State-of-the Art of Shape Memory Microactuators

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The ongoing miniaturization and increase of functionality have enabled the development and widespread use of smart devices and systems. The field of microelectromechanical systems (MEMS) has undergone an exceptionally dynamic evolution from silicon micromechanics to a highly diverse field comprising a large variety of materials and corresponding technologies. However, actuation on small scales has been an issue since the early nineties, where MEMS technology was still in its infancy. Silicon is not a transducer material, therefore, additional materials have to be introduced for conversion of energy into mechanical work. Shape memory microactuators are potential candidates for MEMS applications as they exhibit highest work densities compared to other actuation principles in the order of 10^7 Jm^{-3} [1].

Two approaches for producing planar shape memory alloy (SMA) materials for microactuation have been developed: (1) magnetron sputtering of SMA thin films and (2) the integration of rolled SMA foils, which both turned out to be very successful creating a paradigm change in microactuation technology. An intriguing feature of SMA materials is their multifunctionality allowing for, e.g., structural stability, electrical and thermal conductance, actuation and self-sensing at the same time. This feature of being a "smart material" becomes particularly advantageous on small scales, at which technology constraints pose severe limitations on the number, geometry and size of functional structures. As a consequence, monolithic SMA microparts have been designed with different subunits and multifunctional performance that can be fabricated in a single micromachining step. Following this philosophy of "the material is the machine" opened up new routes for creating fabricable smart SMA microactuators and corresponding devices [2].

This review covers important milestones of the research and development of both, SMA film- and foil-based microactuators. Major material properties will be summarized and key processing technologies for fabrication of functional SMA microactuators will be presented. Selected demonstrators will be discussed including their potential applications and transfer to commercial products.

[1] S. Miyazaki, Y. Q. Fu, and W. M. Huang, Eds., *Thin Film Shape Memory Alloys: Fundamentals and Device Applications*. Cambridge, 2009.
[2] M. Kohl, *Shape memory microactuators*, Springer book series on Microtechnology and MEMS, Springer-Verlag Berlin Heidelberg, 2004.