

# Platforms for Boundary-Controlled Synthesis of Screw Dislocations in Single-Crystalline Semiconductors

**Zachary A. Handoklow,<sup>1,2</sup> Emma J. Renteria,<sup>1</sup> Jordan P. Neely,<sup>1,2</sup> Darryl M. Shima,<sup>1</sup> and Francesca Cavallo<sup>1,2</sup>**

<sup>1</sup>*Center for High Technology Materials, University of New Mexico, Albuquerque, NM-87106*

<sup>2</sup>*Department of Electrical and Computer Engineering, University of New Mexico, Albuquerque, NM-87131*

Recent research efforts have demonstrated the prospect of repurposing screw dislocations (SDs) into channels for coherent spin transport and solid-state qubits, igniting interest in promoting, understanding, and controlling the synthesis of these line defects [1]. Despite numerous theoretical models suggesting that changes in elastic energy and crystalline structure at surface and interface boundaries may play a significant role in determining the kinetics of SDs' growth as well as the structure of individual SDs and their networks [2,3], a comprehensive experimental study of boundary controlled synthesis of these line defects has not been carried out, primarily due to the shortage of suitable materials platforms to implement it.

Here, we present robust fabrication processes of platforms to investigate the effect of fixed and free surface boundaries on the nucleation and growth of SDs by annealing of twisted bicrystals (TBiCs), i.e., two single-crystalline materials overlayed at a non-zero twist angle. TBiCs include an array of disregistry at the interface that promotes nucleation and growth of SDs across the thickness of the crystal during annealing [4]. Our platforms rely on the use of nanomembranes (NMs) or slabs of materials with a thickness in the range of 5-500 nm and an aspect ratio of  $10^3$ - $10^6$  between lateral dimensions and thickness. Briefly, we isolate Si NMs with a thickness in the range of 20 to 220 nm from commercially available Si-on-Insulator (SOI) substrates by selective erosion of the buried SiO<sub>2</sub> in hydrofluoric acid (HF). Upon release, the Si NMs are bonded to a bulk Si substrate with a twist-angle ranging from 0° to 45° to create a crystal with a free boundary (i.e., the top surface of the NM exposed to air) and a fixed boundary (i.e., the bottom surface of the NM interfaced with bulk Si). By varying the thickness of the NMs, we tailor the distance between the nucleation site of a SD (i.e., an interfacial twist boundary) and the free surface boundary, a parameter that is also expected to affect the formation and characteristics of SDs. We anneal all fabricated Si TBiCs at 1000-1100°C to assess their structural stability during the required process, which fosters the nucleation and growth of SDs. In addition to a detailed description of the fabrication process of TBiCs with tunable boundaries, we present characterization results for these platforms using top-down optical microscopy as well as top-view and cross-sectional electron microscopy. Specifically, we ascertain the stability of the NMs and the quality of the interface, which is crucial to the synthesis of SDs by our approach.

[1] Hu, L.; Huang, H. Q.; Wang, Z. F.; Jiang, W.; Ni, X. J.; Zhou, Y. N.; Zielasek, V.; Lagally, M. G.; Huang, B.; Liu, F., *Phys. Rev. Lett.*, **121** (6), 066401 (2018).

[2] Bai, J.; Wang, S. *Int. J. Plas.* **87**, 181 (2016).

[3] Yoffe, E. H., *Phil. Mag.* **6** (69), 1147 (1961).

[4] Rouviere, J. L.; Rousseau, K.; Fournel, F.; Moriceau, H., *Appl. Phys. Lett.* **77** (8), 1135 (2000).