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24.09. – 25.09. 2025

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Infrared Thermography for Precise Microscale Temperature Measurements on NiTi-Based Shape Memory Alloy Wires

The shape memory effect and superelasticity of nickel-titanium alloys (NiTi) make them highly attractive for actuators and elastocaloric cooling technologies, enabled by a reversible phase transformation between martensite and austenite triggered by temperature or stress. Thin NiTi wires are often used due to their favorable surface-to-volume ratio and manufacturability [1]. However, accurate temperature measurement in these wires is challenging, as conventional contact thermometry may interfere with phase transformation behavior. Non-contact infrared thermography offers a promising alternative but requires precise knowledge of the surface emissivity.

This study presents a dedicated apparatus for measuring the emissivity of metallic surfaces at the microscopic scale over a temperature range of 308 K to 423 K, utilizing a self-built reference-quality black body cavity (BBC) under identical thermal and optical conditions [2, 3]. NiTi samples with different surface finishes, i.e., unprocessed, polished, electrical discharge machined (EDM), laser-machined, diamond-smoothed, and oxidized, were systematically analyzed. Additionally, the effect of composition was studied by measuring emissivity for two unprocessed NiTi samples with varying compositions.

The results reveal that emissivity strongly depends on surface condition, composition, and temperature. The average emissivity of EDM and oxidized samples was about twice that of polished and diamond-smoothed surfaces. Furthermore, temperature-dependent emissivity data for oxidized samples were fitted to a mathematical model and applied to measure the temperature of a 75 µm diameter NiTi wire operating as an electrically powered actuator. A temperature deviation of up to 80 K was observed when comparing corrected and uncorrected emissivity, underscoring the importance of accurate emissivity data.

[1] S.-M. Kirsch et al., 'NiTi-based elastocaloric cooling on the macroscale: From basic concepts to realization', Energy Technol., vol. 6, no. 8, pp. 1567–1587, 2018. [2] Javed, Muhammad Ali et al. "Black Body Cavity Apparatus for Measuring the Emissivity of Nickel-Titanium-Based Shape-Memory Alloys and Other Metals." International Journal of Thermophysics 45.11 (2024): 157. [3] S. Morozova et al., Vacuum variable-temperature blackbody VTBB100. Int. J. Thermophys. 29, 341–351 (2008)