Enhancing Electron Transport in Silicon Self-Switching Devices: A Study on Triangular Barrier-Induced Ballistic Effects

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ABSTRACT

With the increasing demand for high-frequency applications due to congestion in lower frequency bands, the need for high-performance diode detectors has become critical. Achieving fast and efficient high-frequency response requires diodes with strong rectification capability and sharp nonlinearity. These electrical characteristics, particularly the I–V behavior of the device, strongly influence key performance metrics such as the curvature coefficient and current responsivity. Derived from the I–V curve shape, these metrics reflect the device’s nonlinear behavior. This study investigates how geometrical modifications influence ballistic transport and electrical performance in silicon-based self-switching devices (SSDs). A triangular potential barrier is introduced within the channel to promote ballistic-like electron transport, especially when the channel dimensions are comparable to or smaller than the mean free path (MFP) of charge carriers. Device structures are designed using Silvaco Devedit 3D and simulated in ATLAS. I–V characteristics are extracted, and corresponding curvature coefficients and current responsivity calculated to assess rectification. A curvature coefficient of at least 3.5 V⁻¹ was targeted to indicate strong rectification. Among the simulated structures, the SSD with integrated planar and triangular trenches achieved the highest curvature coefficient and significantly enhanced forward current. This geometry is considered the most promising within the scope of the simulations, with its narrow trench width and short channel length suggesting the possibility of quasi-ballistic or ballistic-like transport. Results further indicate that both the size and shape of the triangular barrier critically affect electrical characteristics, showing their importance for future SSD optimization.

**Keywords:** rectification performance. curvature coefficient, ballistic transport, current response, triangular barrier