Helmholtz - OCPC - Programme 2017-2021
for the Involvement of Postdocs in Bilateral Collaboration Projects with China

PART A

Title of the project: Printed soft electronic devices from ultra-stretchable, highly conductive elastomers with low silver content

Helmholtz Centre and institute: Karlsruhe Institute of Technology (KIT), Institute for Mechanical Process Engineering & Mechanics

Project leader: Prof. Dr. Norbert Willenbacher

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

Flexible and stretchable conductors combining electrical functionality with distinguished deformability are a crucial for advances in the field of soft electronics, including wearable electronics, bendable displays, soft robotics and real-time healthcare monitoring. With the growing demand of these applications, the development of low-cost and high-performance stretchable conductors is of vital importance.
Recently we developed a versatile and cost-effective approach to obtain ultra-stretchable, highly conductive elastomers based on commonly used polymers. Self-assembly of silver particles into a sample-spanning, conductive network is triggered by addition of an immiscible secondary fluid to the ink prior to printing (so-called capillary suspension concept [1]). Due to this self-assembly, Ag consumption is dropped by more than 50% compared to the state of the art and a high conductivity ~10^3 S/cm is preserved even at silver loadings as low as 10-15 vol.%. These conductive elastomers offer unprecedented stretchability (> 1600%) and cyclic stability (> 1000 cycles at 100% strain). Resistivity-type sensors with high gauge factor (GF $\approx$ 9) as well as wirings with low resistance change during stretching ($\Delta R/R_0 \approx 0.5$) were fabricated using direct ink writing (DIW).

The project proposed here wants to take advantage of this material design concept to build fully 3D printed soft electronic devices, including sensors, actuators or bendable circuits. This comprises two aspects:

A) Material development

1. Development of a highly stretchable, dielectric elastomer also based on the capillary suspension concept for capacitive-type sensors.
2. Foams based on conductive and dielectric elastomers as described above for large deformation sensors.
3. Development of ultra-stretchable, highly conductive or dielectric elastomers suitable for filament deposition modelling (FDM) based on the capillary suspension concept to expand the application range of these unique materials with their low filler content.

B) Device architecture

Starting with the inks developed above deformable sensors, circuits and actuators will be 3D printed (DIW or FDM) onto different substrates such as textiles and soft elastomers, targeting at different applications.

1. Multi-dimensional resistive/capacitive sensors with proper architecture design such as pre-strain [2] and different pattern layout [3] shall be used to deliver high sensitivity and low hysteresis for motion monitoring.
2. Large area sensor arrays detecting pressure, strain and proximity to be used as artificial skin have to be designed.
3. Soft actuators made from hierarchy elastomer foam will be used as artificial muscles [4,5].

A soft robot gripper integrating above sensors and actuators, mounted on a flexible circuit, enabling feedback for computerized control is to be built based on the materials and devices described under A) and B) above.

References:

[1] Koos, Erin and Willenbacher, Norbert "Capillary forces in suspension rheology." *Science* **331**, 897-900 (2011).

[2] Kim, Kyun Kyu, et al. "Highly sensitive and stretchable multidimensional strain sensor with prestrained anisotropic metal nanowire percolation networks." *Nano letters* 15.8 (2015): 5240-5247.

[3] Guo, Shuang-Zhuang, et al. "3D printed stretchable tactile sensors." *Advanced Materials* 29.27 (2017): 1701218.

[4] https://www.creativemachineslab.com/soft-actuator.html

[5] Yang, D., et al. "Buckling pneumatic linear actuators inspired by muscle." *Advanced Materials Technologies* 1.3 (2016): 1600055.

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

We are looking for a partner institute with strong experience in fabrication of soft electronic devices.

Expertise in additive manufacturing techniques like DIW or robocasting, i.e. rapid prototyping concepts, but also in mass production technologies like screen printing or extrusion.

Know-how regarding development of sensors for robots, e.g. proximity or pressure and strain sensors.

Experience in the development of personal healthcare and wearable devices including soft electronic sensing and wiring components.

Expertise in the field of consumer electronics and internet of things were flexible wiring or soft sensors are requested.

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Required qualification of the post-doc:

- PhD in electrical engineering, material science or chemical engineering
- Experience with electrical engineering of sensor devices
- Additional skills in materials for soft electronics and wearables

PART B

Documents to be provided by the post-doc, necessary for an application to OCPC via a postdoc-station in China, which is affiliated to a research institution like a university:

- Detailed description of the interest in joining the project (motivation letter)
- Curriculum vitae, copies of degrees
- List of publications
- 2 letters of recommendation
- Proof of command of English language

PART C

Additional requirements to be fulfilled by the post-doc:

- Max. age of 35 years
- PhD degree not older than 5 years
- Very good command of the English language
- Strong ability to work independently and in a team

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