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Characterization of the polysilicon resistor in silicon strip sensors for ATLAS Inner Tracker as a function of temperature, pre- and post-irradiation

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The high luminosity upgrade of the Large Hadron Collider, foreseen for 2028, requires the replacement of the ATLAS Inner Detector with a new all-silicon Inner Tracker (ITk). The expected total integrated luminosity of 4000 fb^−1 means that the strip part of the ITk detector will be exposed to the total particle fluences and ionizing doses reaching the values of 1.6E15 1 MeV n_eq/cm^2 and 0.66 MGy, respectively, including a safety factor of 1.5. Radiation hard n+-in-p micro-strip sensors were developed by the ATLAS ITk strip collaboration and are produced by Hamamatsu Photonics K.K. The active area of each ITk strip sensor is delimited by the n-implant bias ring, which is connected to each individual n+ implant strip by a polysilicon bias resistor. The total resistance of the polysilicon bias resistor should be within a specified range to keep all the strips at the same potential, prevent the signal discharge through the grounded bias ring and avoid the readout noise increase. While the polysilicon is a ubiquitous semiconductor material, the fluence and temperature dependence of its resistance is not easily predictable, especially for the tracking detector with the operational temperature significantly below the values typical for commercial microelectronics.

Dependence of the resistance of polysilicon bias resistor on the temperature, as well as on the total delivered fluence and ionizing dose, was studied on the specially-designed test structures called ATLAS Testchips, both before and after their irradiation by protons, neutrons, and gammas to the maximal expected fluence and ionizing dose. The resistance has an atypical negative temperature dependence. It is different from silicon, which shows that the grain boundary has a significant contribution to the resistance. We will discuss the contributions by parameterizing the activation energy of the polysilicon resistance as a function of the temperature for unirradiated and irradiated ATLAS Testchips.

Collaboration

ITk Strip Sensor collaboration

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