2023 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Elastocaloric microcooling based on shape memory alloys

Helmholtz Centre and/or institute:

Karlsruhe Institute of Technology (KIT), Institute of Microstructure Technology (IMT)

Project leader:

Dr. Jingyuan Xu
Prof. Manfred Kohl

Contact Information of Project Supervisor: (Email, telephone)

Dr. Jingyuan Xu, jingyuan.xu@kit.edu, +49 721 608-22752
Prof. Manfred Kohl, manfred.kohl@kit.edu, +49 721 608-22798

Web-address:

https://www.imt.kit.edu/

Department: (at the Helmholtz centre or Institute)

Mechanical Engineering Department

Programme Coordinator (Email, telephone and telefax)

Karlsruhe Institute of Technology (KIT)
International Affairs
Name: Oliver Kaas
Kaiserstr. 12, 76131 Karlsruhe
Phone: + 49 721 608-45323 Telefax: 0721 60845326
Email: oliver.kaas@kit.edu

Description of the project (max. 1 page)**:**

The elastocaloric cooling technology utilizing the elastocaloric effect (eCE) is one of the most promising cooling technologies as stated by the US Department of Energy because of low device cost and high-efficiency [1]. The origin of the eCE is the thermal response of shape memory alloys (SMAs) upon the forward and reverse martensitic transformation (MT) driven by uniaxial stress. To explore the potential of the eCE for miniaturized active cooling, with large surface-to-volume ratio SMAs (i.e. thin films, microwares, ribbons and foams) are particularly attractive for micro cooling devices with high heat transfer capacity, low thermal hysteresis and high working frequency.

Recently, the Ni-Mn-based Heusler-type alloys have exhibited great potential in the field of elastocaloric cooling, owing to their large eCE at relatively low stress field and hysteresis. At a low stress of 175 MPa, the $Ni_{55}Mn_{19}Ga_{25}Ti_1$ alloy can produce a ΔT_{ad} of 12.9 K. Large ΔT_{ad} close to 20 K can be achieved in $Ni_{50}Mn_{35}In_{15}$ alloy at a stress of 350 MPa [2]. Colossal ΔT_{ad} of 31.5 K can be obtained by applying a stress field of 700 MPa to $(Ni_{50}Mn_{31.5}Ti_{18.5})_{99.8}B_{0.2}$ alloy, which exceeds even the majority of Ni-Ti-based alloys [3]. Nevertheless, constrained by the intrinsic brittleness of Heusler-type intermetallic compounds, their practical applications are greatly limited. Therefore, achieving large eCE, low hysteresis, low stress field and high fatigue life in Ni-Mn-based alloys through composition design is of great importance for miniaturized elastocaloric cooling.

The goal of the postdoc candidate will be to prepare the miniaturized elastocaloric cooling device with excellent elastocaloric properties using Ni-Mn-based Heusler-type alloys. Special focus will be on the first-principles calculations to design Ni-Mn-X (X = Ga, In, Sn, Sb, Ti) alloys with potentially large eCE and excellent mechanical properties. Candidates will also pay particular attention to the validation of experimental material characterization properties and the explanation of the intrinsic reasons for the excellent physical properties of the alloy by optimizing the composition design and improving the preparation process of the Ni-Mn-based alloys. Prototype of the miniaturized elastocaloric cooling devices based on Ni-Mn-based Heusler-type alloys are expected to be developed.

The candidate will be fully supported by our team and will benefit from the expertise of the group especially regarding material characterization technologies including tensile test, infrared thermography and differential scanning calorimetry, as well as prototype development. Furthermore, the candidate will have access to state-of-the-art equipment at IMT including 600 m² clean room, rapid prototyping processes such as 3D printing and laser cutting, assembly and joining technology laboratories, various metrological laboratories.

The results of the candidate will allow a better understanding of the elastocaloric effects in Ni-Mn based Heusler type alloys and use them to develop cooling devices for micro-cooling applications, e.g. for electronics and lab-and-chip cooling.

References:

[1] Energy savings potential and RD&D opportunities for Non-Vapor-Compression HVAC technologies, March 2014 Report of the U.S. Dpt. of Energy.

KIT – International Affairs (INTL) Contact: Oliver Kaas Phone: +49 721 608 45323 Email: oliver.kaas@kit.edu

[2] Z.Z. Li, et al., *Acta Mater.* 192 (2020) 52-59.
[3] D.Y. Cong, et al., *Phys. Rev. Lett.* 122 (2019) 255703.

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

Northeastern University (NEU) is a key university under the direct administration of the Ministry of Education of China and is one of the oldest universities in China. Prof. Dr. Liang Zuo in the School of Material Science and Engineering has wide expertise in the development of Ni-Mn-based multiferroic shape memory alloys. His group also has a particular interest in material characterization and crystallography. Up to now, they already have numerous papers published in high-ranked journals like Acta Materialia, Scripta Materialia, and International Journal of Plasticity. The KIT and NEU partner groups will collaboratively work on the development of a miniaturized elastocaloric cooling device based on Ni-Mn-based alloys. The planned experiments will be carried out in very close cooperation including joint supervision and discussion.

Required qualification of the postdoc:

- PhD in mechanical engineering, electrical engineering or physics
- Experience with materials science of shape memory alloys
- Additional skills in mechanical design and micro technologies
- Language requirement: fluent in English