Type of presentation: Oral

**MS-3-O-3483 STEM and EELS study of Graphene/$Bi_2Se_3$ Interface**

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$Bi_2Se_3$ is a 3D topological insulator (TI) that has attracted a lot of research due to exotic properties associated with topologically protected helical two-dimensional surface states and one-dimensional states associated with bulk line defects such as dislocations. Recently it has been shown that when $Bi_2Se_3$ is grown either on epitaxial graphene or self-standing graphene flakes [1,2], a rich grain structure of film is developed due to the spiral nature growth of the film. The grain boundaries and growth screw dislocations in this system provide a ground for new physics that can be accessed by combination of scanning tunnelling microscopy and transmission electron microscopy techniques such as STEM-HAADF and EELS. In this work we investigate the nature of the graphene/$Bi_2Se_3$ interface in order to understand the complex epitaxy between the film and substrate which ultimately determine the structure and functional properties of the $Bi_2Se_3$ surface topological states.

We have grown $Bi_2Se_3$ films on both epitaxial graphene/SiC(0001) at 275-325 °C and chemical vapor deposition produced graphene flakes. We have studied their surface states by STM, and interface structure and electronic properties by cross-sectional TEM/STEM and EELS, respectively, by using aberration corrected 200kV JEOL 2200FS and NEON 100 at 100kV.

Fig. 1 shows the interface region of SiC/graphene/$Bi_2Se_3$. Due to the Z-contrast sensitivity in the HAADF imaging, we can clearly identify the Bi, Se and Si columns. The dark region between the SiC and $Bi_2Se_3$ corresponds to the graphene monolayer which is clearly seen in BF-STEM imaging condition (not shown here). Fig. 2 is EELS spectra from the interface region following the C edge from the substrate through the C layer between the SiC substrate and first Se atomic plane from the $Bi_2Se_3$. By quantifying the $\sigma^*/\pi^*$ ratio we found that the C layer at the interface is behaving like self-standing graphene monolayer. This indicates that the bonding between Se and graphene has Van der Waals nature. Such weak bonding would be the key factor for the multiple epitaxial relations which leads to both low and high angle boundaries observed in $Bi_2Se_3$ thin films when grown on graphene substrate [1,2].

1. Liu, Y., et al., Charging Dirac States at Antiphase Domain Boundaries in the Three-Dimensional Topological Insulator $Bi_2Se_3$. Physical Review Letters, 2013. 110(18): p. 186804.

2. Liu, Y., et al., Tuning Dirac states by strain in the topological insulator Bi2Se3. Nat Phys, 2014. advance online publication.

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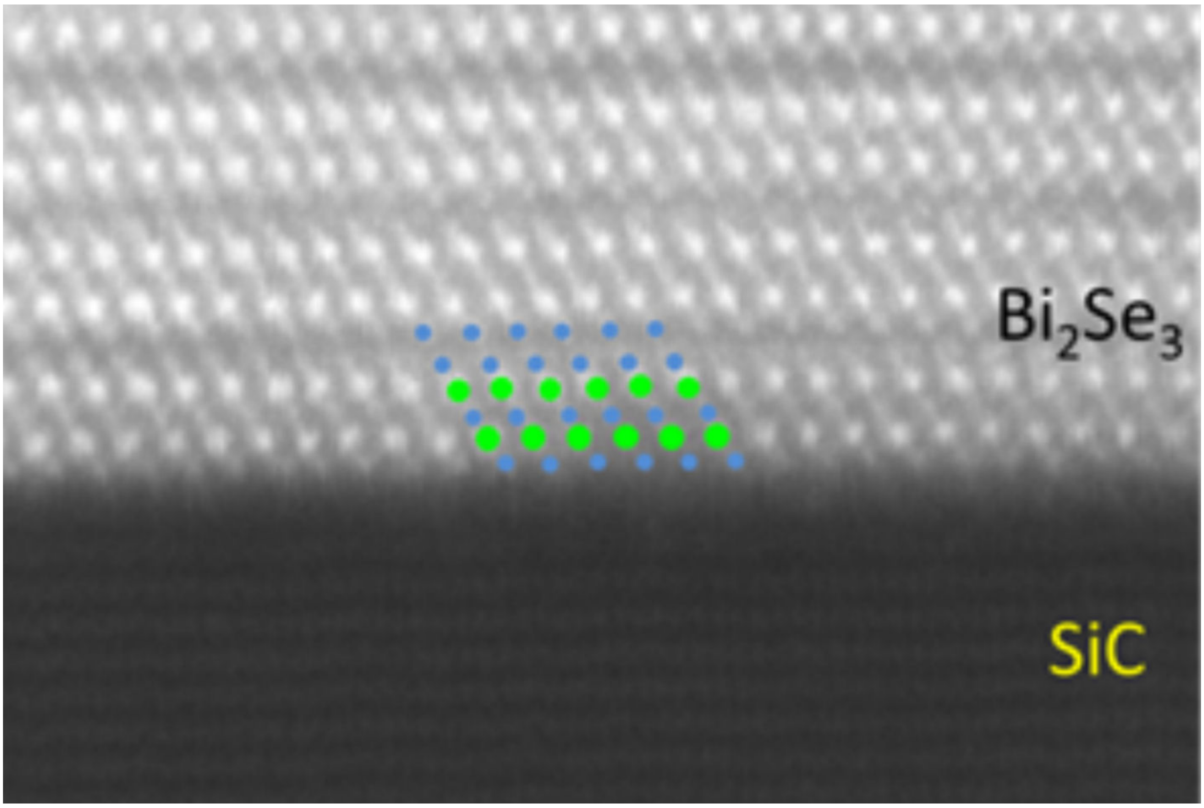


Fig. 1: HAADF-STEM image of the interfacial region of SiC/graphene/$Bi_2Se_3$. Green solid circles represent Bi, and blue Se atomic columns.

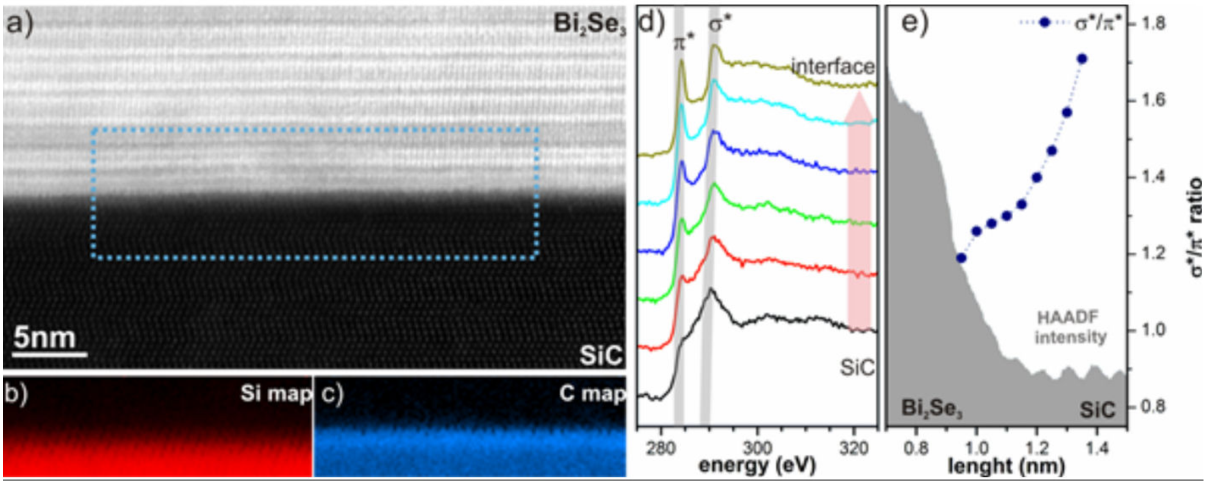


Fig. 2: a) HAADF STEM survey image showing the $Bi_2Se_3$ film and SiC substrate, b,c) Si $L_{2,3}$ and C K EELS elemental maps from the area across the $Bi_2Se_3$/SiC interface marked in a. d) Selected C K EELS spectra from the interface region and e)$\sigma^*/\pi^*$ ratio of the C K edge at the $Bi_2Se_3$/SiC interface.