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RECRYSTALLIZATION TEXTURE FORMATION IN AN ULTRA-LOW C TI-ADDED STEEL WITH 1.5% SI

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1. INTRODUCTION

The mechanism for the recrystallization texture formation based on the orientated nucleation and selective growth theory has been widely accepted. Recently a nucleation mechanism through twinning has been proposed for the dynamic recrystallization of Al single crystals /1/. The authors found that ultra-low C Ti-added steels with 1.5% Si showed a very sharp so called α -fiber cold rolling texture (<110>//RD) and a very sharp near {554}<225> recrystallization texture at the center layer. The subgrain coalescence mechanism does not seem to be dominant, because there are very few common orientation components between cold rolling and recrystallization textures. Then with a particular emphasis on a nucleation mechanism through twinning, the recrystallization texture formation in ultra-low C Ti-added steels with 1.5% Si is discussed.

2. EXPERIMENTAL PROCEDURE

Ultra-low C Ti-added steels containing 0% and 1.5% Si, as given in Table 1, were melted in vacuum. The 20 mm thick slabs were soaked at 1573 K for 1 h, air-cooled to 1323 K, and then hot rolled to 4 mm thick above 1223 K.

After hot rolling the hot bands were immediately quenched into water. They were thinned to 2 mm thick by machining and cold rolled to 0.5 mm by 75% reduction. Subsequently they were annealed at 1123 K for 3 min in a salt bath. X-ray texture analysis was conducted for the central layers of the hot bands, cold rolled and annealed steels.

Table 1 Chemical composition of steels (in weight pct.)

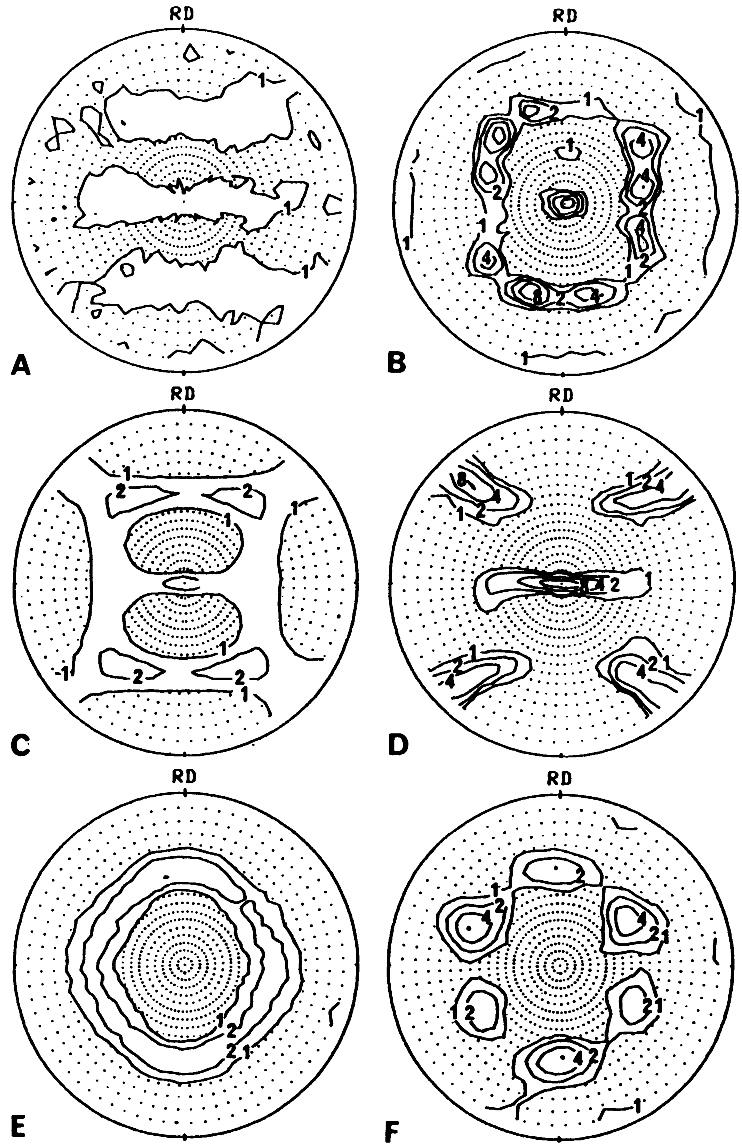
No.	C	Si	Mn	P	S	Al	N	Ti
A	0.0005	<0.01	0.05	0.001	0.001	0.059	0.0033	0.078
B	0.0010	1.52	0.05	0.001	0.001	0.019	0.0027	0.071

3. EXPERIMENTAL RESULTS

Figure 1 summarizes the {200} pole figures of the hot-rolled, cold-rolled and annealed specimens for both 0% and 1.5% Si steels. Although the hot rolling texture of a 0% Si steel was random, that of a 1.5% Si steel was a sharp ND//<100> and <111> texture, which was predicted from the full constrained Taylor model. The texture components developed by cold rolling in 0.0%Si steel was both α - and γ - (<111>//ND) fibers, which are known as normal cold rolling texture of low C steels. While in the case of 1.5%Si steel was a only α -fiber. Latter can be arisen from the hot band structure with elongated grains of 1.5%Si steel, as calculated with the relaxed Taylor model by Van Houtte /2/. Also there were a large difference between the annealing of them. Those were the full γ - fiber and a near {554}<$2\bar{2}5$> textures, respectively.

4. DISCUSSION

It is well established that a near {554}<$2\bar{2}5$> component has the orientation relationship {211}<$0\bar{1}1$> in α - fiber in the cold rolling texture by 35° rotation around <110> near normal direction. This orientation relationship results from high angle boundary migration during the grain growth. However the nucleation mechanism of {554}<$2\bar{2}5$> is still unclear. Figure 3 shows the {200} pole figure, on which the areas with the intensity higher than 1.5 times of random level in both the cold rolling and



A,C,E: 0.0%Si steel
B,D,F: 1.5%Si steel

A,B: Hot band
C,D: Cold rolled sheet
E,F: Annealed sheet

Fig.1 {200} pole figure of hot bands, cold rolled sheets and annealed sheets of ulra-low C Ti-added steels containing 0.0% and 1.5% Si.

recrystallization textures are depicted. Because of the lack of common components between both textures, the subgrain coalescence dose not seem to be dominant in the present case. Thus in the following discussion, a new nucleation mechanism will be discussed in order to explain the present result.

Recently it was reported that nucleation occurs through multiple twinning in Al single crystals. In steels with the increase in Si and the decrese in C, the stacking foukt energy decreses. Therefore in 1.5% Si Ti-added steel, the nucleation through twining can be expected. Then with a particular emphasis on a nucleation mechanism through twinning, an analysis was done as in Fig.2.

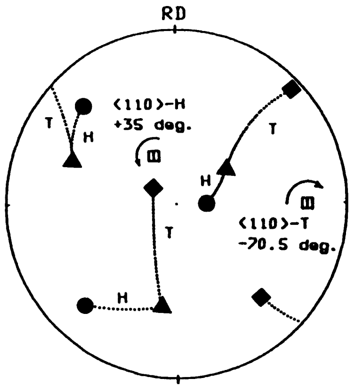
(1) One major component in the α -fiber was chosen, e.g. (112)[1$\bar{1}$0], (114)[1$\bar{1}$0] and (001)[1$\bar{1}$0], as the deformed matrix where nuclei grow (Orientations G).

(2) Orientations in the 35° rotation relation about <110> axes with orientations G were calculated (Orientation R).

(3) Twin orientations of Orientation R were calculated and checked whether they are in the α-fiber (Orientation T).

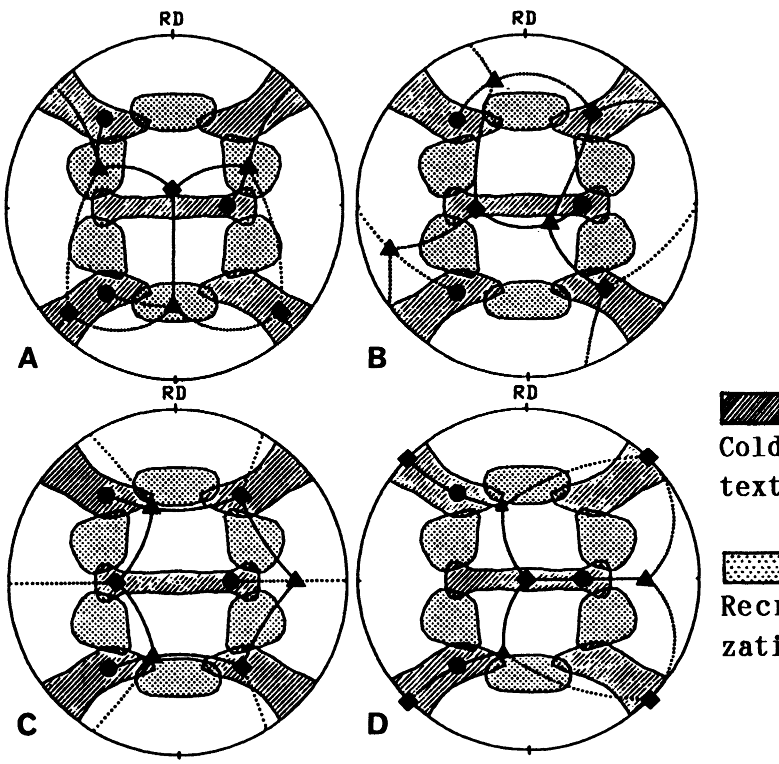
As to (112)[1$\bar{1}$0], only 4 combinations can give orientation T in the α -fiber, as shown in Table 2 and Fig.3. There are three different rotation paths from orientation T to orientation R, because three different twin systems with the same twinning direction give the same Orientation R. However in the present result only one of them, that is A in Fig.4, seems to have occurred. Therefore another condition is required.

To consider the activation stress of every twin system, Schmid's factors were calculated for the Tucker stress state, that is, the compressive stress in normal direction and the tensile stress in rolling direction, as shown in Table 2. Then only two combinations are expected to occur. The combination B gives {5,3,16}<12,$\bar{4}$,$\bar{3}$> recrystallization component. In the case of combination B, the orientation T and the orientation G are mirror-symmetric to each other. Therefore the growth probability should be much smaller than that of the combination A.



● : Orientation G
◆ : Orientation T
▲ : Orientation R

Fig.2 Schematic illustration of orientation change through oriented nucleation by twinning and selective growth by high-angle boundary migration.



: Cold rolling texture

: Recrystallization texture

Fig.3 Schematic illustration of nucleation through twinning in one major component in α -fiber cold rolling texture and growth through high-angle boundary migration into (112)[1$\bar{1}$0] cold rolled matrix on co-plotted {200} pole figure of cold rolling and recrystallization texture regions with 1.5 times random. (A-D coresponding to A-D in table 2)

Table 2. Calculation results for $(112)[1\bar{1}0]$.

	Orientation T	Twin system	Schmid's factor	Orientation R
		$(2\bar{1}\bar{1})[111]$	-0.754	
A	$(71\bar{1})[2\bar{7}7]$	$(\bar{1}2\bar{1})[111]$	0.383	$(545)[2\bar{5}2]$
	near$(100)[0\bar{1}1]$	$(\bar{1}\bar{1}2)[111]$	0.372	
		$(\bar{2}\bar{1}\bar{1})[\bar{1}11]$	0.112	
B	$(\bar{1}\bar{1}2)[1\bar{1}0]$	$(12\bar{1})[\bar{1}11]$	0.675	$(5,3,16)[12,\bar{4},\bar{3}]$
		$(1\bar{1}2)[\bar{1}11]$	-0.787	
		$(2\bar{1}\bar{1})[111]$	-0.252	
C	$(533)[0\bar{1}1]$	$(\bar{1}2\bar{1})[111]$	0.126	$(12,2,9)[3\bar{9}\bar{2}]$
	near$(211)[0\bar{1}1]$	$(\bar{1}\bar{1}2)[111]$	0.126	
		$(2\bar{1}1)[11\bar{1}]$	0.236	
D	$(010)[101]$	$(\bar{1}21)[11\bar{1}]$	-0.471	$(12,2,9)[3\bar{9}\bar{2}]$
		$(\bar{1}\bar{1}\bar{2})[11\bar{1}]$	0.236	

5. CONCLUSION

Ultra-low C Ti-added steels with 1.5% Si were hot rolled in ferritic region and water-quenched immediately. A 1.5% Si steels showed a sharp α -fiber texture after cold rolling and a near $\{554\}\langle 2\bar{2}5\rangle$ texture after subsequent annealing.

The $\{554\}\langle 2\bar{2}5\rangle$ component has the 35° rotation relationship around <110> axes near ND from the near {211} $\langle 0\bar{1}1\rangle$ cold rolling texture component. However the lack of common components between cold rolling and recrystallization textures suggests that the subgrain coalescence was not the dominant process for the texture formation. Then a new mechanism for recrystallization texture formation was discussed by introducing a new nucleation model through twinning in the deformed matrix. It is concluded that sharp $\{554\}\langle 2\bar{2}5\rangle$ recrystallization texture component is nucleated by twinning which occurs in near $\{100\}\langle 0\bar{1}1\rangle$ deformed matrix and grows into near $\{211\}\langle 0\bar{1}1\rangle$ deformed matrix by high angle boundary migration.

References

/1/ G.Gottstein et al.: Met.Sci., 13, p223 (1979)
/2/ P.Van Houtte : Proc. ICOTOM-7, p7, Netherlands Soc. for Mat. Sci., Noordwijkerhout (1984)