Screw Dislocations-Based Spin Valves

F. Haines,[1,2] E. J. Renteria,[1] M. L. Debasu,[1] F. Cavallo,[1,2,3]
[1]Center for High Technology Materials, University of New Mexico, Albuquerque, NM 87106
[2]Nanoscience Microsystems and Engineering Graduate Program, University of New Mexico, Albuquerque, NM 87131
[3]Department of Electrical and Computer Engineering, University of New Mexico, Albuquerque, NM 87131

We fabricated and characterized a vertical spin valve (VSV) based on single-crystalline Si nanomembranes (NMs) engineered with 2D arrays of screw dislocations (SDs) throughout their thickness. The device includes a bottom soft ferromagnetic contact (NiFe), Si NMs, and a top hard ferromagnetic contact (Co). Based on previously reported theoretical calculations, we expect that the operation of the VSV relies on the coherent transport of spin-polarization through SDs [1]. The first step in the fabrication of the VSV is patterning a 220 nm-thick Si NM into a 2D array of pixels with lateral sizes in the range of 200-400 μm. At this stage of the process, the NM is bonded to a SiO_2-coated bulk Si substrate. Si pixels are released in place by selective etching of the SiO_2 layer. An adhesive stamp removes the pixels from the original substrate and transfers them onto a second array of patterned pixels at a controlled twist angle, Ψ. The twisted NM pairs are then annealed at 1000-1200 °C in N_2 atmosphere to grow the SDs. Annealed NMs are finally transferred to a bulk substrate coated with NiFe. A dielectric barrier and a Co/Au top contact are fabricated using conventional top-down processes. The coercivity of the ferromagnetic films used for the contacts is extracted from measured magnetization curves on a Quantum Design Magnetic Properties Measurement System 3 (QD-MPMS3). Magneto-transport measurements characterize the resistance of the VSV at different magnitudes of magnetic induction (B). We observe a change in resistance at B corresponding to the measured coercivity of NiFe. The estimated magnetoresistance ratio, $MR(\%) = \frac{R_{AP}-R_P}{R_P}$ is -0.38 % at 300 K. No change in resistance was measured for VSVs based on Si NM that did not include SDs, suggesting that the line defects are responsible for the probed MR at 300K.

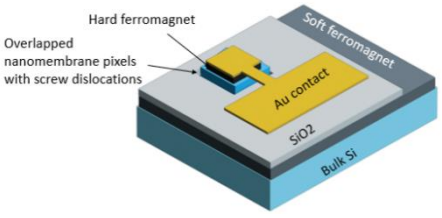


Figure 1. Schematic illustration of a vertical spin valve based on Si NMs embedding an array of screw dislocations.VSV Structure.

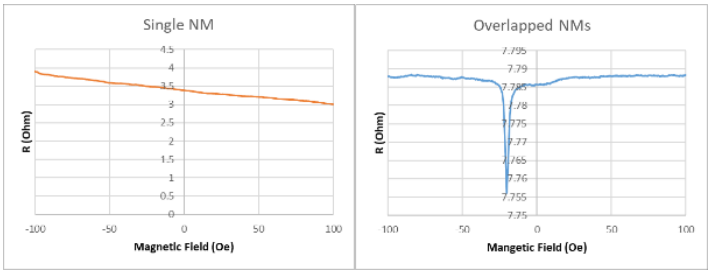
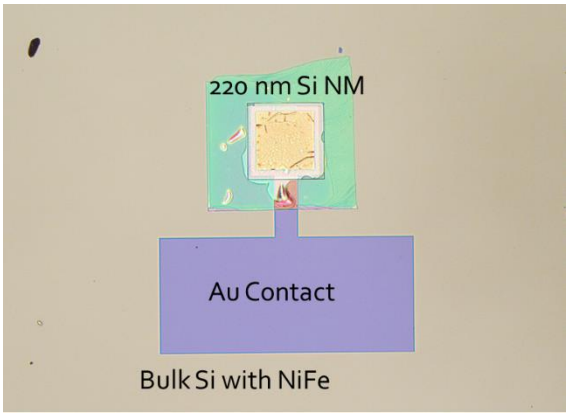


Figure 2. Magnetoresistance vs. magnetic induction for a VSV based on a Si NM that does not have screw dislocations (left panel) and for an annealed Si twisted bicrystal (right panel).

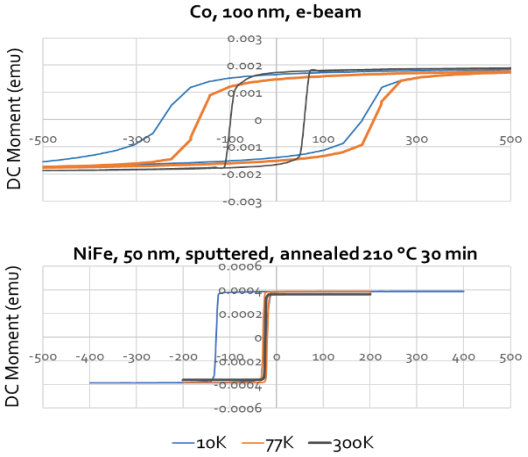
[1] L. Hu, H. Huang, Z. Wang, W. Jiang, X. Ni, Y. Zhou, V. Zielasek, M. G. Lagally, B. Huang and F. Liu, *Phys. Rev. Lett.*, 2018, **121**, 66401.

[+] Author for correspondence: fhaines@unm.edu

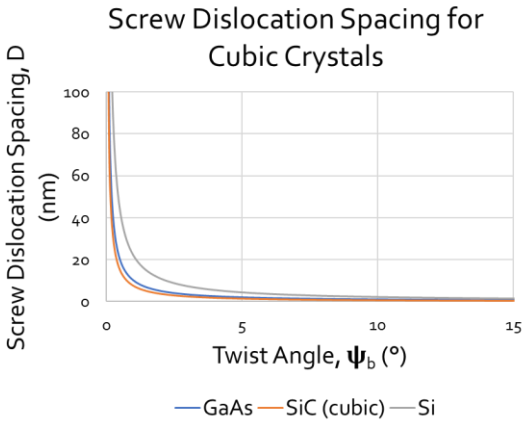
Supplementary Pages



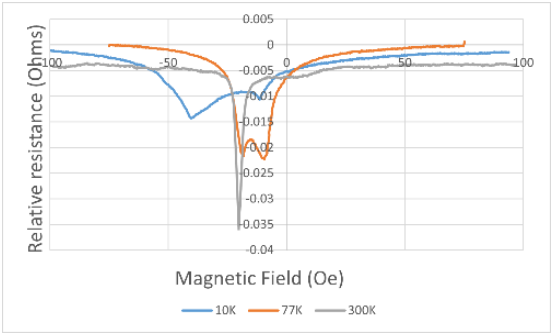
Supplementary Figure 1. Optical image of a fabricated VSV.



Supplementary Figure 2. Cobalt (hard) ferromagnetic layer and NiFe (soft) layer hysteresis



Supplementary Figure 3. Screw dislocation spacing vs. twist angle between two cubic crystals.



Supplementary Figure 4. Magnetoresistance vs. magnetic induction for annealed Si twisted bicrystals at different temperatures

ACKNOWLEDGEMENT. Work at the University of New Mexico was supported by the NSF CAREER award No. 2144944. This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the US Department of Energy (DOE) Office of Science by Los Alamos National Laboratory (Contract 89233218CNA000001) and Sandia National Laboratories (Contract DE-NA-0003525).