Heat Transport in Thin Films with Shape Memory

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Materials with shape memory as the NiTi alloys are gaining importance for applications in microsystems and thin film technology. Shape memory alloys are used to fabricate microgrippers or microactuators. Since the shape memory effect is induced by heating or cooling the material over characteristic transition temperatures, the thermophysical properties like the thermal conductivity and the heat capacity determine the behavior of the temperature field in space and time and therefore its operational performance. The transition temperatures of these alloys can be adjusted from room temperature up to 500°C by adding Pd or Cu and reducing the Ni content.

Measurements of the thermal diffusivity and the heat capacity have been performed on thin films of NiTi, NiTiCu, NiTiPd and TiPd as a function of temperature in order to evaluate the changes of these properties below and above the phase transition associated with the shape memory effect. The thickness of the free standing films which have been fabricated by a magnetron sputtering technique is in the range between 10 and 13 µm. The thermal diffusivity has been determined with a photothermal method with an experimental setup which allows for sample heating up to 500° C. The heat capacity has been measured with a Perkin-Elmer DSC. From the experimental data of the density, the thermal diffusivity and the specific heat the thermal conductivity values of the films could be calculated.

The heat capacity of the films changes only slightly with temperature with exception of the transition region where it exhibits strongly pronounced peaks. Temperature hysteresis could be observed on heating and cooling of the sample. The thermal conductivity is significantly reduced in the NiTi film compared to a 500 µm thick NiTi foil. The behavior the thermal conductivity as a function temperature in the film differs also from that of the foil. Up to the transition temperature (T =) its value decreases and starts to increase after passing the phase transition. Whereas in the foil an increasing thermal conductivity could be observed on heating with no changes in slope at the transition temperature. Changing the stochiometry of the films by adding Cu or Pd and reducing the Ni content the transition temperature, temperature hysteresis and temperature dependent behavior of the thermal conductivity is affected. The experimental results will be discussed within a framework of a heat transport model for the shape memory alloys.