# The influence of laser energy density on microstructure and critical current of YGBCO and HGBCO thin film prepared by PLD

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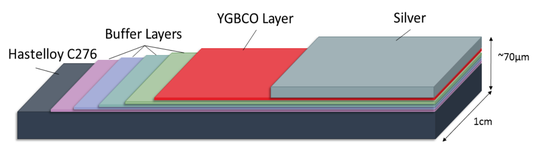
## Abstract

$Y_{0.5}Gd_{0.5}Ba_2Cu_3O_{7-\sigma}$ (YGBCO) and $Ho_{0.5}Gd_{0.5}Ba_2Cu_3O_{7-\sigma}$ (HGBCO) targets of similar density are prepared by solid-state reaction method. These targets are used to prepare superconducting thin film respectively using pulsed laser deposition (PLD). During the experiment, we alter laser energy by changing optical lens. X-Ray diffraction (XRD) is adopted to analyze the structure and texture of $RE_{0.5}Gd_{0.5}Ba_2Cu_3O_{7-\sigma}$ (RGBCO, RE=Y, Ho) thin film. Also, atomic force microscopy (AFM) and scanning electron microscopy (SEM) are used to observe the surface morphology, and superconducting current is measured in 77 K by employing standard four-probe method. The laser energy density and different doping element can affect properties of RGBCO thin film, which may be related to target particle ejection process and size of rare earth atoms.

## Motivation

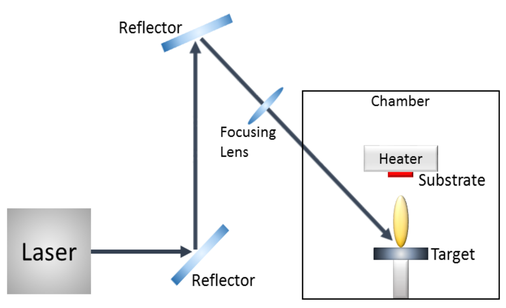
- HGBCO film exhibited better structure, surface morphology and superconducting quality than YGBCO film.
- The relationship profile between laser energy density and current is "U" shaped.
- High quality HGBCO thin film with critical current density of 1.8 MA/cm$^2$ is successively prepared.
- Targets with doping element of similar atom size to substituted atom would be helpful to optimize the property of thin film.

## Method




YGBCO films were deposited on $CeO_2/MgO/Y_2O_3/Al_2O_3$ buffered C276 tape by PLD method.

Fig.1 Basic structure of YGBCO coated conductor.




The following factors are fixed: the laser repetition frequency ; the pressure of oxygen; the distance between the target and the substrates; the substrate temperature.

Fig.2 Sketch of the pulse laser deposition system.

**Table I**

**The relationship between focus lens length and laser energy density**

| Focus Length of lens (m) | Laser Energy Density (mJ/cm$^2$/s) |
|---|---|
| 1.5 | 114 |
| 2.0 | 254 |
| 3.0 | 439 |

The difference between samples is the laser energy density and doping element.

## Conclusion

- Both of YGBCO and HGBCO thin films have c-axis oriented structures and similar surface morphology, but HGBCO layer have lower FWHM values of ϕ and ω scan, smoother surface with less particles and higher critical current.
- Under very low and very high energy density, thin film could possess nice structure and fine surface, but these properties would degrade under medium energy.
- The highest $J_c$ value appeared on the RGBCO film with good in-plane and out-of-plane texture that are strongly linked with the energy density

## Results and discussion

- **X-ray diffraction analysis**

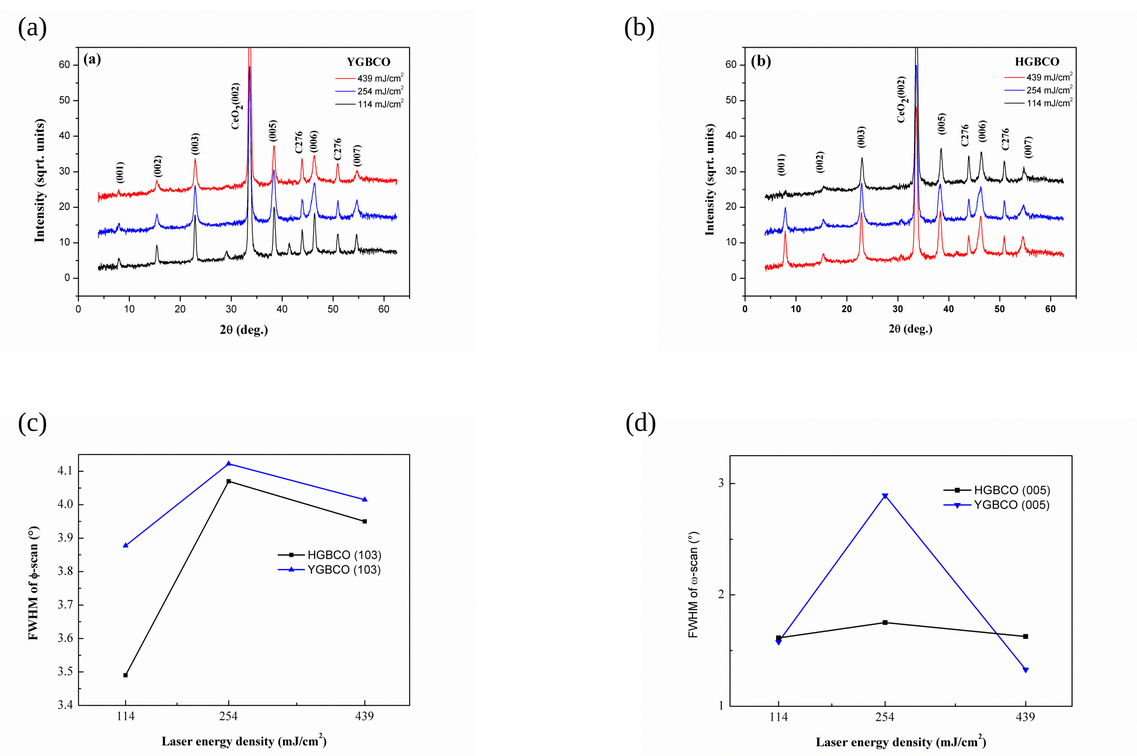



Fig.3(a)(b)θ-2θ scans of samples deposited using different targets and energy density; (c) (d)Δω, Δφ and intensity of YGBCO and HGBCO dependence of energy density.

- **Surface morphology of samples**

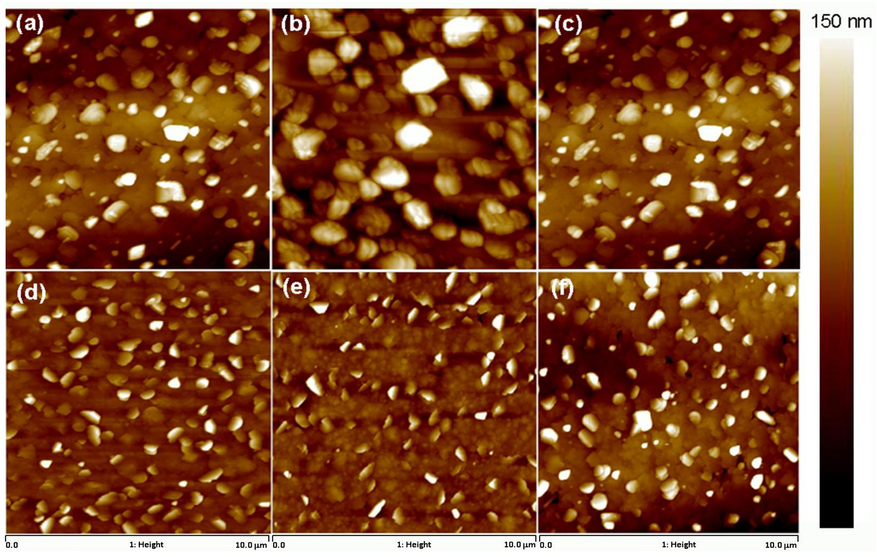



Fig.4 AFM images of sample prepared by different targets and energy density. (a)(b)(c) for YGBCO and (d)(e)(f) for HGBCO. From (a) to (c) and (d) to (f), the energy density increases from 114 mJ/cm$^2$, 254 mJ/cm$^2$ to 439 mJ/cm$^2$

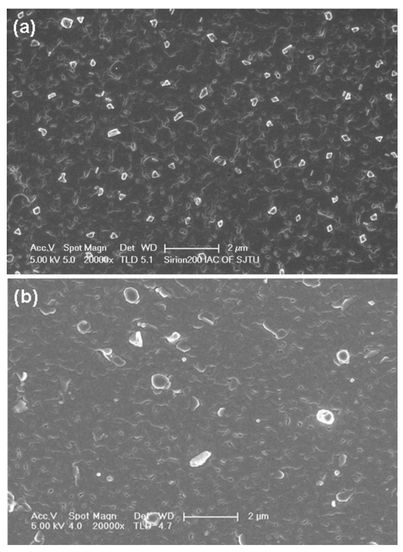



Fig.5 SEM images of typical YGBCO sample (a) and HGBCO sample (b) deposited under optimized condition.

- **Critical current measurements**

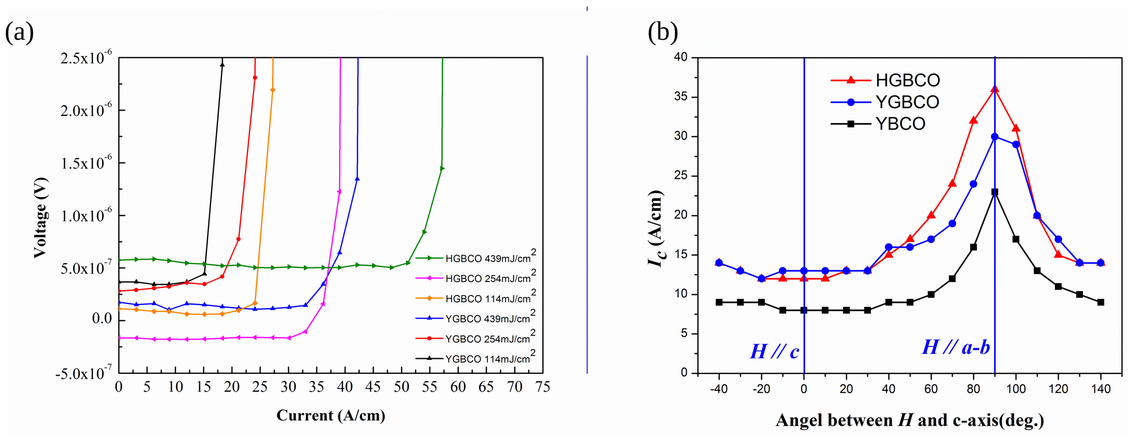



Fig.6 (a) End-to-end I–V characteristics of superconducting films at 77 K and 0 T using standard four-pole method.
(b) The relationship between critical current and the angel at 77 K and 2 T, all samples deposited with the energy density of 439 mJ/cm$^2$

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