Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary information for

A compact skyrmionic leaky-integrate-fire spiking neuron device

S1. Simulation details

Our work is performed by micromagnetic simulations using the Object Oriented MicroMagnetic Framework (OOMMF) software that contains the extension module for the interfacial Dzyaloshinskii–Moriya interaction (DMI). We include the exchange energy, the DMI energy, the perpendicular magnetic anisotropy energy, the demagnetization energy, and the AFM exchange coupling energy between the top and bottom FM layers. The magnetic material parameters used in our simulations are: saturation magnetization $M_s = 580 \times 10^3\ A/m$, exchange stiffness $A = 15 \times 10^{-12}\ J/m$, the perpendicular magnetic anisotropy $K_u = 8 \times 10^5\ J/m^3$, the continuous effective DMI constant $D = 3.5 \times 10^{-3}\ J/m^2$, Gilbert damping $\alpha = 0.3$ and the interlayer exchange coefficient of the two FM layers equals $-2 \times 10^{-3}\ J/m^2$ in our simulated structure, both the thickness of the FM layer and the spacer are 1 nm[1-3]. A discretization size of 2 nm × 2 nm × 1 nm is used in our simulations. Note here that some shunted currents may flow through the FM layers when the driving current flows through the heavy metal. However, as the thickness of the FM layer (~1 nm) is far less than that of the heavy metal (>10 nm), the number of electrons flowing through the FM layers is far less than that flowing through the heavy metal. In addition, the physical theory has shown that the spin torque efficiency of the current- perpendicular-to-plane (CPP) case is almost ten times higher than that of the current-in-plane (CIP) case[4]. Thereby, the spin torque contribution of the CIP case is reasonably neglected in our simulations.

S2. Detailed fitting values

The position of skyrmion X_c as a function of time in the backward process is fitted as equation (1), in which the fitting values of $b(k)$ equal to 0.92, 0.72, 0.57, 0.42, and 0.30 associated with the k values of 0.2, 0.175, 0.15, 0.125, and 0.1, respectively while b_0 is a fixed value of 4.7. In the meantime, the fitting value$^{s\ of}$ $a_1(k)$, $a_2(k)$ and $d_0(k)$ in equation (2) are dependent on the slope k as well: $a_1(k)$ equals to 9.36, 11.35, 10.77, 10.36, and 17.58; $a_2(k)$ equals to 5.16, 5.00, 4.70, 4.38, and 4.13; and $d_0(k)$ equals to 29.38, 30.53, 30.44, 30.32, and 36.15 when the corresponding k is 0.2, 0.175, 0.15, 0.125, and 0.1, respectively.

References

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