Elastocaloric Cooling Shape Memory Alloy for Future Smart Building

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Abstract: Elastocaloric cooling is an emerging refrigeration mechanism that offers an alternative to environmentally harmful vapor-compression technology and other energy insufficient technologies. It potentially can provide one of the largest opportunities for energy savings among all non-vapor-compression technologies, with beneficial environmental impact and zero carbon emissions towards future urban high-performance building systems. In 2017, the U. S. Department of Energy published an assessment of heating, ventilation, and air-conditioning (HVAC) systems by screening over 300 technology solutions and revealed elastocaloric effects (E-CEs) cooling as one of the most promising caloric solutions with 0.41 Quads/yr. against 0.26 Quads/yr. of electrocalorics and 0.21 Quads/yr. of magnetocalorics. Base materials for E-CEs are pseudoelastic shape memory alloys (SMAs) that exhibit a large latent heat due to stress-induced phase transformation, good thermal conductivity, and long-term fatigue resistance. We developed (Ni, Mn, Ti)B-based SMA materials via compositional design and different thermal treatments providing large latent heat, low mechanical hysteresis, and compatible phase transition temperatures, which can substantially response to a large temperature span of E-CEs cooling. We also demonstrated a maximum temperature difference of ~15 K in a miniature cooling device. In addition, we investigated additive manufacturing (AM) to fabricate SMAs with large surface-to-volume ratio. In parallel, we developed an accompanying simulation model that captures its system-level performance as a function of key design parameters, derived from a combination of physics-based principles and experimental data and used to determine target values for key performance metrics to guide the device design and ensure that it provides impactful capabilities supporting decarbonization of buildings.