Project report 2020

MISTRAL

MIniature-Scale Energy GeneraTion by Magnetic Shape MemoRy ALloys

MAIN PARTICIPANTS


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OVERVIEW *(keep within this page)*

Starting year: 2014 **Current researchers** (permanent/non-permanent): 3/3 person-month/year

Positioning *(Multiple selection allowed – total 100%)*	**Transportation**	**Energy**	**Eng. for Health**
Materials and structure design		20 %	30 %
Surfaces and interfaces		5 %	5 %
Simulation and modeling		20%	20 %

Other:

Include partner from ☒ Outside ELyT ☐ Industry

Main funding source(s)
☒ Public project(s) ☐ Industrial ☐ Own resources

IFS CRP/LyC project? ☐ Yes ☒ No

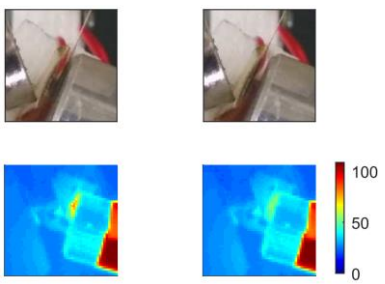
For main projects: Agency / year / name of project *(up to 3, past projects in gray)*
- DFG Germany, 2019-2022, THERVESTII
- JSPS, 2019-2020, invitational fellowship

Estimated annual budget: 50 k€

Highlights & Outstanding achievements *(3-5 bullet points)*

- Scaling performance of heat transfer dynamics during resonant self-actuation and effect of film thickness and device footprint on power and efficiency
- Electrical power per footprint increases with film thickness by a factor of 3.4 (50 µW/cm² at a temperature change of 3 °C)
- Multifunctional energy conversion (e.g., incl. pyroelectric)
- Publication: J. Joseph, M. Ohtsuka, H. Miki, M. Kohl, Upscaling of Thermomagnetic Generators Based on Heusler Alloy Films, (2020) to be published in Joule 4, Dec 16. DOI:10.1016/j.joule.2020.10.019
- JSPS invitational and post-doc fellowships (10+13 months)

Illustration *(5x5 cm² max)*



PROJECT DESCRIPTION

Background (10 lines max; Calibri 11)

MISTRAL aims at providing new routes for electrothermal energy conversion, for instance providing alternatives to thermoelectric modules that exhibit large thermal conductivity that prevents energy entering within the device.

Progress in development of films that exhibit large abrupt changes in magnetization such as NiMnGa films and rapid heat transfer unclose the development of thermodynamically efficient thermomagnetic generators.

Local vibrations and time-domain temperature variations can be converted into electricity by electroactive materials. Pyroelectric elements for conversion of local temperature change with time showed a magnification of the output power.

Key scientific question (2 lines max; Calibri 11)

Understanding heat transfer dynamics in thermomagnetic generators

Improving power output and efficiency

Research method (8 lines max; Calibri 11)

Detailed experiments and lumped element simulations for the case of Heusler alloy film Ni-Mn-Ga show that scaling of film thickness and device footprint oppositely affect power output. Based on this understanding, we could increase the electrical power per footprint by a factor of 3.4 for increasing film thickness from 5 to 40 µm reaching values of 50 µW/cm² at a temperature change of only 3 °C. These results pave the way for the development of advanced generators consisting of parallel architectures with tailored footprint and films operating well below 100 °C that open up waste heat recovery near room temperature. Also, including as much electroactive materials as possible, exploiting the maximum amount of energy sources permits increasing the power density.

Research students involved *(gray color for previous years)*

Ph.D. candidates (years, institution):

- Joel Joseph (2019-present, KIT)

Master/Bachelor students (years):

- Lena Seigner (2020, KIT)

Visits and stays *(gray color for previous years)*

FR to JP (date, duration):

- M. Lallart (Sept. 2019-July 2020, 10 months)
- L. Yan (Sept. 2019-Sept. 2020, 13 months)

JP to FR (date, duration):

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COMMUNICATIONS AND VALORIZATION

Journal publications *(gray color for previous years)*

	Authors	Title	Journal	Vol.	pp. / ID	Year	DOI
1	J. Joseph, M. Ohtsuka, H. Miki, M. Kohl	Upscaling of Thermomagnetic Generators Based on Heusler Alloy Films	Joule	*In press*		2020	DOI:10.1016/j.joule.2020.10.019
2	M. Lallart, H. Miki, L. Yan, G. Diguet, M. Ohtsuka	Investigation of Low Field Response of Metamagnetic Heusler Alloys as MultiPhysic Memory Alloys	J. Phys. D: Appl. Phys.	53	345002	2020	https://dx.doi.org/10.1088/1361-6463/ab8c7c
3	H. Miki, E. Abe, S. Takeda, M. Ohtsuka, M. Kohl	Metamagnetic Shape Memory Alloy Thin Plates Consolidated by Compression Shearing Method at Room Temperature for Thermal Energy Harvesting Device	Sensors and Materials	32(8)	2867-2875	2020	https://myukk.org/SM2017/article.php?ss=2938
4	M. Gueltig, F. Wendler, H. Ossmer, M. Ohtsuka, H. Miki, T. Takagi, and M. Kohl	High-Performance Thermomagnetic Generators Based on Heusler Alloy Films	Adv. Energy Mater.	7	1601879	2016	DOI: 10.1002/aenm.201601879.
5	M. Gueltig, M. Ohtsuka, H. Miki, K. Tsuchiya and M. Kohl	Thermomagnetic actuation in low hysteresis metamagnetic Ni-Co-Mn-In films	Materials Today: Proceedings,	2	S883–S886	2015	https://doi.org/10.1016/j.matpr.2015.07.423
6	M. Gueltig, H. Ossmer, M. Ohtsuka, H. Miki, K. Tsuchiya T. Takagi and M. Kohl	High Frequency Thermal Energy Harvesting Using Magnetic Shape Memory Films	Adv. Energy Mater.	4	1400751	2014	https://doi.org/10.1002/aenm.201400751

Conferences *(gray color for previous years)*

	Authors	Title	Conference	Date	City	Country	DOI *(if applicable)*
1	M. Lallart, H. Miki, L. Yan, G. Diguet, M. Ohtsuka and G. Sebald	Low-Field Modeling of Heusler MultiPhysic Memory Alloys	The 17th International Conference on Flow Dynamics (ICFD2020)	October 28 - 30, 2020	Sendai	Japan (online)	

2	L. Seigner, J. Joseph, M. Lallart, H. Miki and M. Kohl	Upscaling of a Thermomagnetic Generator Based on Magnetic Shape Memory Alloys	ELyT Workshop 2020	Feb. 17-19, 2020	Vogüé	France	
3	H. Miki, M. Kohl, M. Lallart and L. Yan	Future prospects in the MISTRAL (Miniature-Scale Energy Generation by Magnetic Shape Memory Alloys) project	ELyT Workshop 2019	March 10-12, 2019	Osaki	Japan	
4	M. Kohl, H. Miki, M. Lallart, M. Gueltig, M. Ohtsuka	MIniature-Scale Energy GeneraTion by Magnetic Shape MemoRy Alloys	ELyT Workshop 2018	March 6-8, 2018	Satillieu	France	
5	H. Miki, K. Tsuchiya, E. Abe, S. Takeda, M. Ohtsuka, M. Gueltig, M. Kohl and T. Toshiyuki Takagi	Improvement in Magnetic Properties of Metamagnetic Shape Memory Alloy Processed by Compression Shearing Method at Room Temperature	The 14th International Conference on Flow Dynamics (ICFD2017)	Nov. 1-3, 2017	Sendai	Japan	

Patents *(gray color for previous years)*

	Inventors	Title	PCT #	Year
1				
2				

Others *(gray color for previous years)*

	People	Event	Description	Date
1				
2				