Polymer films pass electron gun test

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HSE researchers, jointly with colleagues from the RAN Institute of Organoelement Compounds and the RAN Institute of Physical Chemistry and Electrochemistry, have studied the properties of a polyarylene ether ketone-based copolymer (co-PAEK) for potential space applications. Co-PAEK films are highly resistant to electrostatic

discharges caused by ionizing radiation and can thus be used as protective coating for spacecraft electronics. The study findings have been published in *Polymers*.

Spacecraft electronics are continuously exposed to the ambient space plasma. Its ionizing radiation causes electric charge to accumulate in dielectric materials on board space-based vehicles, leading to electrostatic discharges which can result in failures of electronic devices and, ultimately, of the spacecraft itself.

Worldwide, just three research centres are equipped and staffed to study the effects of ionizing radiation on materials used in spacecraft construction in virtually real-life conditions. These facilities are the MIEM HSE Laboratory of Space Vehicles and Systems' Functional Safety (Moscow), John Robert Dennison's Laboratory at Utah State University (Logan, Utah, U.S.), and Thierry Paulmier's Laboratory in Toulouse, France.

The researchers investigated the conductive properties of co-PAEK films by first supplying film specimens with very thin aluminium electrodes via vacuum deposition and then placing the specimens inside a vacuum chamber equipped with an electron gun. By bombarding the specimens with charge carriers of 50,000 eV, the researchers measured the film's radiation-induced conductivity associated with electron-hole pairs produced by the radiation. This parameter reflects how effectively materials can remove accumulated charges. In particular, the researchers examined the current-voltage (I-V) characteristics, i.e., the relationship between the electric current passing through the film and the voltage at the electrodes; they found that due to their super-linear I-V characteristics, the films are highly effective in removing electrostatic charges. The researchers also studied the films' switching effect, i.e., the polymer's ability to make a reversible transition from a high-ohmic to a low-ohmic state in a strong electric field. This latter state increases the

polymer's conductivity.

There is still no generally accepted physical model describing the switching effect in thin polymer films. However, the co-PAEK films' low switching thresholds and the reversibility of these effects appear highly promising. Notably, it is possible to modify the co-polymers' resistivity switching ability by varying its phthalide content.

The authors investigated the transport of charge carriers in co-PAEK films with varied phthalide content; for this purpose, they synthesized 20- to 25-micron films with 3, 5 and 50 percent of phthalide-containing units.

The results show that an increase in phthalide-containing units in co-PAEKs from 3 to 50 percent produced virtually no change in radiation-induced conductivity within the studied electric field range. This indicates that charge carriers in these experiments moved in an isolated manner and that the applied electric fields were below the threshold needed for collective interaction of charges and formation of conductive channels triggering the effect of high-to-low resistivity transition.

Unfortunately, at the studied film thicknesses, further increase in electric fields causes an electric breakdown; therefore, it may be too early to plan for their space application. Nevertheless, the researchers believe that this material is highly promising and that further research of the switching effect could produce more conclusive results. This copolymer has already been used to protect prototype models of silicone solar cells in spacecraft.

More information: Evgenii D. Pozhidaev et al, Radiation-Induced Transient Currents in Films of Poly(arylene ether ketone) Including Phthalide Moiety, *Polymers* (2019). DOI: 10.3390/polym12010013