Correlation between structural properties and nonradiative recombination behaviors of threading dislocations in freestanding GaN substrates grown by hydride vapor phase epitaxy

Yongzhao Yao,[1,a)] Yoshihiro Sugawara,[1] Daisaku Yokoe,[1] Koji Sato,[1] Yukari Ishikawa,[1] Narihito Okada,[2] Kazuyuki Tadatomo,[2] Masaki Sudo,[1,3] Masashi Kato,[3] Makoto Miyoshi,[3] and Takashi Egawa[3]

[1]Japan Fine Ceramics Center, 2-4-1 Mutsuno, Atsuta, Nagoya 456-8587, Japan

[2]Graduate School of Sciences and Technology for Innovation, Yamaguchi University, 2-16-1 Tokiwadai, Ube, Yamaguchi 755-8611, Japan

[3]Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya 466-8555, Japan

SUPPLEMENTARY FIGURE/VIDEO CAPTIONS
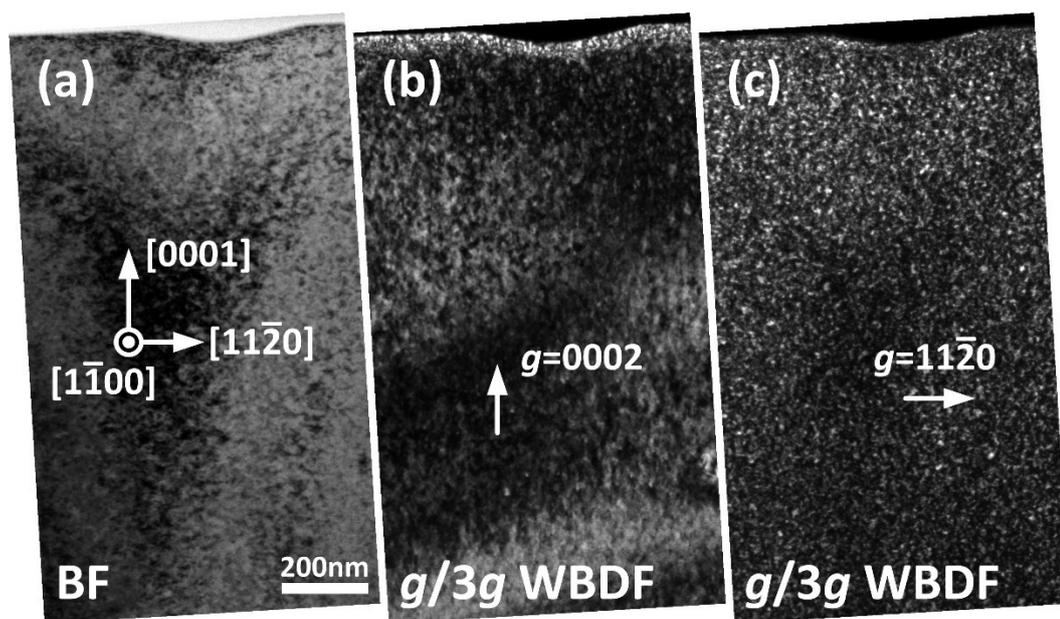
Fig. S1 TEM images of (a) BF, (b) $g/3g$ WBDF with g=0002, and (c) $g/3g$ WBDF with g=$11\bar{2}0$ as observed from an area under a dent. The results confirm that the dents are not related to dislocations.

a)Author to whom correspondence should be addressed: y_yao@jfcc.or.jp. ORCID :0000-0002-7746-4204
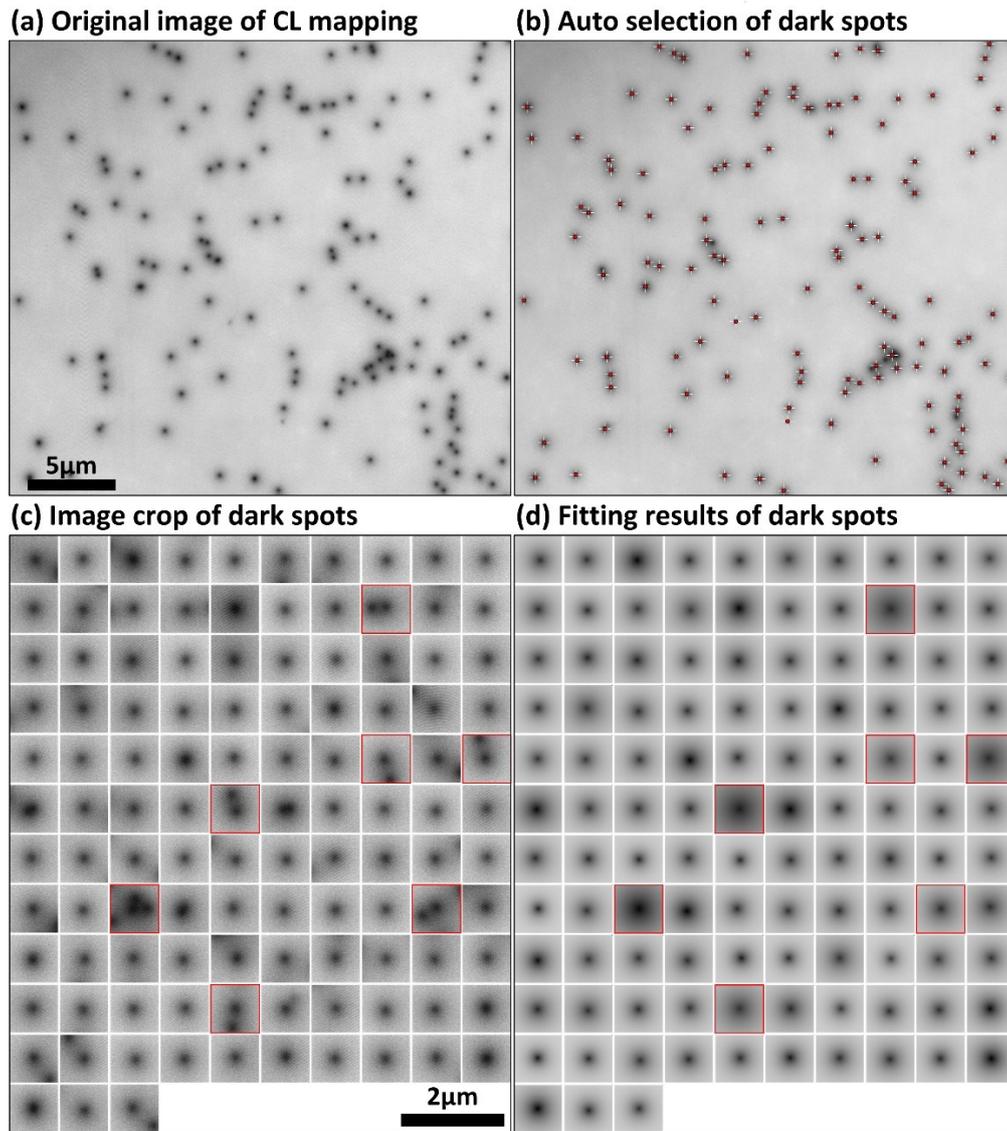
Fig. S2 An example showing the image processing for the fitting of the dark spots. (a) The original image of the panchromatic CL mapping containing more than 100 dark spots, (b) location of the dark spots using the "Find Maxima" function in the ImageJ software. The coordinates (x,y) of each dark spot are automatically recorded. (c) Automatically crop the dark spot areas to images of 80×80 pixels centered at the above coordinates, and (d) images after fitting. The red frames in (c) and (d) indicate areas containing dislocations that are spatially close. These areas can be easily excluded from the analysis as they have much greater L_d in the fitting results.

(a) Original etch pit image   **(b) Extracting pit size and coordinates**
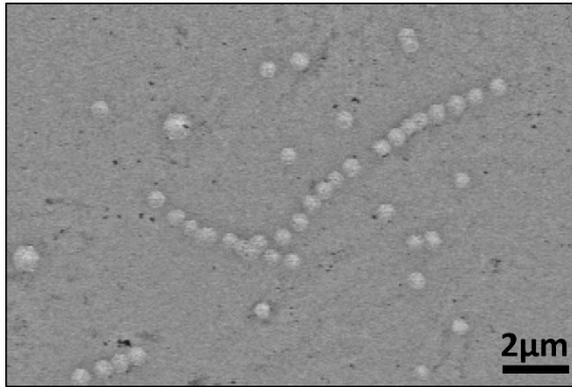
2μm
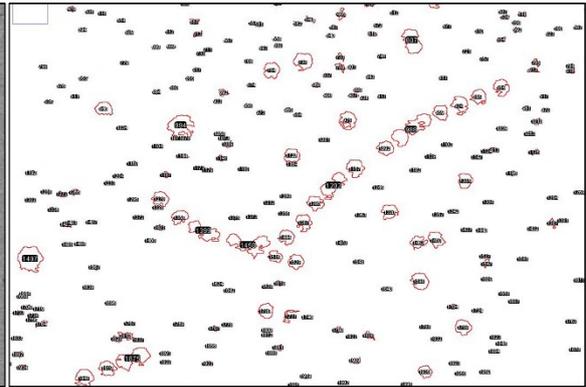
Fig. S3 An example of automatically obtaining the pit sizes and coordinates from an optical image. The area of the etch pits is distinguished using the "Analyze Particle" function in the ImageJ software with a properly set contrast threshold. Manual counting confirms that the errors are smaller than 1%.

Video Clip 3D visualization of the dislocations shown in Fig. 18.