Karlsruhe Institute of Technology

Institut für Neutronenphysik und Reaktortechnik

HELMHOLTZ ASSOCIATION

LIMTECH Alliance and HEMCP

B4: Phase changes in liquid metals for direct energy conversion.

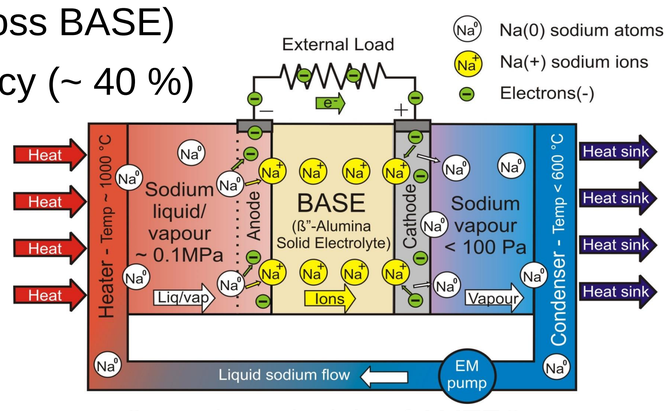
Alkali Metal Thermo-Electric Converter (AMTEC)

N. Diez de los Rios Ramos, M. Bologa, A. Onea, W. Hering, R. Stieglitz

Alkali Metal Thermo-Electric Converter (AMTEC)

- Direct conversion of heat to electricity
- Working fluid/vapor: sodium **Na → $Na^+ + e^-$**
- Key process: (Δp across BASE)
- High expected efficiency (~ 40 %)
- Nernst voltage:

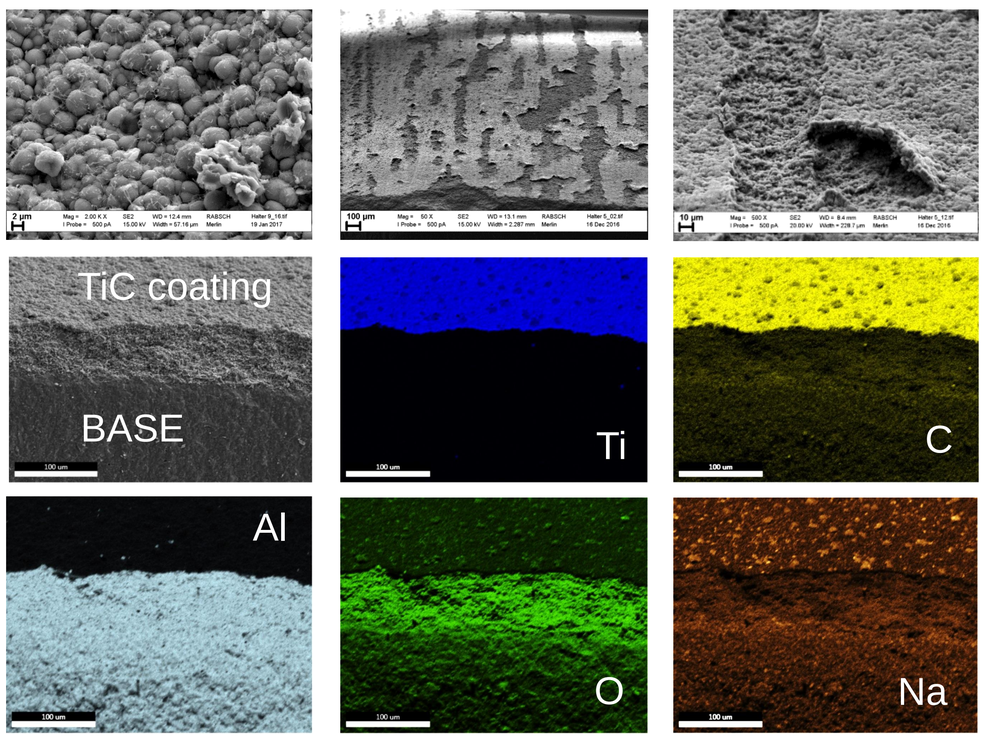
$$V_{cell}{}^{oc} = \frac{RT_B}{F} ln \frac{p_B(T_B)}{p_e{}^{oc}}$$



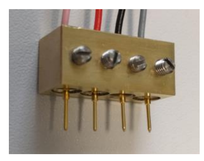
Operation principle of AMTEC

Electrode sputter layer analysis

- SEM analysis (TiC)
  - ✓ Porous structure
  - \- Partial detachment of sputter layer
- EDS analysis (TiC)
  - ✓ Confirmed TiC layer
  - ✓ Na diffusion through the electrode
  - \- Two phases in the ceramic



- 4-Point Probe. Sheet resistance measurements*
  - ✓ ρ(TiN)=0.18 – 0.7 Ω/sq, ρ(TiC)=22.6 – 54.8 Ω/sq
  - ✓ Measured ρ lower than in the literature
  - \- Not homogeneous resistance (detached areas)



* Smits, Bell. Sys. Tech. J. (1957)

Summary

The aim of the work was to develop a layout and engineering solutions for the construction and set into operation of the ATEFA and AMTEC test cell by using available technologies within the Helmholtz AMTEC center (HAC) and based on the experiences in liquid metal technology in the Helmholtz Alliance LIMTECH. First step was to regain the know-how in the AMTEC technology based on the work started at KIT in the nineties.

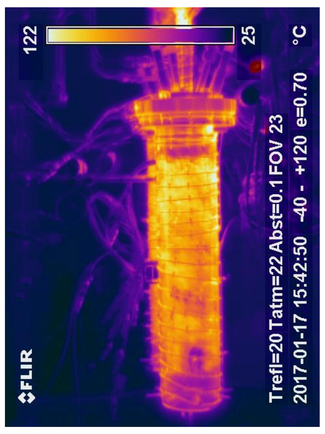
The main challenges of the work regarding the construction of the AMTEC test cell were the development of i) a porous cathode coating of the BASE, ii) a high temperature resistant ceramic-metal joint, iii) a fully electrically isolated cell design, iv) a fully instrumented cell considering the reduced space of the cell structure, the corrosive medium (Na) and the high operating temperature. Moreover a data acquisition and control system were defined and the experimental procedure was developed taking into consideration handling solutions for high-temperature liquid sodium.

ATEFA has been set into operation and short term tests have been successfully performed up to 700 °C. The proof of concept of the AMTEC technology has been achieved and the cell behavior was analyzed at different temperature and pressure conditions. The evaluation of results are in good agreement with the literature.

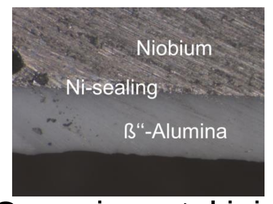
AMTEC TEst FAcility (ATEFA), status

- ✓ Integration of AMTEC test module finished
- ✓ Construction of ATEFA finished
- ✓ Data acquisition and control system finished and tested
- ✓ Ceramic -metal joint tested (700 °C)
- ✓ Ceramic coating experimentally analyzed (SEM, EDS,4-point probe)
- ✓ ATEFA successfully tested (700 °C) → pressure and heating/cooling tests
- ✓ Measurement campaign finished
- ✓ AMTEC proof of concept achieved
- ✓ Evaluation of results finished

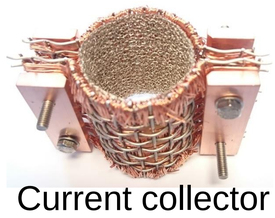
AMTEC Test cell



Cell temp. distribution



Ceramic-metal joint

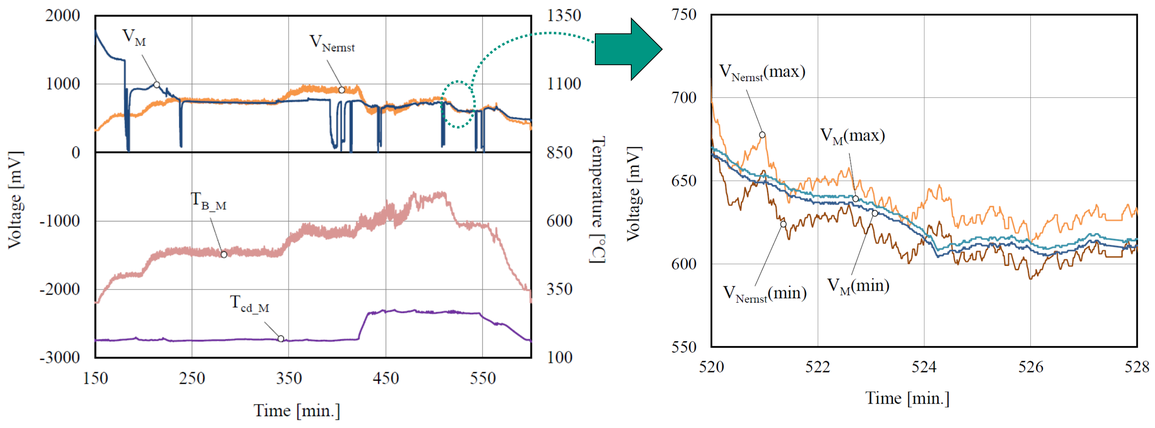


Current collector

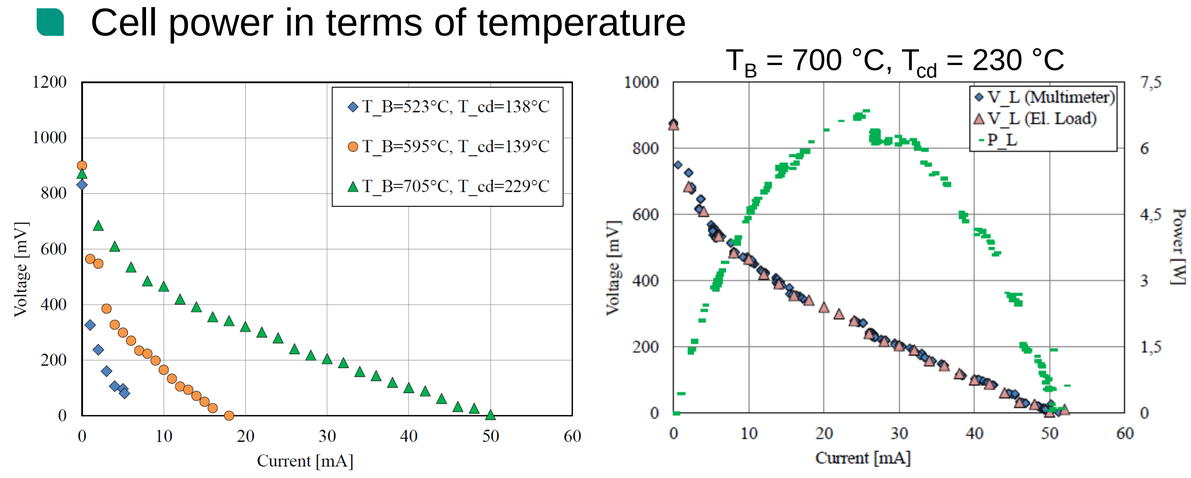
ATEFA

AMTEC experimental results

- Open circuit voltage (OCV) vs. Nernst voltage



- Cell power in terms of temperature



- Summary and conclusions
  - Cell power measured at 500 – 700 °C
  - Large influence of the ceramic wetting (<350 °C) on OCV
  - Quantitative good agreement of OCV with literature
  - Qualitative good agreement of IV curve with literature
  - Low cell current due to lack of electrode coating
  - Cell power increase with T_B