SOFT ROBOTICS IN RADIATION ENVIRONMENTS FOR SAFEGUARD APPLICATIONS

Tyler Oshiro, Camille Palmer, Geoffrey Hollinger, Yigit Menguc, Taylor Courier, and Osman Dogan Tirmibesoglu

SELECTING ENVIRONMENTS

- Three environments were chosen from a paper on various robot prototypes in the nuclear industry (Figure 3, highlighted in blue) to represent the general diversity of potential applications (Houssay, 2000).
- Dose rate maximums or averages were extrapolated to a cumulative dose after 12 hours as a general estimate of robot task time.

IDENTIFYING COMPONENTS

- Actuator body: polydimethylsiloxane (PDMS)
- Microchannels: Gallium, Indium, Tin (Galinstan) + Nickel

METHODS

- Gamma Testing: "dog bone" and cylinder PDMS samples were created from molds with Smooth-On Dragon Skin Fast brand silicone. Samples were irradiated in a GammaCell220 Co-60 irradiator. Irradiated samples were tested with a Mark-10 motorized stand.
- Neutron Analysis: A 2 g sample of PDMS was exposed to the rotating rack in Oregon State University’s Triga Reactor (OSTR) for 7 hr (thermal flux: 3.8E13 + 4.8E11 cm^-2 s^-1); the NIST activation calculator was used to estimate activation in identical conditions.

GAMMA-INDUCED MECHANICAL CHANGES TO PDMS

- Tensile tests: increased cumulative gamma dose led to decreased elongation and an initial increase followed by an overall decrease in tensile strength.
- Discs: increased cumulative gamma dose led to increased force needed to achieve the same level of compression (increased "stiffness"). Surpassed 50% change in highest dose environment.

NEUTRON-INDUCED ACTIVATION OF PDMS

- Higher activity of measured sample suggests unexpected contaminants in PDMS.
- Profile of PDMS reveals the contaminants: Na-24 plays a major role along with some long-lived lanthanides.

CONCLUSIONS

- With increasing gamma dose: tensile strength initially increases, then eventually decreases; elongation decreases; and stiffness increases.
- In all but compression in the highest environment, PDMS remained within 50% mechanical change post-gamma irradiation.
- For activation of PDMS, contamination by Na-24 and lanthanides makes neutron activation difficult to predict.

NEXT STEPS

- For liquid metal sensors: determine electron liberation on sensor functionality.
- For overall assessment: compare magnitude of effects to soft robotic mechanical parameters.

BACKGROUND

Nuclear safeguards include the "institutional, legal, and technical mechanisms" that monitor and maintain the non-weaponized status of signatories to the Nuclear Non-Proliferation Treaty (NPT). This research looks specifically at the potential for one emerging technology, soft robotic systems, to contribute to the field of nuclear safeguards.

SOFT ROBOTICS

Robots have a long history in the nuclear field, from the incident at Three Mile Island in 1979 to the 2011 disaster in Fukishina. However, where “rigid” robots are composed of rigid material like metals and plastics, soft robots are composed of soft materials like rubber and polymers. Being composed of soft materials confers these advantages to soft robotic systems:

1) Potential for infinite degrees of freedom
2) "Intrinsic" safety
3) Little resistance against obstacles
4) Adaptive and responsive to environment
5) Relatively cheap and disposable

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