Karlsruhe Institute of Technology

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

Alkali Metal Thermo-Electric Converter (AMTEC)

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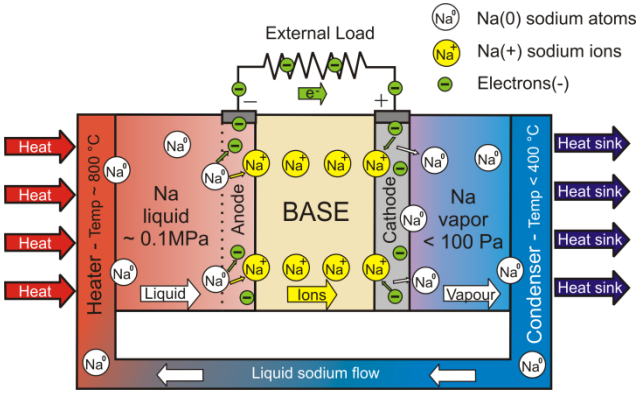
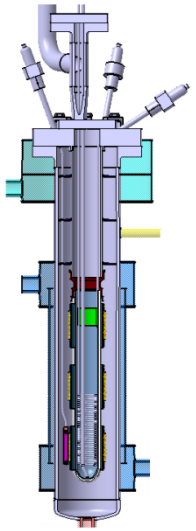


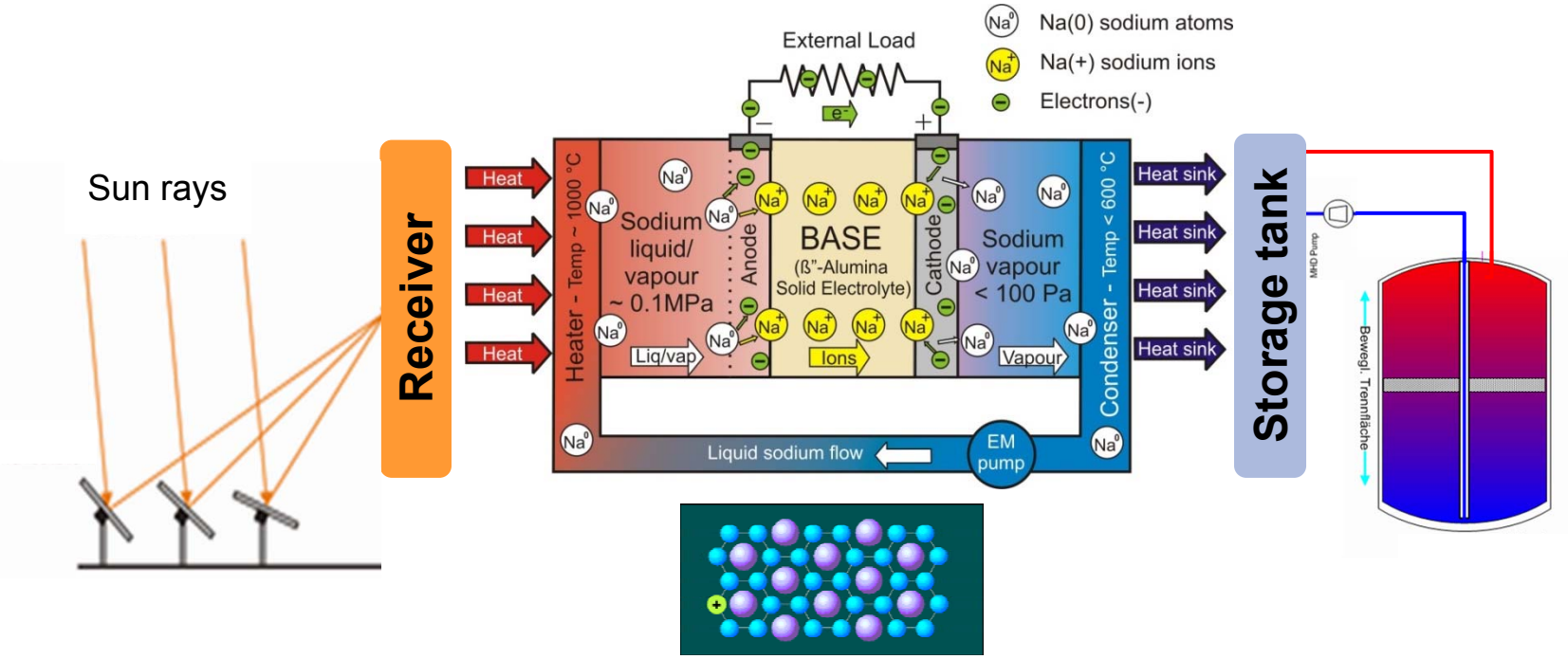


Content

- Introduction – AMTEC process
- Experimental setup
  - ATEFA
  - AMTEC test cell
- Analysis of former measurement data (Heinzel et al. 1993)
- Summary & outlook

AMTEC – direct heat to electricity conversion

Alkali Metal Thermo-Electric Converter



- Key component: β''-Alumina Solid Electrolyte (BASE)
- Key process: Na-ionization
  ΔP across BASE → Δ(sodium activity)

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

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Experimental setup

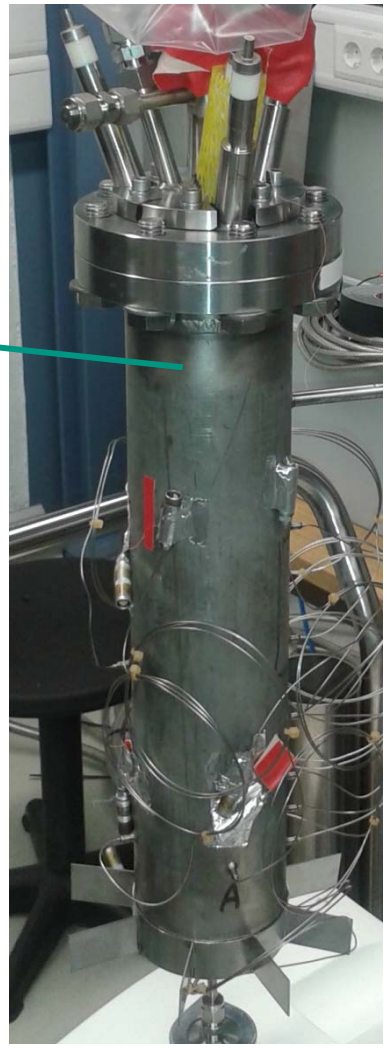
AMTEC Test Facility (ATEFA)

- Data acquisition and control system finished (test phase ongoing)
- ATEFA in last phase of construction

Preliminary tests*

- First successful ceramic-metal joint (10^{-5} mbar)
- TiC, TiN, Mo electrodes achieved
- Analysis of electrode ongoing

*together with other institutes in KIT



Nb - BASE
- Cathodes

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Analysis of former measurement data (1993)

Basic equation system

- Open circuit (oc) voltage, Nernst equation:

$$E_{cell}{}^{oc} = \frac{RT_B}{F} ln \frac{p_a}{p_c}$$

- Closed circuit (cc) voltage:

$$E_{cell}{}^{cc} = E_{cell}{}^{oc} - \underbrace{(\xi_a - \xi_c)}_{0} - \xi_r$$

Polarization losses | Ohmic losses

Applying Butler-Volmer equation for overvoltage:

$$E_{cell}{}^{cc} = \frac{2RT_B}{F} ln \left[\frac{p_a}{2({p_c}^T + (K_f + m_i)i)} \left\{ -\frac{i}{i^{ex}} + \sqrt{\left(\frac{i}{i^{ex}}\right)^2 + \frac{4({p_c}^T + (K_f + m_i)i)}{p_a}} \right\} \right] - i \, {R_\Omega}^{cell}$$

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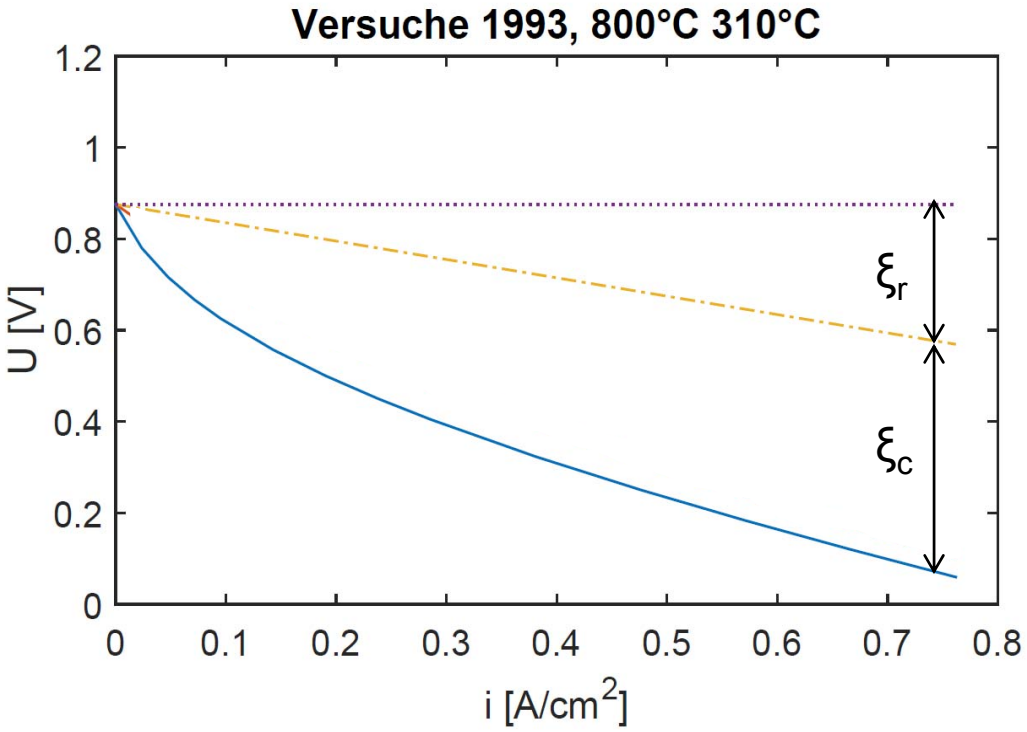
Analysis of former measurement data (1993)

Overvoltage losses

Voltage drop:

- Ohmic losses:
  $\xi_r = i\, R_\Omega{}^{cell}$
  (~ 20 %)
- Polarization losses: ξ_c
  (~ 80 %)
  - Grain size
  - Porosity
  - Thickness
  - Current collector structure
  - Material properties



Heinzel et al. 1993

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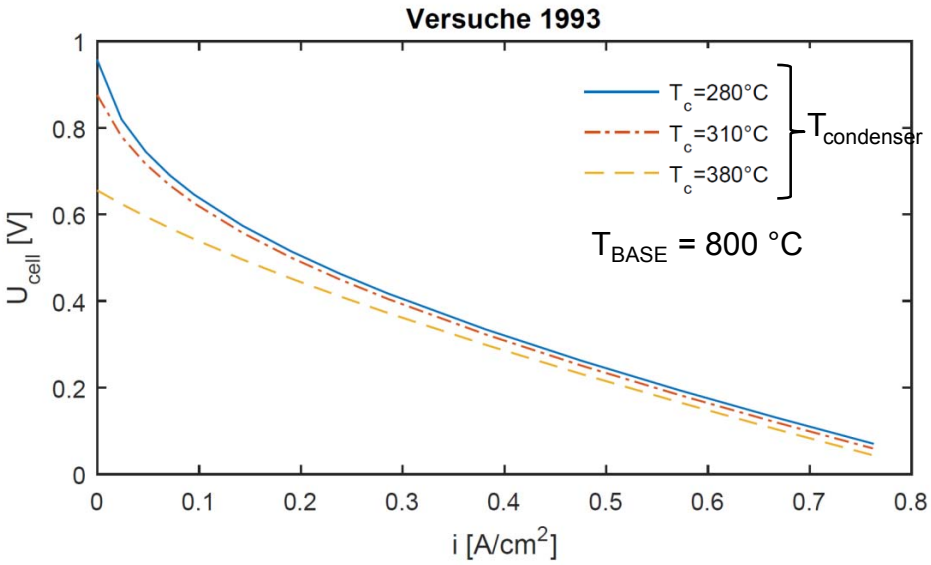
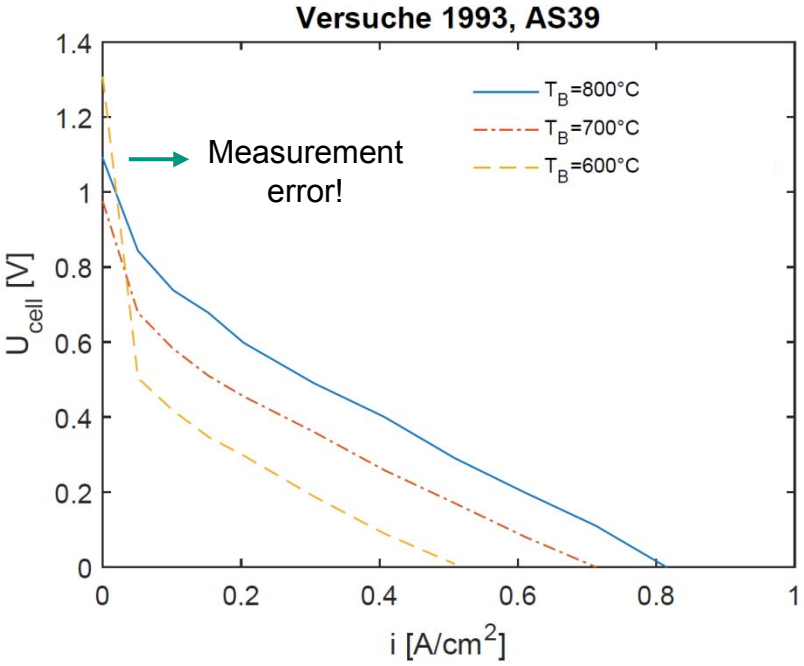
Analysis of former measurement data (1993)

Effect of the temperature

- Characteristic curve (IV)



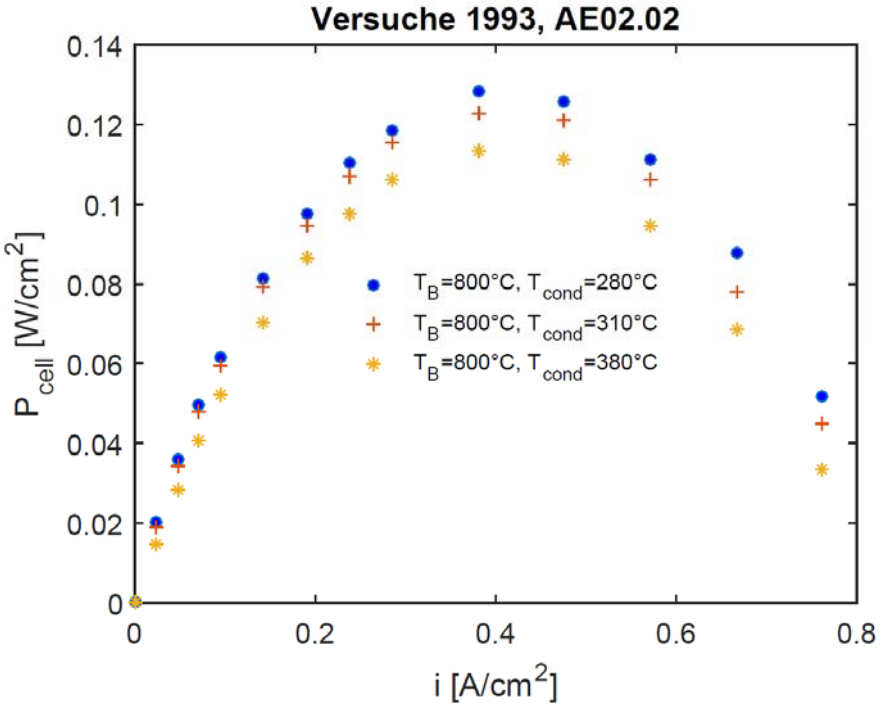


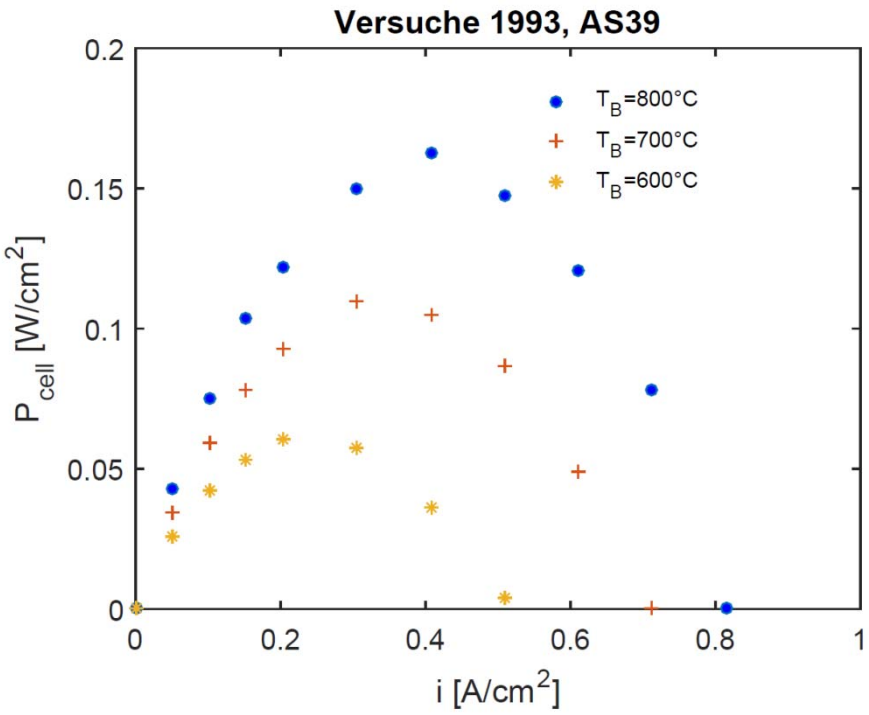
Heinzel et al. 1993

- Decreasing T_{cond} increases U_{cell}
- Increasing T_{BASE} increases U_{cell}
- Effect of T_{BASE} >> effect of T_{cond}

Analysis of former measurement data (1993)

Effect of the temperature





Heinzel et al. 1993

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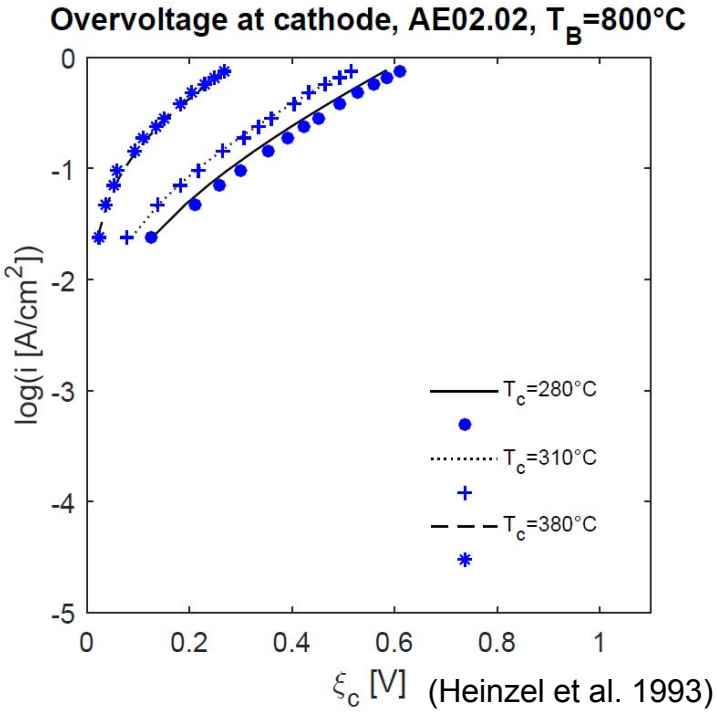
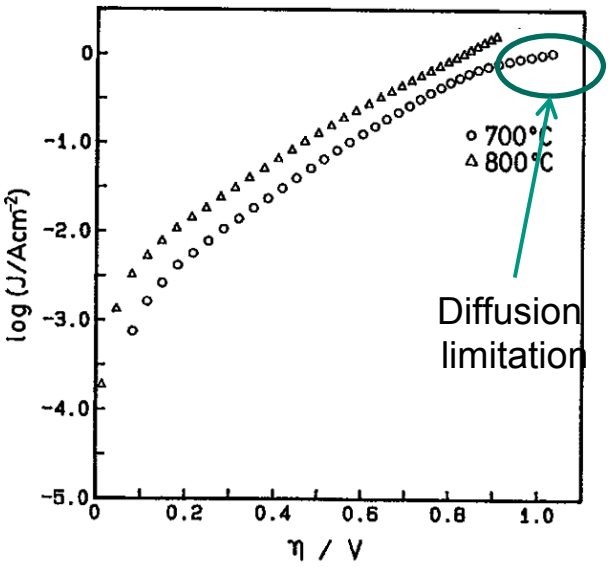
Analysis of former measurement data (1993)

Effect of the polarization - overvoltage



(Heinzel et al. 1993)



(Kato et al., 1992)

Fig. 9 Relation between overvoltage and logarithm of current density of AMTEC with TiC–A2 electrode.

- Overvoltage increases with current
- Overvoltage increases with decrease of T_{BASE} & T_{cond}
- No diffusion limitation is at T_{BASE}>800 °C for i<1.1 A/cm²

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Summary and Outlook

- ATEFA waiting for TESTCELL
- Preliminary tests in ceramic-metal joining finished
- Analysis of the electrode ongoing
- Data acquisition and control system finished (test phase ongoing)
- Programed data-analysis (evaluation) system in Matlab finished
- Former measurement data analyzed

- Set into operation of ATEFA (Sept. 2016)
- Start measurement campaign (Oct. 2016)

THANK YOU
QUESTIONS?