Influence of annealing in argon on microstructural and superconducting properties of Al doped YBCO bulks

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Košice - 24.06.2009
Samples preparation:

Materials Physics Laboratory

Magnetization measurements:

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Atomic Institute of the AU in Vienna

X – ray measurements:

Institute of Materials Research in Košice,
RNDr. Viktor Kavečanský, CSc.
Substitution the Cu atoms in the CuO chains of $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ lattice

Tetragonal structure ($\delta > 0.5$)     Orthorhombic structure ($\delta \leq 0.5$)

**Al**  G.Lacayo et al., *Physica C* 192 (1992) 207  

**Fe**  Y.Xu et al., *Phys. Rev. B* 39 (1989) 6667  

H.Renevier et al., *Physica C* 202 (1994) 143
Preparation of Al – doped YBCO bulk superconductors

Samples:
$YBa_2Cu_3O_7 + 0.25Y_2O_3 + 0.5 \text{ wt. } \% \ CeO_2 + Al_2O_3$
$YBa_2(Cu_{3-x}Al_x)O_7, (x = 0.0025, 0.005, 0.02, 0.05)$

TSMG:
pellets $\phi = 20 \text{ mm}$, Sm 123 seeds, chamber furnace in air

The samples were cut from a – growth sectors of the bulks at the distance of 1 mm from the seed
1) **Standard oxygenation (SO)**
The samples were heated to 800 °C in flowing O$_2$ atmosphere and kept there for 2 hrs, then cooled to 400 °C and held at this temperature for 240 hrs, then cooled down to room temperature.

2) **Annealing in flowing argon**
The samples were heated to 800 °C in flowing Ar atmosphere and annealed there for 2 hrs, then cooled to room temperature. After annealing in Ar the samples were heated to 400 °C in flowing O$_2$ atmosphere and held there for 240 hrs, then cooled down to room temperature.
**Magnetization measurements**

VSM with magnetic fields of up to 5 Tesla at a constant sweep rate of 0.25 T/min, applied magnetic field parallel to the c-axis

$T_c$ measured at applied magnetic field of 2 mT

**Bean model**

$J_c(B) = \frac{m_i(B)}{\Omega} \frac{2}{b(1 - b/3a)}$

$m_i = \frac{1}{2}(m_+ - m_-)$, $\Omega = a \times b \times c$, $a \geq b$

Checking samples for homogeneity by trapped field scanning
Critical current densities

$x = 0.0025$ (SO), $x = 0.05$ (Ar)

$J_c \approx 1.8 \cdot 10^4 \text{ A/cm}^2$, $B = 1 \text{ T}$
The rise of the transition width, $\Delta T_c$, with increasing Al content for SO samples may reflect microscopic inhomogeneities entire the samples.

Influence of substituent on carrier concentration and $T_c$

According to the BCS theory: $T_c \approx \exp(-1/NV)$

$N$ – carrier concentration,
$V$ – volume fraction of the crystal lattice

H. Renevier et al., *Physica C* 220 (1994) 143
Twins in undoped YBCO bulks
Twinning structures in $\text{YBa}_2(\text{Cu}_{1-x}\text{Al}_x)_3\text{O}_{7-\delta}$ bulks after SO

$x = 0.005$

$x = 0.05$
Twinning structures in $\text{YBa}_2(\text{Cu}_{1-x}\text{Al}_x)_3\text{O}_{7-\delta}$ bulks after argon annealing

$x = 0.005$

$x = 0.05$
Influence of the Al atoms on twinning formation

Standard oxygenation

Annealing in argon

- Cu
- $O_2$
- Al
- $O_2(1/2,0,0)$
Influence of the Al atoms on twinning formation

Standard oxygenation

- $Cu$
- $O_2$
- $Al$
- $O_2(1/2,0,0)$

Extra oxygen
Influence of the Al atoms on twinning formation

Extra oxygen

Annealing in argon

- **Cu**
- **O**
- **Al**
- **O**

(O_2) (1/2,0,0)
$X$ – ray diffraction studies for $YBa_2(Cu_{1-x}Al_x)_3O_{7-\delta}$
Conclusions

- **Al doping and oxygenation procedure (SO, Ar) influence on:**
  - The transition temperature, $T_c$, and transition width, $\Delta T_c$
  - Orthorhombicity
  - Twin spacing
  - Pinning behaviour

- **It is supposed that these observed changes are caused by different Al distribution in the Y123 lattice:**
  - random distribution of the Al atoms after SO
  - clustering after annealing in Ar
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