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Interface-driven nanoscale skyrmions - a new twist for spintronics

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Nanoscale magnetic knots, called skyrmions, are novel types of localized non-collinear spin textures which offer great potential for future magnetic memory and logic devices [1]. The twisting in the skyrmions' magnetization profile leads to a gain in energy with respect to a homogeneously magnetized, ferromagnetic state. As a result of this magnetization twisting, skyrmions have non-trivial topological properties, described by a topological charge, and are topologically protected against a transition into topologically trivial states. The energetics of skyrmionic states is explained by the Dzyaloshinskii-Moriya interaction [2] being relevant in material systems exhibiting large spin-orbit coupling and a lack of inversion symmetry, in contrast to magnetic bubble domains which are stabilized by dipolar magnetic interactions. Recent experimental and theoretical work has focused on atomic- and nanolayers of magnetic materials with intrinsic or interface-induced chiral interactions, thereby achieving full compatibility with state-of-the-art technology which has been developed over the past decades in the field of GMR- and TMR-based devices. It has been shown both experimentally and theoretically that magnetic skyrmions in ultrathin film systems can be as small as one nanometer in diameter [3] and that their properties can largely be tuned by the choice of the substrate and overlayer materials [4]. Atomic-resolution spin-polarized scanning tunneling microscopy (SP-STM) and spectroscopy [5] has proven to be an invaluable tool for revealing the atomic-scale properties of ultimately small skyrmions [6-9]. By locally injecting spin-polarized electrons from an atomically sharp SP-STM tip, we are able to write and delete individual skyrmions one-by-one, making use of spin-transfer torque exerted by the injected high-energy spin-polarized electrons [4]. Switching rate and direction can be controlled by the parameters used for current injection. Alternatively, individual skyrmions can be created and deleted by local electric fields [10], which can be of great advantage in view of energy-saving skyrmionic device concepts. The subsequent detection of the written skyrmions can also be achieved by electrical means rather than by using a magnetic sensing element [11]. The demonstration of various methods for the creation and annihilation as well as the detection of individual nanoscale skyrmions highlight their great potential for future spintronic devices making use of individual topological charges as information carriers.

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