1492
doi:10.1017/S1431927616008308
Microsc. Microanal. 22 (Suppl 3), 2016

Irradiation Induced Defects in $YBa_2Cu_3O_{7-\delta}$ Coated Conductors

Huaping Sheng[1], Jianguo Wen[1], Lifen Wang[1], Dean J. Miller[1], M. Leroux[2], U. Welp[2], W.-K. Kwok[2], M. W. Rupich[3], P. M. Niraula[4], A. Kayani[4], S. Eley[5], L. Civale[5]

[1.] Center for Nanoscale Materials, Argonne National Laboratory, Argonne, IL
[2.] Materials Science Division, Argonne National Laboratory, Argonne, IL
[3.] American Superconductor Corporation, 64 Jackson Rd, Devens, MA
[4.] Department of Physics, Western Michigan University, Kalamazoo, MI
[5.] Materials Physics and Applications Division and Condensed Matter and Magnet Science, Los Alamos National Laboratory, Los Alamos, NM

The contributions of defect structures to the critical currents of $YBa_2Cu_3O_{7-\delta}$ (YBCO) superconductors have been studied extensively [1]. Coated conductors, long-length conductors produced by deposition of YBCO onto textured templates, exhibit excellent performance in part due to a complex pinning landscape produced during growth. However, it may be possible to improve upon their already impressive performance. Recently, Leroux et al. demonstrated an efficient method to enhance the in-field critical current by using oxygen irradiation to introduce additional defects into YBCO coated conductors [2]. However, the microscopic details of the defects induced by oxygen irradiation remain obscure. We used diffraction contrast and high-resolution transmission electron microscopy (TEM) to help elucidate the nature of these defects.

The introduction of defects was realized by irradiating coated conductor samples with $^{16}O^{3+}$ ions beams using a process that is compatible with manufacturing needs. Some pieces of these samples were also annealed to explore the evolution of defect structures. TEM specimens were prepared using a FIB lift out technique followed by low energy Ar ion milling to eliminate any FIB-induced defects. The defect structures were imaged by TEM using two beam diffraction contrast conditions and by high-resolution imaging.

Fig.1 shows the defect morphologies for pristine, as-irradiated, and irradiated plus annealed samples imaged under two beam diffraction contrast conditions {002} (a, c, e) and {200} (b. d. f). All samples show discrete rare-earth precipitates and some stacking faults that are produced in the growth process of these coated conductors. Aside from those pre-existing defects, the YBCO matrix of the pristine sample is relatively clean and free of small defects (a, b). After irradiation, a high density of new defects was observed, appearing as small dots or short lines. These defects appeared sharper and more linear in the {200} imaging condition compared to {002}, suggesting the possibility that they are dislocation loops. It is very likely that there are also many smaller defects produced by the irradiation, such as point defects, that are invisible to TEM. Fig. 2b shows a high-resolution image from the region marked with the dashed square in Fig. 2a. The main defects observed in this area were dislocation loops, as shown in the filtered images (c and d) in which the extra plane is visible. Upon annealing, many of the smaller point defects disappeared, while the linear defects tended to be somewhat larger (e and f compared to c and d).

Considering all of these results, we conclude that the irradiation used here is effective in introducing new defects into the pinning landscape of coated conductors. Many of the defects are small dislocation loops, but it is likely many point defects are also produced. The annihilation and merging of defects is an important part of the evolution of the defect landscape during annealing [3].

References:

[1] Dam, B., et al. *Nature* 2015, **399**(6735), 439-442.
[2] Leroux, M., et al. *Appl. Phys. Lett.* 2015, **107** (19), 192601.
[3] This work was supported as part of the Center for Emergent Superconductivity, an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, and Office of Basic Energy Sciences. Electron microscopy was performed in the Electron Microscopy Center at the Center for Nanoscale Materials, a U.S. Department of Energy Office of Science User Facility under Contract No. DE-AC02-06CH11357.

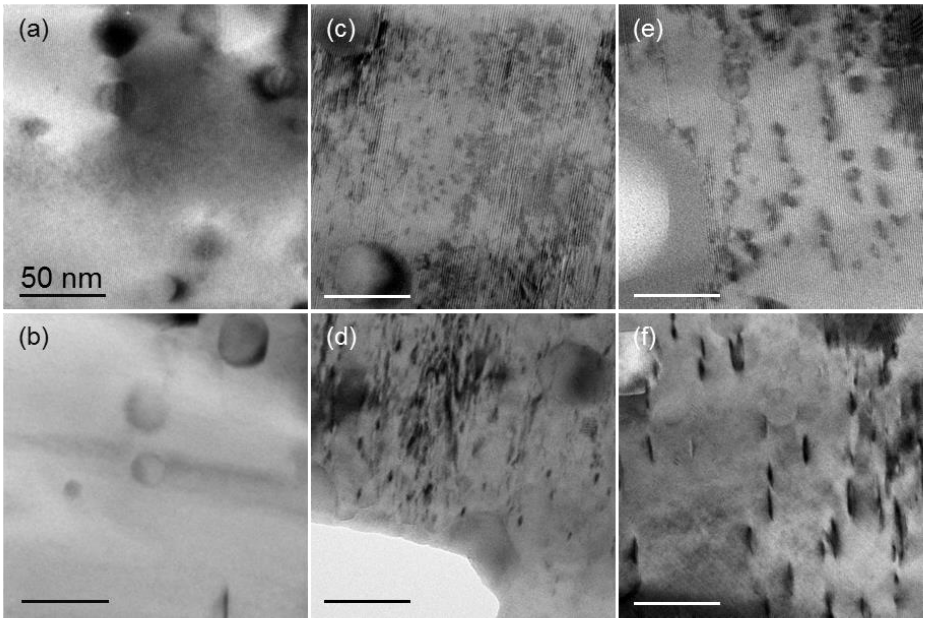

Figure 1 Diffraction contrast images showing the morphologies of the defects in pristine (a, b), as-irradiated (c, d) and irradiated plus annealed samples (e, f). (a) (c) (e), {002} two beam condition; (b) (d) (f), {200} two beam condition.

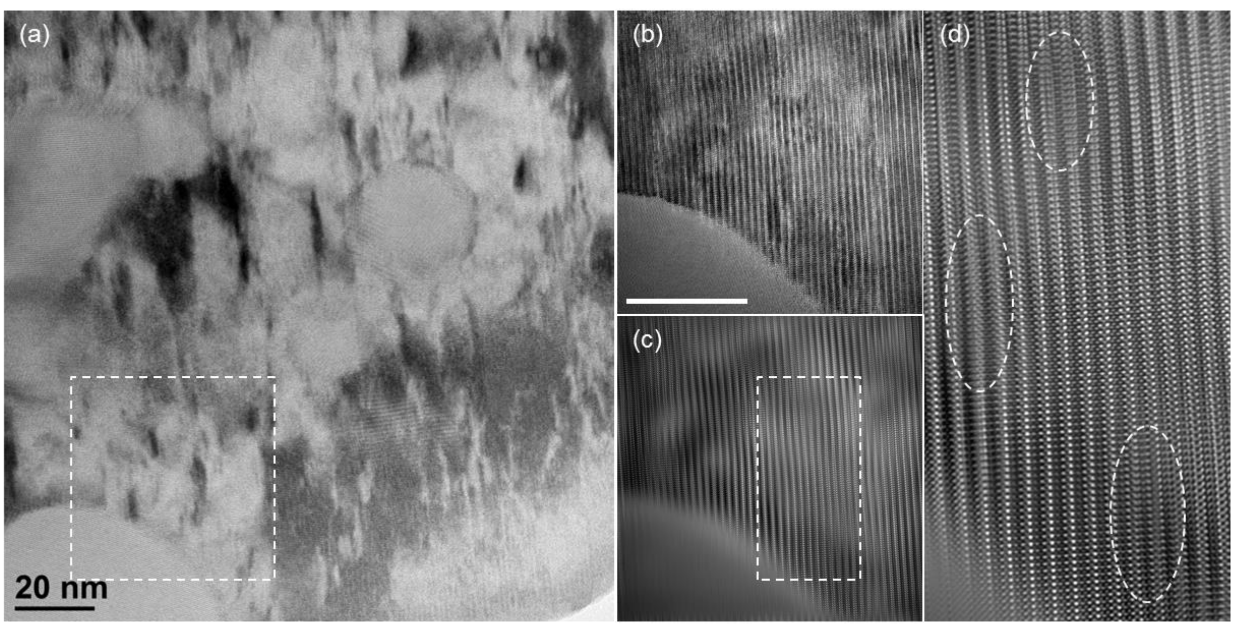

Figure 2 (a) Bright field image of the annealed sample. (b) HRTEM image taken from the dashed area in (a). (c) FFT filtered image of (b). (d) Enlarged image of the dashed area in (c). Three dislocation loops are marked with dashed ellipse.

https://doi.org/10.1017/S1431927616008308 Published online by Cambridge University Press