doi:10.1017/S1431927620023867
Microsc. Microanal. 26 (Suppl 2), 2020

Electron Microscopy and Interface Plasmons Characterization of Cadmium Telluride Thin Film Grown Incommensurately with Weak Bonding on Sapphire

Hesham El-Sherif, Stephen Jovanovic, John Preston and Nabil Basim

McMaster University, Hamilton, Ontario, Canada

Cadmium Telluride (CdTe) thin films are important materials for optoelectronic and radiation detection applications. Fabrication of CdTe films has been studied using a variety of substrates via heteroepitaxial growth. As a result of the lattice mismatch strain, the CdTe films usually contain threading and misfit dislocations that limit device performance. Recently, a remote epitaxy technique [1] was demonstrated for homoepitaxial systems by transferring a graphene sheet onto the substrate before deposition of the film. Applied to a heteroepitaxial system, this type of compliant interface would allow for the accommodation of misfit strain due to weakened interfacial bonding. In this current work, a similar compliant interface is created by direct growth [2], without the use of pre-transferred graphene, and instead by the self-assembly of a Tellurium (Te) monolayer at the interface [3]. Utilizing pulsed laser deposition (PLD), high-quality epitaxial CdTe films can be grown on sapphire and then transferred from their substrate to be freestanding leaving the substrate for subsequent growths.

Probe-corrected TEM experiments were used to image the interface in Fig. 1-a and 1-b, show a sharp growth interface where a high-quality CdTe film grows on its (111) orientation on the (0001) sapphire face. The interface in the HAADF-STEM image (Fig. 1-a) shows a monolayer with less on Sapphire with less contrast than the CdTe crystal. A direct electron detector (Gatan’s K2 SI) is used to acquire an atomically resolved EELS map of the film (Fig. 1-c) that shows a CdTe(111) with Cadmium up polarity for the crystal, which means a Te termination at the sapphire surface. In addition, the core-loss EELS map (Fig. 1-d) shows a Te-layer nucleating on the sapphire before the CdTe film.

To investigate the bonding at the interface, a monochromated STEM experiment was conducted trying to achieve acceptable both energy and spatial resolution to image and map the Te layer at the interface. Fig. 2-a shows typical atomically resolved STEM-HAADF images acquired with a monochromated beam with around 140 meV energy resolution. With this unique beam, a low-loss EELS map was acquired at the interface region using a US1000FTXP CCD camera at 300 keV. The resulted EELS map shows two unique interface intensities around 5.0 ±2 eV and 17.5 ±2 eV. To understand the origin of these interface plasmons we conduced another monochromated experiment at the same imaging and EELS acquiring conditions to study the low-loss plasmons of a pure Te sample (black curve in Fig. 2-b). We demonstrate that these interface plasmons match the characteristic plasmon peaks (π and σ+π) of a pure Te standard with the hexagonal structure that contains weak interchain vdW bonding. This study reveals that unique surface chemistry drives the formation of a stable Te-monolayer termination of sapphire which leads to vdW-like bonding to the heteroepitaxial CdTe film. This allows for a compliant interface, which greatly reduces mismatch defects, as well as the ability for the film to be removed from the substrate and become freestanding.

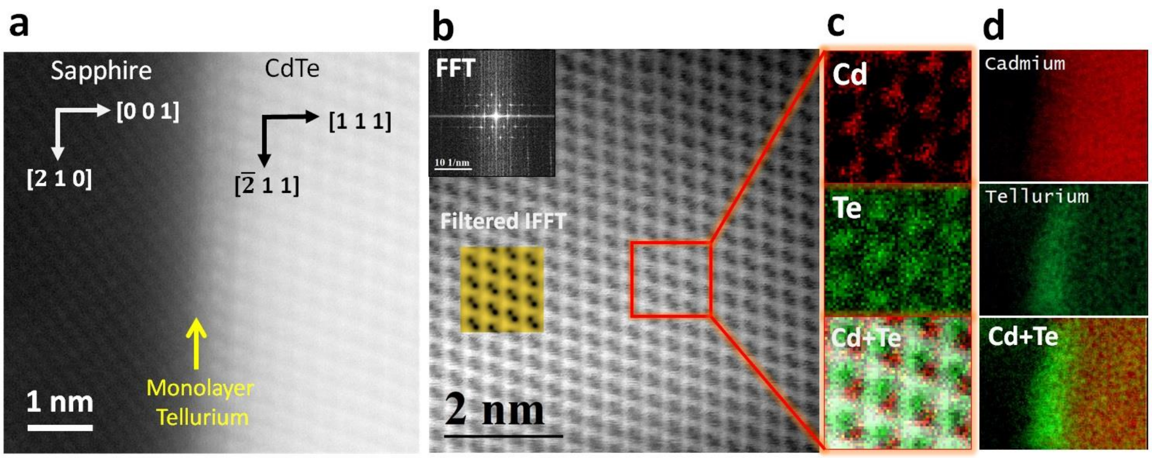

Figure 1. STEM imaging and spectroscopy of the CdTe film. (a) STEM-HAADF image shows that the CdTe grows in the (111) direction and the presence of a monolayer Te at the interface. (b) STEM-ADF image shows the CdTe lattice, its FFT (right-top insert) and a cropped portion of the filtered FFT image (right-middle insert). (c) Atomically resolved EELS maps of Cd and Te shows that the CdTe film starts with Te layer (down) and has a Cd-polarity (up). (d) EELS map at the interface shows a layer of tellurium nucleating on the sapphire before the CdTe film.

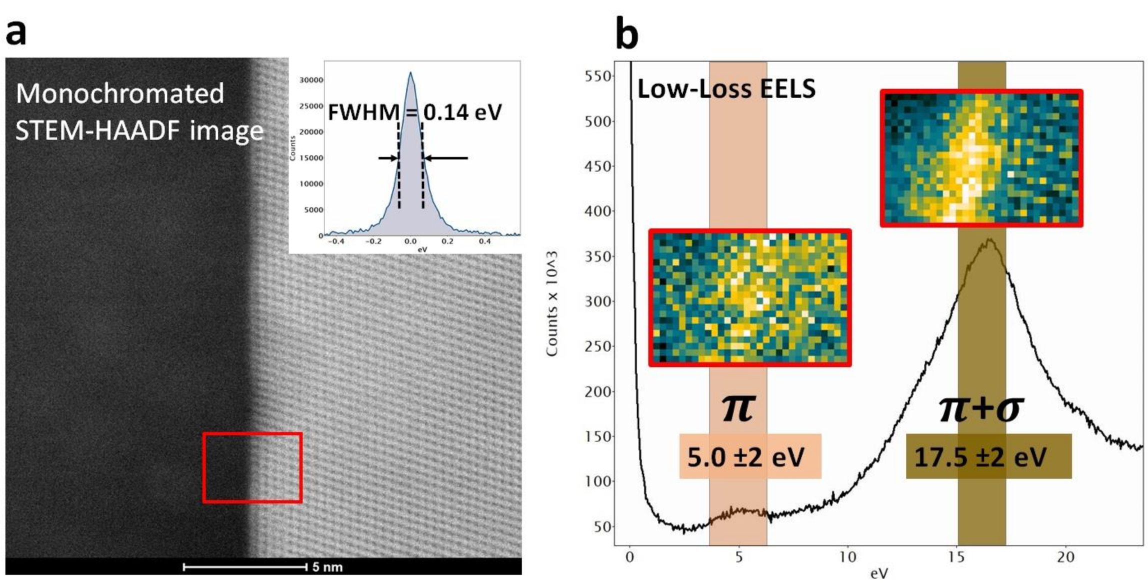

Figure 2. Monochromated STEM experiment for investigating the weak bonding at the interface. (a) STEM-HAADF image achieved with 0.14 eV energy resolution with the possibility of resolving the CdTe lattice fringes and the interface. (b) EELS spectrum (black line) of a pure Tellurium reference shows two main plasmon peaks around 5 ev and 17.5 ev. The two inserted maps are the energy-resolved maps acquired at the interface after integrating the spectrum image slices at the corresponding plasmon centers (± 2ev width) found in the Te reference.

References

[1] Kim, Y., Cruz, S.S., Lee, K., Alawode, B.O., Choi, C., Song, Y., Johnson, J.M., Heidelberger, C., Kong, W., Choi, S. and Qiao, K., 2017. Remote epitaxy through graphene enables two-dimensional material-based layer transfer. Nature, 544(7650), pp.340-343.

https://doi.org/10.1017/S1431927620023867 Published online by Cambridge University Press

[2] Jovanovic, S.M., Devenyi, G.A., Kuyanov, P., Carvalho, J.L., Meinander, K., LaPierre, R.R. and Preston, J.S., 2018. Epitaxial thin film transfer for flexible devices from reusable substrates. Materials Research Express, 6(2), p.025913.
[3] Hwang, J.Y., Kim, Y.M., Lee, K.H., Ohta, H. and Kim, S.W., 2017. Te monolayer-driven spontaneous van der waals epitaxy of two-dimensional pnictogen chalcogenide film on sapphire. *Nano letters*, *17*(10), pp.6140-6145.

https://doi.org/10.1017/S1431927620023867 Published online by Cambridge University Press