Micromagnetic simulation for probabilistic magnetization switching process of a spin-orbit true random number generator

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Abstract

True random number generator (TRNG) is an important component for modern information security technologies. Among the candidates, TRNG with spin-orbit torque (SOT)-induced probabilistic magnetization switching is competitive for its advantages in anti-radiation, unlimited endurance, robust stability, and broad temperature range. However, realization of a SOT-TRNG requires intensive understanding of the magnetic dynamic process under a spin-orbit current. Here, we performed micromagnetic simulation of the SOT-induced probabilistic magnetization switching by using Mumax 3. Without thermal noise, identical magnetic moment precessions were found between repeated simulation cycles, resulting in deterministic magnetization switching. When thermal noises were taken into account, stochastic precession trails and thereby probabilistic magnetization switching were finally obtained. Our results suggest the Mumax 3 to be a practical tool for simulating the probabilistic magnetization switching behavior of a SOT-TRNG, as well as highlighting the crucial role of thermal noise during the simulation.

Full Text

Preamble

Micromagnetic Simulation for Probabilistic Magnetization Switching Process of a Spin-Orbit True Random Number Generator

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Abstract

True random number generators (TRNGs) are essential components for modern information security technologies. Among various candidates, TRNGs based on spin-orbit torque (SOT)-induced probabilistic magnetization switching offer competitive advantages including radiation resistance, unlimited endurance, robust stability, and broad operating temperature range. However, realizing a practical SOT-TRNG requires a comprehensive understanding of the magnetic dynamics under spin-orbit currents. Here, we performed micromagnetic simulations of SOT-induced probabilistic magnetization switching using Mumax3. Without thermal noise, repeated simulation cycles exhibited identical magnetic moment precessions, resulting in deterministic magnetization switching. When thermal noise was incorporated, stochastic precession trajectories emerged, leading to probabilistic magnetization switching. Our results demonstrate that Mumax3 is a practical tool for simulating the probabilistic magnetization switching behavior of SOT-TRNGs and highlight the crucial role of thermal noise in these simulations.

Figure 1 [Figure 1: see original paper]. Schematic drawing of the SOT-TRNG.

Figure 2 [Figure 2: see original paper]. Current-induced magnetization switching process without thermal noise. Identical deterministic switching was obtained for repeated simulation cycles.

Figure 3 [Figure 3: see original paper]. Current-induced probabilistic magnetization switching with thermal noise.

Note: Figure translations are in progress. See original paper for figures.