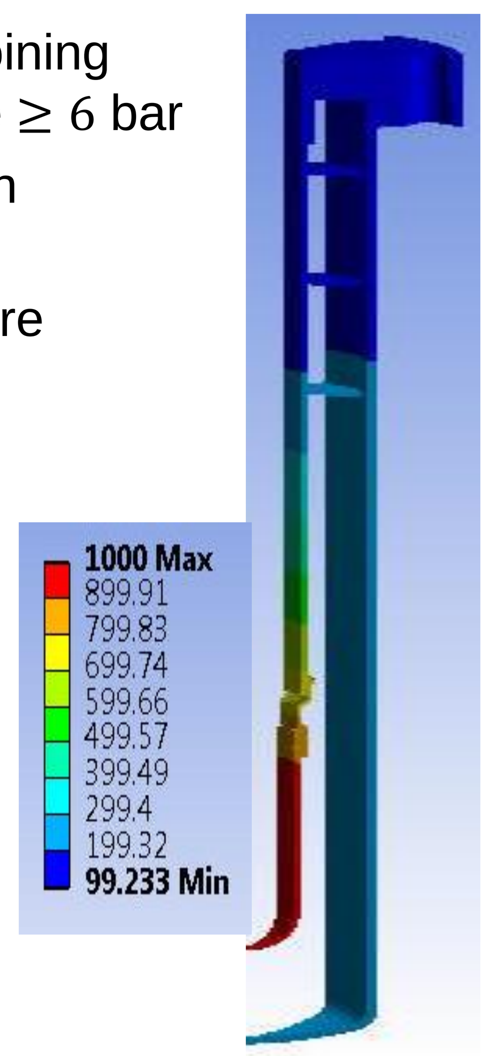
- High leak tightness (+)
- Similar coefficient of thermal expansion (+)
- Chemically stable in sodium environment (+)
- No diffusion of filling material (-)

Thermal and mechanical analysis

- Temperature and stress distribution in cell obtained (steady state and transient analysis)
- No failure at working conditions (1 – 2 bar, 1000 °C)
  → safe design
- Highest stresses in BASE-Nb joining
  → possible failure at a pressure ≥ 6 bar
- Cooling under forced convection (transient) → no failure
- High ΔT along BASE → no failure



Stress distribution in Brazing [MPa]. Steady state.



Temperature distribution in 1/8 of the cell [°C]. Steady state.