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Electrical Creation and Manipulation of Magnetic Skyrmion Bubbles

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Magnetic skyrmions are topologically stable spin textures, which exhibit many fascinating features including an emergent electromagnetic field and efficient manipulation. Nevertheless, until now this has been challenging to achieve at room temperature, which is a bottleneck for technological implementation of skyrmion-based spintronics. Towards this end, room-temperature electric-current creation of skyrmions in two different (metallic and insulating) commonly accessible materials system will be discussed. First, the experimental creation of magnetic skyrmions triggered by an electric current in Ta/CoFeB/TaO_x trilayers is demonstrated. The skyrmion generation is enabled by laterally inhomogeneous current-induced spin-orbit torques. This process is analogous to the spontaneous droplet formation in surface-tension driven fluid flows. We establish a novel phase diagram that summarizes the dependence of skyrmion generation on the external magnetic fields, and the strength of in-plane currents. Furthermore, we reveal the efficient manipulation of these skyrmions by electric currents. More importantly, a prototype skyrmion racetrack memory device will be experimentally demonstrated. Secondly, the manipulation of skyrmion bubbles by using spin Hall spin torques in (Pt or W)/$(Y,Bi)_3Fe_5O_{12}$ (YIG:Bi) bilayers will be discussed. Using MOKE imaging, we have identified a hexagonal lattice of skyrmion bubbles (1.8-μm diameter). Subsequent current pulses through the Pt layer results both in the motion of some of the skyrmions and a reduction in size of others, which is consistent with different wall structures and resultant skyrmion numbers. Furthermore, we have observed distinct anomalous Hall signals associated with the underlying magnetization textures, which may indicate topological Hall effects in bilayers.[1,2]

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[2]This work was performed in collaboration with W. Zhang, M. B. Jungfleisch, F. Y. Fradin, J. E. Pearson, O. Heinonen, S. G. E. te Velthuis, and A. Hoffmann (Argonne National Laboratory), P. Upadhyaya, G. Yu, Y. Tserkovnyak, K. L. Wang (UCLA), Q. H. Yang, Q.Y. Wen, and H. W. Zhang (UESTC, China).