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Delayed avalanche breakdown of high-voltage Si diodes: scenarios and mechanisms of picosecond-range switching

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Delayed avalanche breakdown of reversely biased high voltage Si diodes, known as Silicon Avalanche Shapers (SAS), leads to ˜100 ps switching and has found important pulse power applications. The widely accepted model of delaye d breakdown is a TRAPATT-like ionizing wave that propagates faster than the saturated drift velocity vs. and leaves dense electron-hole plasma behind (see Ref. 1 and references therein). However, both analytical theory and numerical simulations show that TRAPATT-like wave in Si at typical electric field of ˜300 kV/cm is roughly 3 times slower than it is needed to explain 100 ps switching [1].

In this presentation we point out flaws of the TRAPATT-like wave concept in application to SAS diodes and discuss alternative mechanisms of ultrafast avalanche switching. These are scenarios of filamentary back-stroke ionization [2], the concept of non-TRAPATT-like ionizing wave in low-doped structures [3] and, finally, straighforward but efficient mechanism of quasi-uniform avalanche breakdown. First, we argue that experimentally observed switching time of ˜100 ps can be explained assuming that only part of the device cross-section is modulated. We show that such current localization results in qualitative difference in switching dynamics. Second, we describe ionizing waves that differ from TRAPATT-like waves in propagation mechanism and formulate physical conditions for their excitation in SAS diodes [3]. Finally, we demonstrate that avalanche switching with rise-time below ˜100 ps may occur in spatially uniform manner even in pin-diodes where front propagation is impossible. These results are also applicable to optically activated switches. The critical parameters for successfull ps-range switching are the ratio of the maximum electric field to the ionization threshold and the ratio of the RC-time (determined by the intrinsic device capacitance and the external load) to the inverse impact ionization rate.

[1] P. Rodin, U. Ebert, A. Minarsky, I. Grekhov, J. Appl. Phys. 102(3), 034508, 2007.

[2] P. Rodin, A. Minarsky, I. Grekhov, J. Appl. Phys. 108(3), 034501, 2010

[3] P. Rodin, A. Minarsky, I. Grekhov, Technical Physics Letters, 38(6), 535, 2012.

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