X-ray Topography and Transmission Electron Microscopy Analysis of <c + a> Threading Mixed Dislocations in 4H-SiC

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Variants of threading dislocation types are distinguishable in grazing x-ray topography (XRT) by comparing their strain contrast distributions at different $\vec{g}$-reflections. For $\langle c+a\rangle$ threading mixed dislocations (TMDs), although a theoretical relationship between XRT contrast distribution and variant type exists based on ray-tracing simulation results for different $\vec{g}$-reflections [1], direct confirmation must be achieved. In this study, correlations are made between synchrotron XRT images of different $\langle c+a\rangle$ TMD variants in 4H-SiC and their Burgers vectors, $\vec{b}$, as determined by large angle convergent beam electron diffraction (LACBED) via transmission electron microscopy (TEM). LACBED imaging at dislocations will show splitting of excited Kikuchi bands into fringes, where the number of fringes, n, of each band with vector, $\vec{g}$, is given by the relationship $\vec{g}\cdot\vec{b}=n$. This techique has been previously used to analyze a $\langle c+a\rangle$ TMD in 4H-SiC [2]. Figure 1 shows LACBED images of the same dislocation. By determining n for the different split bands, $\vec{b}$ can be calculated. Table 1 shows LACBED results for 6 different $\langle c+a\rangle$ TMDs along with correponding XRT images using the $(1\,1\,\bar{2}\,8)$ reflection. In this table, the dislocation line direction for each TMD is nearly perpendicular to the plane (i.e., surface plane). LACBED directly confirms that the TMDs are $\langle c+a\rangle$ type, i.e., $^1/_3\langle 1\,1\,\bar{2}\,3\rangle$. Also, a consistent relationship between XRT and TEM results is obtained, which renders XRT as a useful technique to map $\langle c+a\rangle$ TMD variants.

[1] J. Guo, Y. Yang, F. Wu, J. Sumakeris, R. Leonard, O. Goue, B. Raghothamachar and M. Dudley (2016), J. Electron Mater., 2045-2050.
[2] Y. Sugawara, M. Nakamori, Y. Yao, Y. Ishikawa, K. Danno, H. Suzuki, T. Bessho, S. Yamaguchi, K. Nishikawa and Y. Ikuhara (2012), Appl. Phys. Express, 081301.

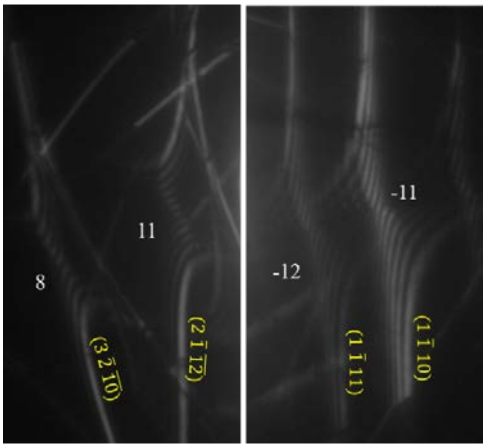


Figure 1: LACBED images at a $\langle c+a\rangle$ TMD showing Kikuchi band splitting.

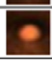
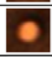
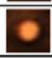
XRT image $\vec{g}$ ← $(1\,1\,\bar{2}\,8)$	$\vec{b}$ (LACBED)	$\vec{b}$ Orientation $\langle a\rangle$	$\vec{b}$ Orientation $\langle c\rangle$
	$^1/_3[\bar{1}\,2\,\bar{1}\,\bar{3}]$	↙	⊗
	$^1/_3[\bar{2}\,1\,1\,3]$	↘	⊙
	$^1/_3[\bar{1}\,2\,\bar{1}\,3]$	↙	⊙
	$^1/_3[2\,\bar{1}\,\bar{1}\,3]$	↖	⊙
	$^1/_3[1\,1\,\bar{2}\,\bar{3}]$	←	⊗
	$^1/_3[\bar{1}\,\bar{1}\,2\,\bar{3}]$	→	⊗
step-flow direction: $[\bar{1}\,\bar{1}\,2\,0]$ →			

Table 1: Correlation between XRT images of different $\langle c+a\rangle$ TMD variants and their Burgers vectors determined from LACBED analysis.