Dimensional dependence of X-ray radiation damage in MEMS devices

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Abstract

Miniaturized sensors and actuators such as accelerometers, resonators, pressure sensors, gyroscopes, and comb drives are examples of common microelectromechanical systems (MEMS). They are extensively used in smart appliances such as smart-phones, robots, self-driving cars, virtual reality gaming devices, etc. These low-cost, lightweight, low-power and highly-reliable MEMS devices are very attractive for space applications. Any electronic equipment used in space is subjected to radiation damage due to ionizing and non-ionizing radiation such as UV, X-ray, proton, neutron, etc. For reliable operation of MEMS devices in space, we need to understand the damage mechanisms so that we can design "radiation hard" MEMS devices. In this research, we fabricated custom T-shaped MEMS resonators of different dimensions to test the effect of 10keV X-ray radiation. We tracked the resonance frequency of the resonator during and after radiation. The resonators were radiated in a vacuum chamber through a beryllium window at an ionizing dose rate of 30.3 krad(SiO_2)/min for a total ionizing dose of 1Mrad(SiO_2). Dimension dependent resonance frequency reduction was observed during X-ray irradiation. The resonance frequencies recovered to their original values after post-radiation annealing for about 9 to 11 hours at room temperature. Dimension dependence of the resonance frequency shift indicates that *surface effect* is a dominant factor in radiation damage. We propose a theoretical model based on hydrogen diffusion in silicon that successfully explains the dimensional dependence of radiation damage. The model shows that larger surface-to-volume ratio devices are more susceptible to radiation and it needs to be considered while scaling MEMS devices, especially for space application.

Biography of Presenter

Pranoy Deb Shuvra is a PhD candidate in the Electrical and Computer Engineering Department of the Speed School of Engineering at the University of Louisville. He is working on the design, simulation, fabrication and testing of microelectromechanical system (MEMS) devices for last five years. He fabricates MEMS devices at the University of Louisville's MNTC cleanroom facility. His current project is to understand the effect of radiation on MEMS devices. This project is funded by DTRA (Defense Threat Reduction Agency). He has published in JMM, IEEE Transaction on Nuclear Sciences, and Physical Review Applied.