Substrate Dependence of the Self-Heating in Lead Zirconate Titanate (PZT) MEMS Actuators

Y. Song, K. Kang, P. Tipsawat, C.Y. Cheng, W. Zhu, M. LaBella, S. Choi, S. Trolier-McKinstry

Lead zirconate titanate (PZT) thin films offer advantages in microelectromechanical systems (MEMS)including large motion, lower drive voltage, and high energy densities. Depending on the application, different substrates are sometimes required. Self-heating occurs in PZT-MEMS due to the energy loss from domain wall motion which can degrade the device performance and reliability. In this work, the self-heating of PZT thin films on Si and glass and a film released from a substrate were investigated to understand the effect of substrates on the device temperature rise. Nano-particle assisted Raman thermometry was employed to quantify the operational temperature rise of these PZT actuators. The results were validated using a finite element thermal model, where the volumetric heat generation was experimentally determined from the hysteresis loss. While the volumetric heat generation of the PZT films on different substrates were similar, the PZT films on Si substrate shows minimal temperature rise due to the effective heat dissipation through the high thermal conductivity substrate. The temperature rise on the released structure is 6.8× higher than that on the glass substrates due to the absence of vertical heat dissipation. Experimental and modeling results show that the thin layer of residual Si remaining after etching plays a crucial role in mitigating the effect of device self-heating. The outcomes of this study suggest that high thermal conductivity passive-elastic layers can be used as an effective thermal management solution for PZT-based MEMS actuators.