In-Situ High Voltage Tests on Pristine and Irradiated Polyimide *

V. Lima[1,2, #], *T. Seidl*[1,2], *E. Mustafin*[1], *E. Floch*[1],*C. Trautmann*[1,2], *and W. Ensinger*[2]

[1]GSI, Darmstadt, Germany; [2]Technische Universität Darmstadt, Germany

Concerning radiation hardness, organic materials such as polymeric insulators are identified as highly sensitive towards ionizing radiation compared to inorganic materials [1]. Despite this fact, these materials are widely used in accelerator components since they have favourable properties for application, often better than comparable inorganic materials. Due to their superior mechanical and dielectric properties, even if irradiated with swift heavy ions [1], polyimides are commonly used as insulator in beam-guiding magnets in ion beam facilities such as the synchrotrons and storage rings of the planned *Facility for Antiproton and Ion Research* (FAIR). FAIR will provide highest beam intensities, and beam losses will partly induce high secondary radiation fields during the pulsed operation of the accelerator. Former studies of radiation induced modifications of electrical properties of polyimide focused on ex-situ measurements of (i) breakdown voltage [1] and (ii) electrical conductivity and dielectric constant [2].

During accelerator operation, the insulators in the magnets are exposed to particle radiation and additionally to electromagnetic fields. Because irradiation-induced damage can initiate electrical breakdowns events [3], this study tackles in-situ breakdown voltage tests during the direct exposure of the material to ion beams. For this purpose, a setup was built where non-irradiated and ion irradiated polyimide samples are mounted between two electrodes and a potential is applied between them.

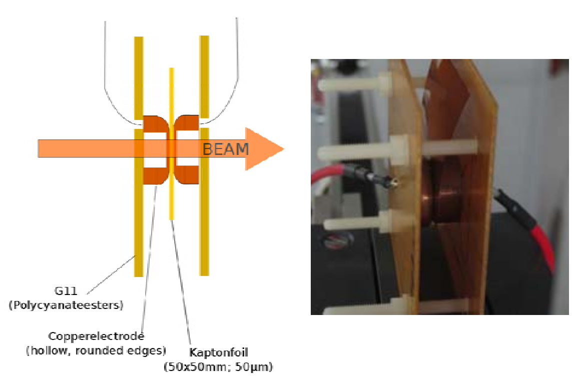

Figure 1: Schematic presentation (left) and photograph (right) of experiment setup.

50-µm thick Kapton^{TM}-type polyimide foils with an area of 50 × 50 mm^2 were cut from commercial rolls. Samples were irradiated at the UNILAC (X0-beamline) with 11.1-MeV/u ruthenium ions and fluences up to 10^{12} cm^{-2} (corresponding to a radiation dose of 8 MGy). For the in-situ breakdown voltage test, samples were mounted between two copper electrodes (see scheme Fig.1 left). These electrodes had a rounded-edge-geometry to avoid increased electrical fields at the edges. The thickness of the electrodes was 2 mm, suitable for the irradiation experiment due to the penetration depth of the ion beam (6 mm in copper, calculated with SRIM-2010 code). The electrode-sample configuration was attached to a glassfiber/composite sample holder having a thickness of 1 mm. Breakdown measurements were conducted using a high voltage power supply (max. voltage: 7 kV) via current measurements with a current clamp. Additionally, the dark current of the high voltage power supply was monitored with an oscilloscope.

The in-situ-irradiation experiment was carried out at SIS 100 (Cave A). At first, a voltage of 500 V was applied to the electrodes. Subsequently, several spills of uranium ions (E= 500 MeV/u) were applied for. The flux of the beam was about 2×10^8 cm^{-2}s^{-1}, while the size of the beam spot was about 0.5 cm^2. When no breakdown occurred, the potential was increased in 500-V-steps and the irradiation procedure was continued for each potential.

For pristine non-irradiated samples no breakdown was detected after irradiation with about 20 spills (~ 4×10^9 cm^{-2}) up to the maximum potential of 7 kV. However, during a spill of ions, the dark current shortly increased. Samples pre-irradiated with Ru ions of fluences $\leq5\times10^{11}$ cm^{-2}, failed without or after a few U spills at electrical fields >1 kV.. This is ascribed to the dielectric strength reduced by the Ru ion irradiation. Below 1 kV we did not observe break down events of pre-irradiated samples. However, due to time constraints this stability was not tested over extended time periods.

Samples pre-irradiated with 10^{12} Ru-ions cm^{-2} showed surface flashovers at already low electrical fields ~1 kV. Due to ion-induced carbonization, the samples were black indicating that the surface conductivity is already too high to be used as insulator.

In summary, ion irradiated samples have in general a lower dielectric strength, but there was no correlation observed between direct ion irradiation and in situ breakdown events

[1] T. Seidl, A. Plotnikov, E. Mustafin, R. Lopez, D. Severin, E. Floch, C. Trautmann, A. Golubev, A. Smolyakov, D. Tommasini, and W. Ensinger, Polymer Degradation and Stability 97 (2012) 2396.

[2] J.-P. Salvetat, J.-M. Costantini, F. Brisard, and L. Zuppiroli, Phys. Rev. B 55 (1997) 6238.

[3] C. L. Wadhwa, "High Voltage Engineering". New Age International Publishers, New Delhi, 2007.

* Work supported by BMBF project No. 06DA7027.
# v.lima@gsi.de