

## Identification of Chemical Dopants in $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ by Electron Probe Microanalyzer

Shayna M. Slicer<sup>1</sup>, Charles Q. Luo<sup>1</sup>, Zhiping Luo<sup>1</sup>, Sharon C. Yeung<sup>2</sup>, Paul J. McGinn<sup>2</sup> and Dean J. Miller<sup>3,4</sup>

<sup>1</sup>. Department of Chemistry and Physics, Fayetteville State University, Fayetteville, North Carolina, USA

<sup>2</sup>. Department of Chemical Engineering, University of Notre Dame, Notre Dame, Indiana, USA

<sup>3</sup>. Materials Science Division, Argonne National Laboratory, Argonne, Illinois, USA

<sup>4</sup>. TESCAN USA, Warrendale, PA, USA

Melt texturing of polycrystalline  $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$  (YBCO) superconductor is an effective way to enhance its critical current density ( $J_c$ ) due to the preferentially aligned platelets parallel to the **a-b** conduction plane [1]. The improvements of the flux pinning properties originate from secondary particles, refined  $\text{Y}_2\text{BaCuO}_5$  inclusions and possible substitutions the YBCO lattice [2-4]. The work aims to identify the trace level chemical dopants in the YBCO matrix using an electron probe microanalyzer (EPMA).

The experimental sample pellets were prepared by texturing from the mixture of commercial powders of YBCO with  $\text{BaCeO}_3$  and  $\text{MgO}$ . Textured samples were embedded into epoxy resin and then coated with a thin carbon layer (~20 nm). The prepared samples were analyzed in a JEOL field-emission JXA-8530F EPMA, which was equipped with a JEOL SDD X-ray energy-dispersive spectrometer (EDS), and five wavelength-dispersive spectrometers (WDSs), operated at 20 kV. The WDS spectra were recorded using the TAP crystal in channel 3, with the specimen-crystal length  $L$  from 61.5780 mm to 256.976 mm in a step size of 50  $\mu\text{m}$  and dwell time of 1 s. The collecting time of a single WDS spectrum was thus 3,906 s.

The EDS spectra of Mg-doped YBCO and YBCO samples, collected from their matrices without secondary particles, are shown in Fig. 1(a) and (b), respectively. Quantitative analyses showed that their stoichiometric compositions are close to the  $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$  compositions. However, from the EDS spectrum, as shown in Fig. 1(a), the presence of Mg, whose  $K\alpha$  line is located at 1.253 keV as indicated by an arrow [5], is not clearly delineated.

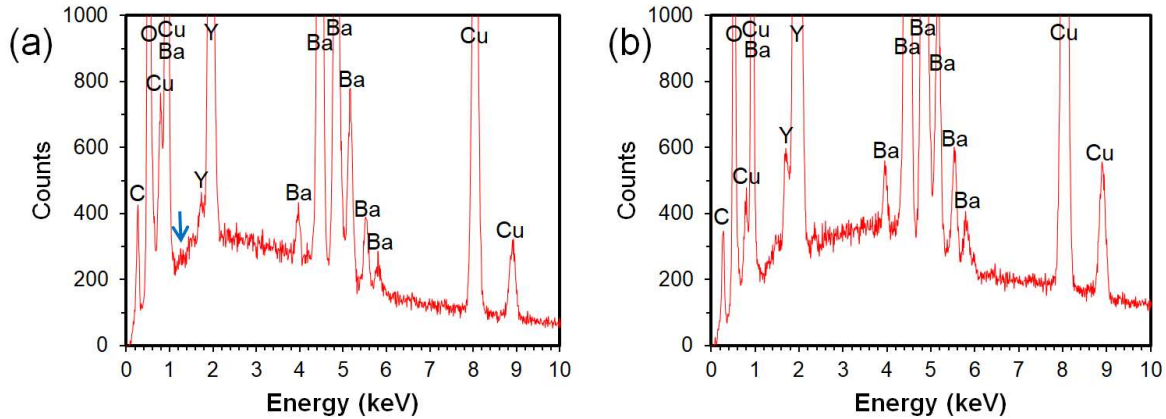
WDS was used to identify the Mg in the YBCO lattice. Since the Mg content is very low, the WDS spectra were collected using very slow scans and processed using an automatic smoothing algorithm. As shown in Fig. 2(a) from the sample of YBCO doped with Mg, a small Mg  $K\alpha$  peak is apparent at 107.510 mm. The Mg peak is well separated from Ba peaks, as shown in Fig. 2(b). In comparison, the YBCO sample does not exhibit such an Mg peak at this position, as indicated by an arrow in Fig. 2(d). Thus, we conclude Mg dopants can reside within the YBCO lattice [6].

### References:

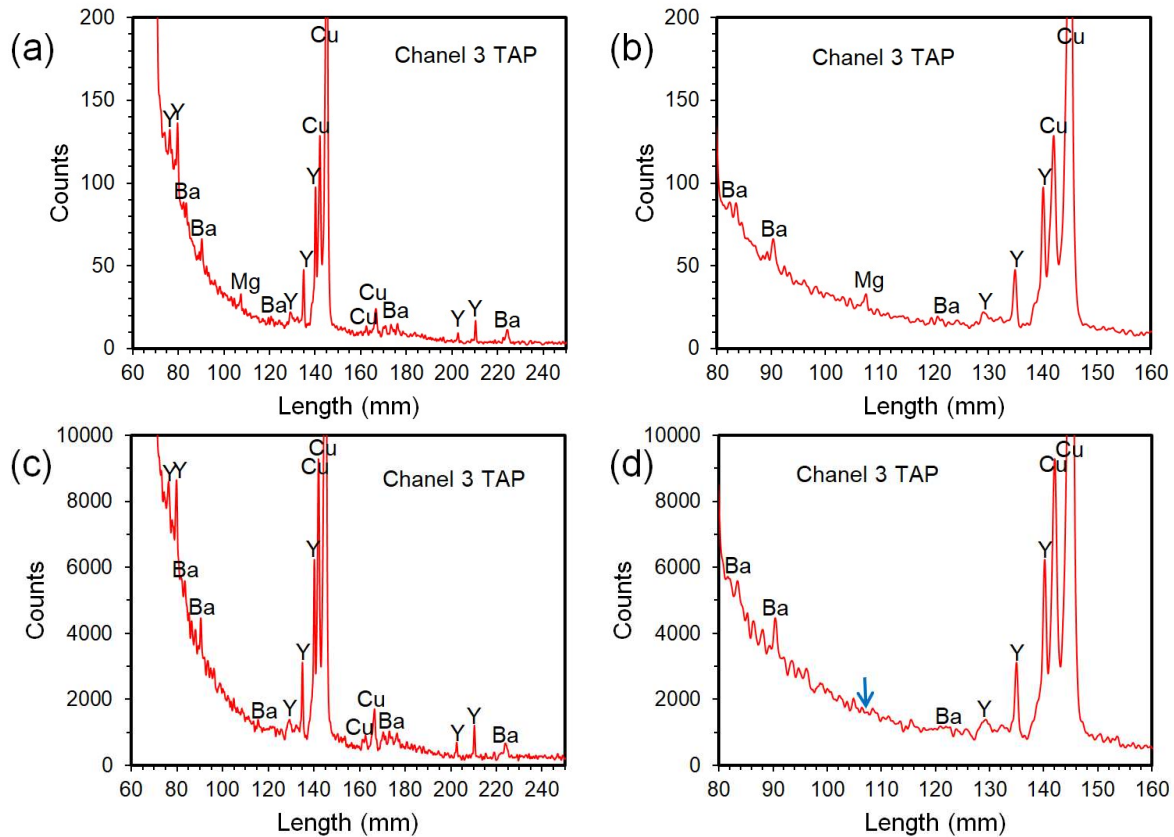
- [1] S. Jin *et al*, Appl. Phys. Lett. **52**, (1988) p. 2074.
- [2] P. J. McGinn *et al*, Appl. Phys. Lett. **71** (1997), p. 3706.
- [3] S.C. Yeung, P.J. McGinn. Physica C **356** (2001), p. 1.
- [4] M.Z. Khan *et al*, Physica C **545** (2018), p. 50.

[5] Z. Luo. A Practical Guide to Transmission Electron Microscopy, Volume II: Advanced Microscopy, (Momentum Press, New York).

[6] The authors acknowledge funding from the NSF HRD 1436120. The instrumentation at FSU was supported by DoD W911NF-09-1-0011, W911NF-14-1-0060, W911NF-15-1-0566 and NSF MRI Program DMR 1626376.



**Figure 1.** EDS spectra from YBCO with Mg (a) and YBCO (b) samples. The location of Mg is indicated by an arrow in (a) although it is not clear.



**Figure 2.** WDS spectra from YBCO doped with Mg (a) and its enlargement in (b), and from YBCO (c) and its enlargement in (d). Mg peak appears at  $L=107.510$  mm in (a) and (b); while at this position, the peak does not exist in the spectrum from YBCO, as indicated by an arrow in (d).