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Environmental conditions stress tests on Low Gain Avalanche Diodes

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Devices with internal gain, such as Low Gain Avalanche Diodes (LGADs) demonstrate O(30) ps timing resolution, and they play a crucial role in High Energy Physics (HEP) experiment. Similarly, resistive silicon devices, such as AC-coupled LGADs (AC-LGADs) sensors achieve a fine spatial resolution while maintaining the LGAD's timing resolution. Devices of both types, with varying gain-layer width and doping characteristics, are produced at Brookhaven National Laboratory (BNL) [1]. However, their performance is strongly affected by environmental factors such as temperature, humidity, rapid changes in bias voltage settings, and storage conditions. For example, phonon scattering, which is strongly affected by temperature, plays a central role in avalanche multiplication at higher temperatures, where phonon scattering becomes prominent due to the temperature dependence of the phonon population [2]. In particular, at high temperatures, carriers tend to lose their energy as they travel through the multiplication region, requiring longer paths, resulting in a weaker multiplication. Therefore, the operating conditions, such as noise, gain and breakdown voltage, depend on these variables. In view of applications beyond the controlled environment of HEP-experiments, these devices are stressed-tested against varying environmental conditions. For example, the challenging operating conditions in outer space impose constraints on the operation performance, against temperature fluctuations, for example. Sensors fabricated at BNL are characterized at the Silicon Lab at BNL and at the RD50 facility at CERN. We study how different devices with different depletion layers and implantation characteristics respond to these changing climatic conditions. In particular, we create a systematic evaluation of the response of LGAD sensors as a function of these environmental parameters. This allows us to map the device performance back to the sensors characteristics. In turn, this will allow the tailored fabrication of devices resilient to the hasheses conditions at no cost to the operational performance in controlled environments.

[1] G. Giacomini et al., Development of a technology for the fabrication of Low-Gain Avalanche Diodes at BNL, https://doi.org/10.1016/j.nima.2019.04.073
[2] M.M. Hayat, Comprehensive Semiconductor Science and Technology, ISBN 978-0-444-53153-7 2011

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