Comment on “High-resolution electron microscopy investigations on stacking faults in $SrBi_2Ta_2O_9$ ferroelectric thin films” [Appl. Phys. Lett. 78, 973 (2001)]

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COMMENTS

Comment on "High-resolution electron microscopy investigations on stacking faults in $SrBi_2Ta_2O_9$ ferroelectric thin films" [Appl. Phys. Lett. 78, 973 (2001)]

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Recently Zhu *et al.*[1] reported a high-resolution transmission electron microscopy (HRTEM) investigation of $SrBi_2Ta_2O_9$ films grown on $Pt/TiO_2/SiO_2/Si$ substrates. Their principal finding—direct HRTEM observation of planar stacking faults consisting of extra Bi–O planes normal to the *c* axis—is not supported by the data. The lattice image, Fig. 4 in Ref. 1, contains little information, and the information that it does contain does not support the conclusions. Below, we present a Fourier analysis of their image, which quantifies the spatial periodicities present.

The imaging conditions for Fig. 4 of Ref. 1 are not well defined, and a combination of significant thickness variation across the area imaged, overlap of neighboring crystallites, and a high amorphous background mask the interpretable information. The grain was imaged along a direction parallel to the *c* planes, but not down the [110] zone axis as claimed by the authors, revealed below in the fast Fourier transform (FFT) of the image [Fig. 1(a)]. (Figure labels were removed by feathered masks prior to calculating the FFT, in order to avoid spurious contributions to the power spectrum.) The 00ℓ Bragg peaks are clearly resolved, but $hk\ell$ Bragg peaks that would indicate imaging along the [110] zone axis are absent.

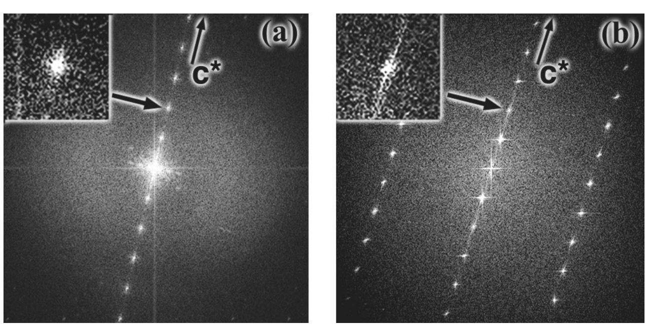

FIG. 1. (a) FFT of Fig. 4 from Ref. 1. No *c*-direction streaking or superlattice peaks that would indicate the presence of an individual or of multiple *c*-plane stacking faults are found in the image. (b) FFT of the HRTEM image in Fig. 2, showing streaking (see inset) due to the presence of a single stacking fault. Data are shown on a log scale to enhance low-level contrast; spatially nonsignificant high-*k* information has been cropped from the FFTs for presentation.

Cycling of the phase contrast, due to thickness variation, confounds straightforward interpretation. Direct observation or reliable measurement of the *c*-direction spacing of potential stacking faults in the image is not possible. The region of the crystal in the image marked specifically as containing a planar fault(s) is overlapped by a differently oriented neighboring crystal, which makes image interpretation difficult even under well-defined imaging conditions.

It is unclear whether the authors believe their image shows a single stacking fault or an array of stacking faults. Evidence for either case is, however, completely absent in the FFT. This would appear as streaking or as superlattice reflections perpendicular to the fault plane (*c* direction) for the two cases, respectively, but, this is absent, as shown in the inset of Fig. 1(a). For comparison, Fig. 1(b) shows a FFT of the HRTEM image in Fig. 2 of a single stacking fault in $SrBi_2Nb_2O_9$ from our own work.[2] The FFT was calculated from a digital image of equivalent area and resolution as the image presented by Zhu *et al.*,[1] in order to confirm that evi-

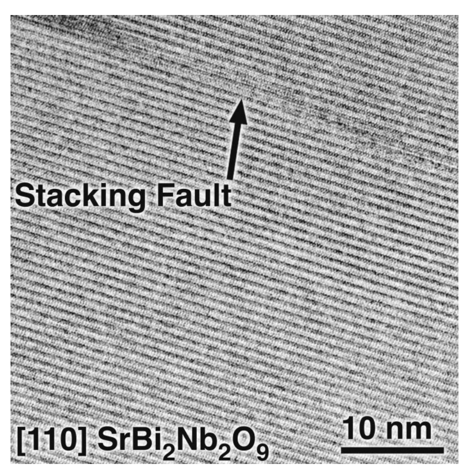

FIG. 2. [110]-zone-axis HRTEM (Ref. 2) image of a region of a $SrBi_2Nb_2O_9$ film containing a single stacking fault. The image is scaled identically to Fig. 4 of Ref. 1, and contains an equivalent sampling area and spatial information density.

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dence of even a single fault would be visible in the FFT. Streaking in the *c* direction from this single stacking fault is evident.

The ''significantly dark background'' contrast they describe could also be attributed to out-of-phase boundaries (OPBs) inclined to the viewing direction. HRTEM images of $SrBi_2Ta_2O_9$ and $SrBi_2Nb_2O_9$ generally reveal OPBs,[3–6] which typically have the same type of ''significantly dark background'' contrast, due to the overlap of two identically oriented but spatially out-of-phase crystals. Their presence does not cause *c*-direction streaking in a FFT. We observe OPBs in *all* of the $SrBi_2Ta_2O_9$ and $SrBi_2Nb_2O_9$ epitaxial and polycrystalline films we have examined by HRTEM.[2,5,6] Therefore, the authors' claim that excess bismuth incorporation (via stacking faults) leads to improved properties, is also unsubstantiated.

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