第15卷 第2,3期 广 东 有 色 金 属 学 报 Vol. 15, No. 2,3
2005年9月 JOURNAL OF GUANGDONG NON-FERROUS METALS Sep 2005

Article ID: 1003-7837(2005)02,03-0205-05

Influence of the substrate thickness on texture of tape*

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Abstract: Fabrication of a strong cube texture Ni substrate through thermomechanical process is reported by ORNL research group. Decreasing the substrate thickness, the engineering critical current density will be improved. Rolled substrates are electropolished to the final thichness of 100, 80, 50, 40, and 20 μm, respectively. Electropolished substrates are recrystallized at temperatures between 800-1000℃ and in a mixed atmosphere of 4% H_2 in 99.99% purity Ar. Orientation mappings of recrystallizated tapes are conducted through an EBSD system mounted on a LEO-1450 SEM. The influence of the substrate thickness on texture of the tape is studied in this paper. Results show that with the decrease of substrate thickness, the texture of the tapes with the same recrystallization process is more and more closed to the exact position of cube orientation.

Key words: substrate thickness; orientation mapping; coated conductor

CLC number: TM26 **Document code**: A

1 Introduction

Three different approaches are applied to increase the engineering current densuity of the coated conductor. The first is to enhance the critical current density of the YBCO film[1-3]. The second is to increase the thichness of the YBCO film[1-3]. The third is to reduce the thickness of the metallic tape[4]. For the RABiTS technique the metallic tape has to provide the cube texture for the epitaxial film and sufficient strength. Therefore it is necessary to increase the tape strength in order to reduce its thickness without losing mechanical performance. Alloy Ni tapes, such as Ni-W, Ni-Cr, Ni-V, Ni-Al and Ni-Cu etc, is chosen to meet the aim described above[4-9]. Effect of the grain number and width of substrate on critical current density was researched by Goyal, etc[10]. For 1 cm width substrate, if the grain size is too large(>100 μm), the critical current density is deteriorated. It is necessary to reduce the grain size of the matalic tape, Ni alloy is chosen to accomplish the need. In this paper the main effort is focused on influence of substrates thickness on microstructure and grain size of cube-texture Ni tape.

Received date: 2005-08-18

* **Foundation item**: Project supported by National High Technonogy Research and Development Program(2002AA306211, 2004AA306130)

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2 Experimental

Ni ingot is prepared by melting the elements having a purity of about 99.999% in an vaccum furnace. Ni plate, gotten by hot forging and hot rolling treatment, is cold rolling with several passes down to the final thickness of 120 μm. Electropolishing is chosen to improve the surface quality of the tape and reduce the thickness of the tape in a mixed solution of H_3PO_4, $C_3H_8O_3$ and a little additive. Electropolished substrates with the final thickness of 100 μm, 80 μm, 50 μm, 40 μm, and 20 μm, respectively, are recrystallizated at temperatures between 800—1000℃ either in a mixed atmosphere of 4% H_2 in 99.99% purity Ar. Recrystallizated grain size of substrates are measured using LEO—1450 SEM(scanning electron mcroscopy). Orientation mappings of recrystallizated tapes are conducted through an EBSD system mounted on a LEO—1450 SEM.

3 Results and analysis

3.1 Results

Relationship of average recrystallizated grain size and substrate thickness is indicated in Fig. 1. The results show that when the substrate thickness is 120—60 μm, with reducing the substrate thickness, average recrystallizated grain size decreases. When the substrate thickness is less than 60 μm, with decreasing the substrate thickness, average recrystallizated grain size increases. The minimum size of the average recrystallizated grains is 70 μm corresponded to substrate with 60 μm thickness.

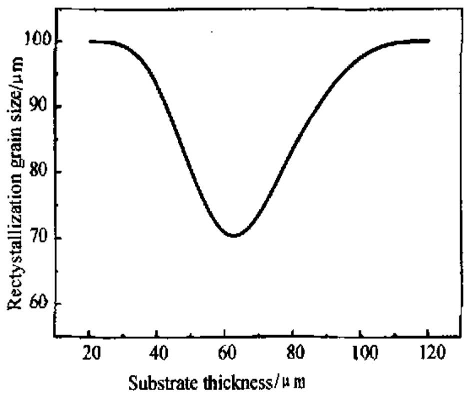

Fig. 1 Curves of substrate thickness vs recrystallization grain size

Orientation mappings of substrates with different thickness are revealed in Fig. 2. Red grains show cube orientation grain. Color of grains is heavier, orientation of those grains is closer to the exact position of the cube orientation. With decreasing the substrate thickness, the cube texture of the tapes with the same recrystallization process is more and more close to the exact position of the cube orientation.

3.2 Analysis

In three dimension samples, drive force for grain growth mainly originate from grain boundary energy. During grain growth, with average grain size increasing, total area of grain boundary decrease, in order to reduce free energy, which provide drive force for the grain growth[11].

When average grain size is close to the substrate thickness, almost grains are exposed on the metallic tape surface, at this time, balanceing grain boundary energy and surface energy on the substrate surface. Their balance would prevent grain growth. The grain boundary on the tape surface would tend to smooth, so grain curvature radius perpendicular to the substrate surface is infinite. The drive force for grain boundary move(P)is given by[11]:

$$P=\gamma\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}\right) \tag{1}$$

where γ is free energy of grain boundary per unit area, ρ_1 and ρ_2 are grain curvature radius. From equation (1), with increasing the grain curvature radius, decreasing the drive force for the grain boundary mobility.

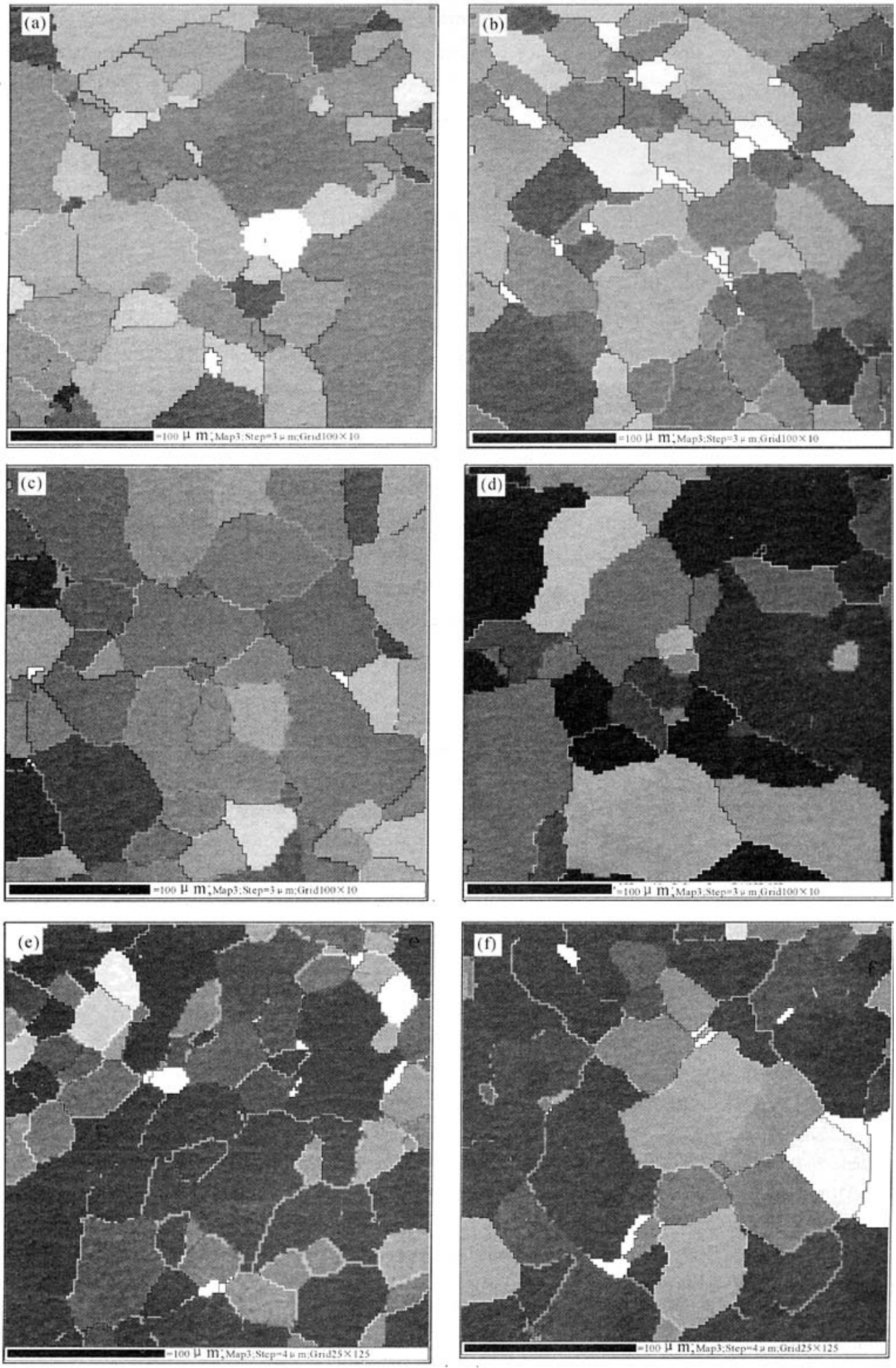

Fig. 2 Orientation mappings of substrates with 120μm(a), 100μm(b), 80μm(c), 50μm (d), 40μm(e), and 20μm(f)

On the other hand, surface thermal groovings are formed on the tape surface in recrystallization, due to the balance of the grains boundaries and the surface tension of the metallic tape. These thermal groovings prevent the grain boundary mobility. Two reasons described above can prevent the grain growth with exposed on the tape surface. The average grain size$\bar{R}_{\lim}$ can even solved analytically[11], giving:

$$\bar{R}_{\lim}=\frac{3\gamma_s}{10\gamma_b}d \tag{2}$$

where d is substrate thickness, γ_s and γ_b are surface energy and grain boundary, respectively. For high pure metal, γ_s is 2—3 times larger than γ_b. From equation (2), $\bar{R}_{\lim}$ is close to d, for pure metal, which is consistent with experiment results that when the substrate thickness is over 60 μm, with reducing the substrate thickness, average recrystallizated grain size decrease and approximate to the substrate thickness.

When the substrate thickness is less than 60 μm, as decreasing the substrate thickness, influence of the surface on the recrystallizated grains growth is much higher than grain boundary, and the surface energy would became the main drive force for the grain growth. The surface energy of {111} planes and {100} planes are minimum in F. C. C. metals. The sharp cube texture is formed during the recrystallizated(in Fig. 2), (100) planes are lain on the substrate surface. The planes exposed on the tape surface off (100) planes are further (grains with lighter color in Fig. 2), the surface energy of grains are higher. during the grain growth caused by the surface energy, the grains with planes close to (100) planes grow, and those with planes off (100) planes vanish. This reason described above explain when the substrate thickness is less than 60 μm, with descreasing the substrate thickness, the recrystallizated grains are closer to the exact position of the cube orientation(color of grains is heavier) and the recrystallizated grain size is 3—4 times larger than the substrate thickness.

4 Conclusions

When the substrate thickness is 120—60 μm, the drive force for the grain growth is provided by the reducing of the interface energy, as decreasing the substrate thickness, average recrystallizated grain size reduce. When the substrate thickness is less than 60 μm, the drive force for the grain growth is supplied by the reducing of the surface energy, with decreasing the substrate thickness, average recrystallizated grain size increase, and the cube texture of the metallic tape is more and more close to the exact position of cube orientation.

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