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Burgers Vector Determination of Threading Screw Dislocations in 4H-SiC via Forescattered Electron Channeling Contrast Imaging

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Forescattered electron channeling contrast imaging (ECCI) offers the potential of imaging and analyzing extended defects in a scanning electron microscope (SEM) equipped with a commercial electron backscatter diffraction (EBSD) system. The ability of ECCI to quickly image threading dislocations over large areas of thin film samples, without the difficult sample preparation needed for transmission electron microscopy (TEM), has already been demonstrated [1]. The somewhat more elusive goal of using ECCI to determine the Burgers vector of threading dislocations, however, requires advances in both the determination of experimental parameters and accompanying image simulations. In order to reach this goal we have recorded and simulated ECCI images of an sample with features that are relatively easily studied and modeled: those of specially engineered 4H-SiC mesas (Fig.1) [2]. Imaging of threading screw dislocations (TSDs) penetrating the (0001) surface revealed dark-to-light contrast, the direction of which depends on the acting Bragg reflection, the deviation from the Bragg condition $s_{\mathbf{g}}$, and the dislocation Burgers vector (Fig.2). Burgers vector identification was confirmed through observations of the rotational direction of atomic step spirals associated with various screw dislocations [3].

In electron channeling the incident electron may be modeled as initially undergoing Bragg diffraction, and then directed towards the detector by inelastic scattering (Fig.3) [4]. Using dynamical diffraction calculations analogous to those employed in TEM, electron intensity profiles were simulated and found to qualitatively match channeling contrast of threading screw dislocations (TSDs) experimentally recorded by ECCI. Plan-view images of TSDs penetrating (0001) 4H-SiC surfaces were computed using surface relaxation effects. Simulated diffraction contrast of the TSD allows identification of these threading defects as well as facilitating the determination of the dislocation Burgers vector (Fig.1). The directionality of TSD contrast features, simulated for various Bragg reflections and deviation parameters, is consistent with both ECCI and diffraction contrast imaging by TEM.

The direction of dark-to-light contrast was correlated to the diffraction vector and the sign of the deviation parameter $s_{\mathbf{g}}$ (Fig.2). In addition, TSD ECCI images were found to correspond to dark twin-lobe contrast (Fig.2) when $s_{\mathbf{g}} = 0$. These ECCI contrast features were found to agree with our simulation as a function of $s_{\mathbf{g}}$ when beam convergence is accounted for.

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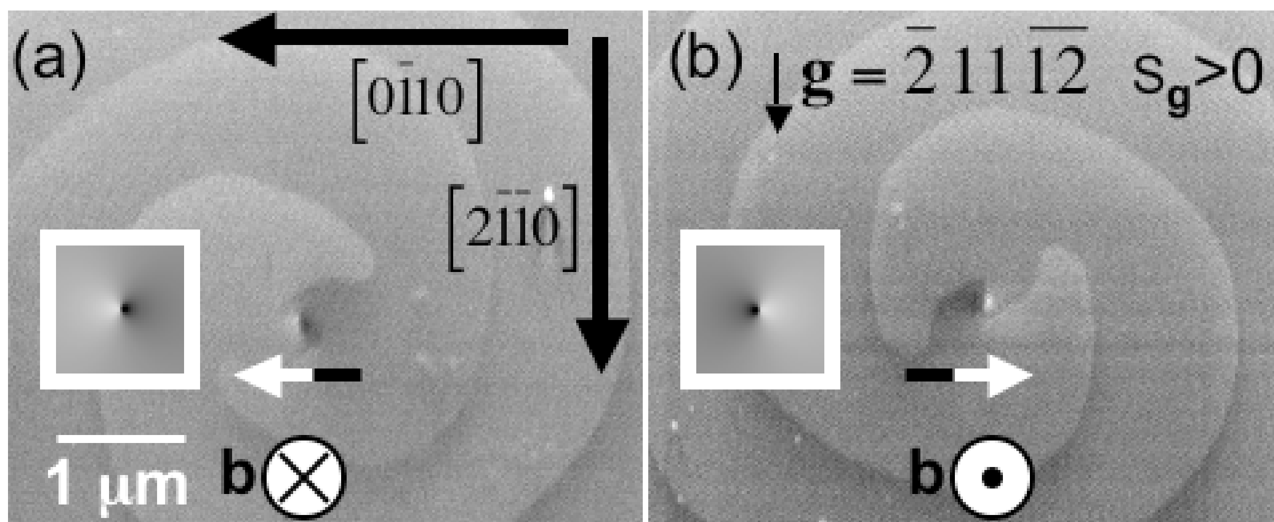

Fig.1 Correlation of step spiral geometry direction with direction of TSD Burgers vector. a) CW spiral with **b** into paper. (b) CCW spiral with **b** out of paper.

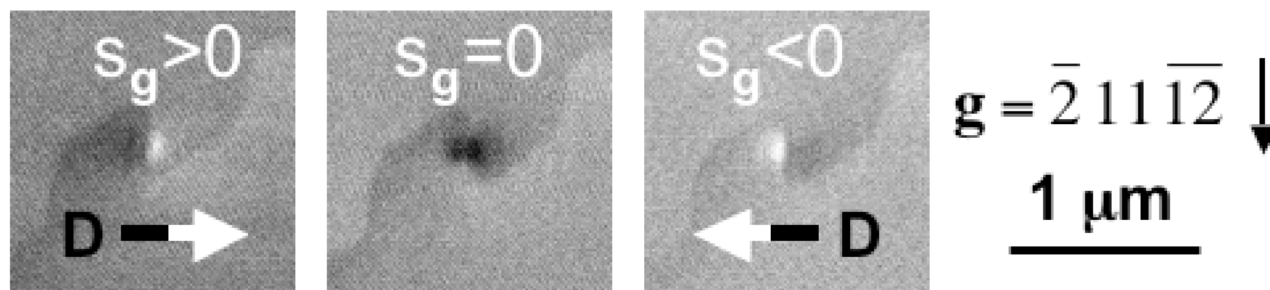

Fig.2 Dependence of the direction **D** of dark-to-light TSD contrast on deviation parameter s_g for the same Bragg condition.

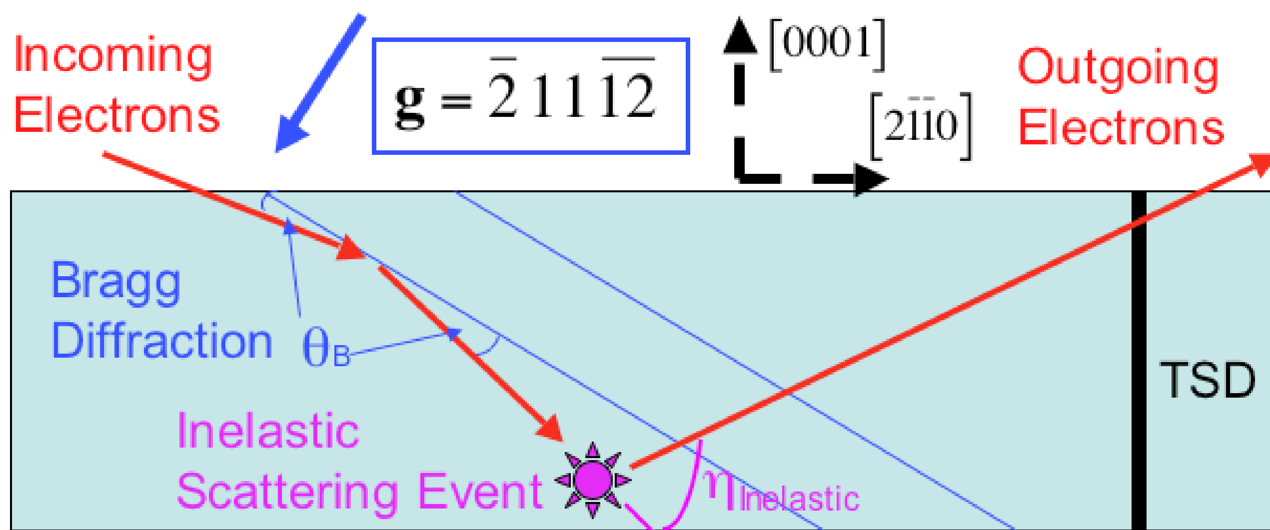

Fig.3 Geometry of Electron channeling Contrast Imaging (ECCI) of threading screw dislocation (TSD) in 4H-SiC where Bragg diffraction of incoming electron is followed by inelastic scattering.

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