Overview of Fraunhofer IPM Activities in High Temperature Bulk Materials and Device Development

2011 Thermoelectrics Applications Workshop, Hotel Del Coronado, San Diego, CA, January 3-6

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Content

Overview about Fraunhofer IPM
New funding situation in Germany
High temperature material and modules
Energy-autarkic sensors
Thermoelectric metrology
Summary
Fraunhofer-Gesellschaft

one of the leading organizations for application-oriented research in Europe

~13 000 number of employees

Fraunhofer has more than 80 research units, including 60 Fraunhofer Institutes in Germany.
Starting Point of thermoelectrics at Fraunhofer IPM
Chalcogenides: From MIR-laser to thermoelectricity

<table>
<thead>
<tr>
<th>wavelength</th>
<th>wave number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb$_{1-x}$Sn$<em>x$Te, Pb$</em>{1-x}$Sn$<em>x$Se or Pb$</em>{1-x}$Sn$_x$Se</td>
<td>Pb$_{51-x}$Se$_x$</td>
</tr>
<tr>
<td>ABSORPTION LINES OF TYPICAL GASES</td>
<td></td>
</tr>
<tr>
<td>HNO$_3$, SO$_2$, H$_2$O, SO$_2$, CH$_4$</td>
<td></td>
</tr>
<tr>
<td>NO, NO$_2$, CO, CO$_2$, CH$_4$, C$_2$H$_4$</td>
<td></td>
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</tbody>
</table>

PbTe  Fh IPM 1989

contacts  8 mm
Thermoelectricity at Fraunhofer IPM

First Si-wafer based module fabrication based on Bi$_2$Te$_3$

1998 - 2006

Micropelt device before soldering

Thermoelectric legs structured on wafer

n/p-„Bi$_2$Te$_3$“
Thermoelectrics at Fraunhofer IPM
Converters for power generation and cooling

- High-Temperature and Nano materials
- Simulation
- System technology
- Development of production process
- Measuring station for materials

- Residual heat
  - Automobile
  - Large-scale facilities
  - Energy-autarkic sensors
  - Monitoring of structures
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Energy Technology Perspectives: Scenarios and Strategies to 2050

“... Guidelines for a clean, reliable and affordable energy supply by the year 2050 are to be outlined in an energy concept. The aim of the energy concept is to provide a road map towards the era of renewable energies. In future, Germany aims to rank amongst the world's most energy-efficient and environmentally friendly national economies, offering competitive energy prices and a high level of prosperity. ...”

Joint press release 2010-8-30

R. Brüderle, Federal Minister of Economics and Technology
N. Röttgen, Federal Minister for the Environment, Nature Conservation and Nuclear Safety
New funding situation in Germany
Energy Technology Perspectives: Scenarios and Strategies to 2050: Energy efficiency in Industry

Technologies for energy harvesting:
1. Thermoelectricity
2. Organic Rankine Cycle (ORC)
3. Kalina Cycle
4. Heat exchanger
5. Industrial heat pumps

Recommendations for public R&D funding:
• Evaluation of usable waste heat source
• New thermoelectric materials
• Industrial production technologies for thermoelectric generators
• Improvement of heat exchanger
• New concepts for ORC
• New refrigeration substances for heat cycle

Result: public R&D is important
## New funding situation in Germany

### 2008-2013

<table>
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<tr>
<th>Funding (M€)</th>
<th>Project volume</th>
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<td>BMBF Scientific Fed. Min. of Education and Research</td>
<td>5.5</td>
</tr>
<tr>
<td>BMBF Applied Fed. Min. of Education and Research</td>
<td>25</td>
</tr>
<tr>
<td>BMWI Fed. Min. of Economics and Technology</td>
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*Designed by A. Jacquot*
Thermoelectric Research in EU

EU FP 7

NMP.2010.1.2-3 Thermoelectric energy (TE) converters based on nanotechnology aspects of the manufactured nanoparticles as well as the composites that would be part of the researched TE converters.

Expected impact: through improved TE materials

?? proposals, 4 funded, all contracts are currently under negotiation ⇒ no additional information about contents

• NANOHIGHTECH
• THERMOMAG
• NEAT
• NEXTEG

FUNDING 13-14 Mio € ⇒ > 20 Mio € project volume

ESA / ESTEC starts with thermoelectric
New funding situation in Germany

<table>
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<th>Driving force</th>
<th>Energy efficiency, waste heat recovery</th>
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<td>Thermoelectric as a chance for better energy efficiency</td>
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<td>demand on high temperature materials, modules, systems</td>
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<th>Key account</th>
<th>Automotive industry (W to kW)</th>
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| Rising market | Energy self powered systems (μW to mW) |
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Thermoelectric at Fraunhofer IPM
High temperature materials

Chalcogenides

Silicide

Half-Heusler

Skutterudite
Thermoelectric at Fraunhofer IPM
material synthesis

Synthesis from melt

Spark plasma sintering

Milling / mechanical alloying

2 zone annealing setup
Thermoelectric at Fraunhofer IPM
contact development

metal – TE – metal – TE – metal

Bad contacts

Good contacts

Resistance [a.u.]

distance [a.u.]
Thermoelectric at Fraunhofer IPM
module fabrication
Thermoelectric at Fraunhofer IPM
module characterisation

$T_{\text{Cold}} : 0^\circ\text{C} - 130^\circ\text{C}$

$T_{\text{Hot}} : \text{RT} - 600^\circ\text{C} \ (700^\circ\text{C})$

In-situ pressure distribution measurement

IR-Thermography
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Energy-autarkic sensors

Structure control in airplanes

~8mW output power with a 10g system

Source: EADS
Thermoelectric at Fraunhofer IPM
Energy-autarkic sensors

insertion thermometer for cooking and food control

Source: E.G.O.
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Thermoelectric Metrology

ZT-meter

Combined measurements of all TE-properties up to 600°C
Thermoelectric at Fraunhofer IPM
Thermoelectric Metrology

In-line material control for large scale TEG production

Seebeck-coefficient and electrical conductivity

High through-put

Autoscreen-System
Thermoelectric at Fraunhofer IPM
Thermoelectric Metrology

Bulk and thin film measurement setup

Seebeck-coefficient and electrical conductivity

Rectangular and round sample shape

Temperature range 300K-900K

Fraunhofer IPM-SRX
Validation with Nickel

☆ and ★, our measurement.
○ and □, data of Burkov et al.
⊕ data of Nemschenko et al.
△ data of Beylin et al.

Fraunhofer IPM-SRX
Thermoelectric at Fraunhofer IPM
Thermoelectric Metrology

Comparison of different measurement setups

ZEM-3:

IPM-SRX:

![Graph showing comparison between ZEM3 and IPM-SRX](image-url)
Thermoelectric Standardisation
Thermoelectric Metrology

New Project: ThermoElectric-Standardisation „TES”

Start date: 01.01.2011
Thermoelectric Standardisation
Thermoelectric Metrology

High temperature materials & thermoelectric generator

Si-Ge

Fe-Si
Thermoelectric Standardisation
Thermoelectric Metrology

Round Robin Tests

High temperature materials

And

thermoelectric generator

European Thermoelectric Society

German Thermoelectric Society

International Thermoelectric Society

Public funded projects in Germany

EURAMET
Thermoelectricity at Fraunhofer IPM - materials, modules, systems and metrology
Thermoelectricity at Fraunhofer IPM - materials, modules, systems and metrology

Thank you!