Strain Soliton Formation in Epitaxial Bismuth Thin Films

Jason T. Dong[1], Hadass S. Inbar[1], Connor P. Dempsey[2], Aaron N. Engel[1], Christopher J. Palmstrøm[1,2]

[1]Materials Department, University of California, Santa Barbara, CA 93106

[2]Deparment of Electrical and Computer Engineering, University of California, Santa Barbara, CA 93106

Strain solitons are topological defects which have been observed in van der Waals materials [1]. Strain solitons are generated as a result of thin film strain and form as ripples in the films, separating commensurate and incommensurate regions. The solitons are analogous to misfit dislocations and cause local relaxation of the crystal. Solitons have been of interest due to their potential for generating novel spatially confined states within two-dimensional materials [2].

In this talk, we report the formation of strain solitons in epitaxial (111) bismuth thin films grown by molecular beam epitaxy on InSb(111)B substrates. The 0.9% lattice mismatch between bulk bismuth and the InSb(111)B substrates results in strain relaxation via strain soliton formation and in-plane edge dislocation formation. Edge dislocations are observed to induce large angle bending of the solitons. The solitons appear to form at the interface and propagate throughout the film. The strain state of the bismuth thin films is characterized by *in-situ* low temperature scanning tunneling microscopy and ex-situ X-ray diffraction. The effect of the solitons on local strain and lattice rotation is mapped from the STM images using the Lawler-Fujita algorithm [3]. Partial relaxation of bismuth is observed to begin at 2 bilayers, and the thin films become fully relaxed by 30 bilayer thick. The evolution of the soliton network and their strain fields as a function of thickness is characterized. Our results indicate that bismuth primarily relaxes by strain soliton formation and enables future investigation of novel states hosted in the bismuth solitons.

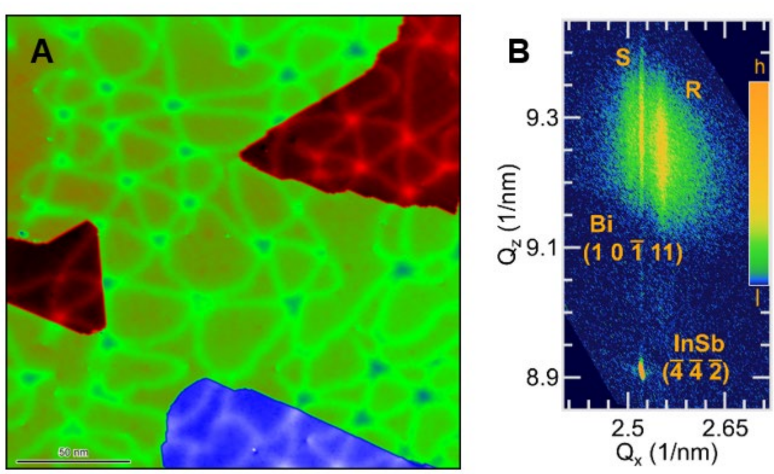

Figure 1: (A) 200x200 nm STM image of 5.5 bilayer bismuth films, soliton are evident. (B) Reciprocal space map of the Bi (1 0 $\bar{1}$ 11) and InSb ($\bar{4}$ $\bar{4}$ $\bar{2}$) peaks. A coherently strained peak (S) and relaxed peak (R) are present.

References

[1] PNAS **110**(28), 11256-11260 (2013).
[2] PRL **121**, 266401 (2018).
[3] Nature **466**, 347–351 (2010).

Supplementary Pages

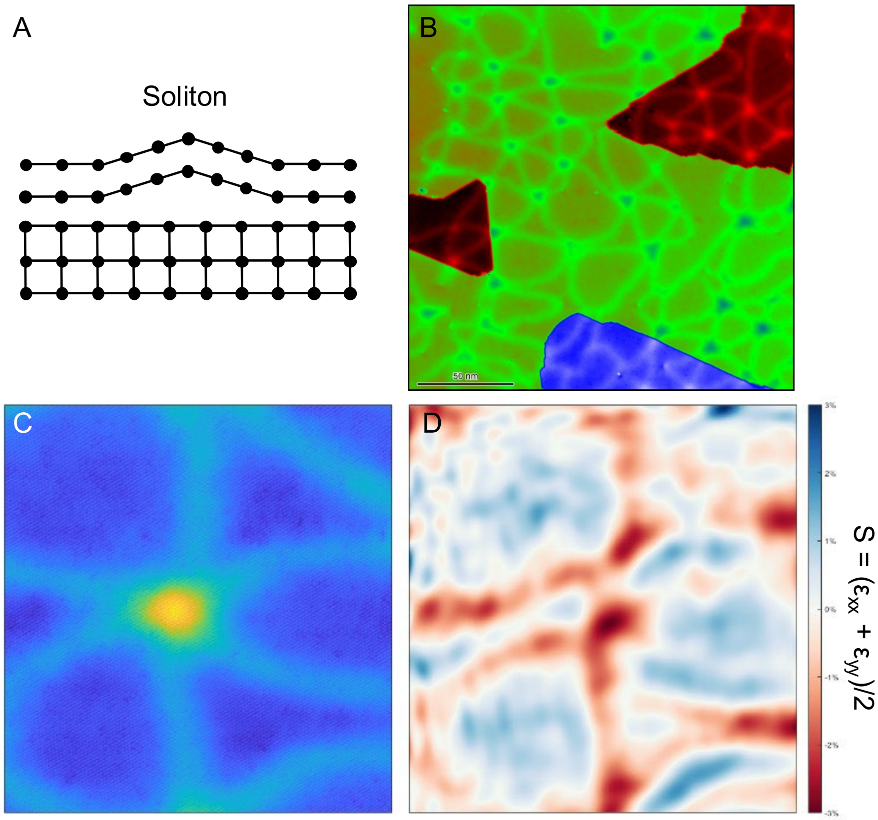

Figure S1: (A) Strain soliton schematic (B) 200x200 nm STM image of 5.5 bilayer bismuth films, soliton are evident. (C) Atomic resolution STM image of soliton. (D) Symmetric strain ($S = \varepsilon_{xx} + \varepsilon_{yy}$) map of the solitons.

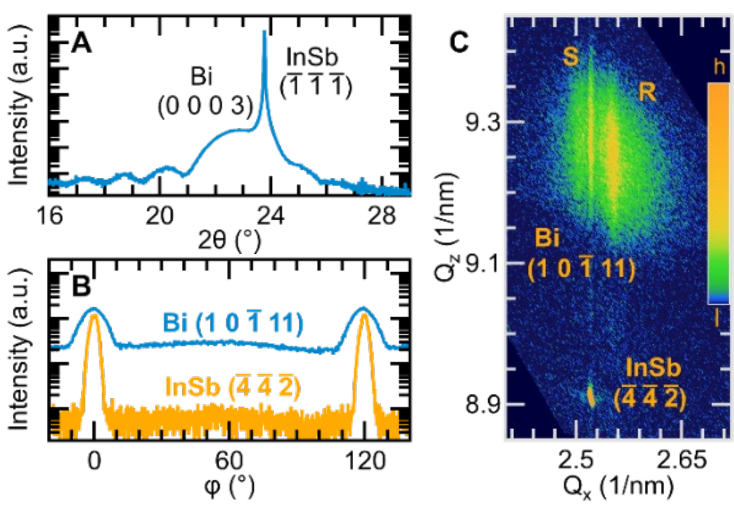

Figure S2: Figure 2: (A) θ-2θ XRD scan of a 13BL Bi film exhibiting thickness fringes indicating a sharp interface. (B) φ scan of the Bi $(1\,0\,\bar{1}\,11)$peak showing the 3-fold symmetry of a single crystal domain. (C) Reciprocal space map of the Bi $(1\,0\,\bar{1}\,11)$ and InSb $(\bar{4}\,\bar{4}\,\bar{2})$ peaks. A coherently strained peak (S) and relaxed peak (R) are present.