“叠轧及再结晶高纯 Al 中的{111}/{111}近奇异晶界”拓展补充材料

王星宇 [1] 王卫国 [1,2] Gregory S Rohrer [3] 陈 松 [1,2] 林 燕 [1,2] 喻志阳 [4] 周邦新 [5]

1 福建理工大学 晶界工程研究所 福州 350118

2 福建理工大学 材料科学与工程学院 福州 350118

3 Department of Materials Science and Engineering, Carnegie Mellon University, Pittsburgh, PA15213-3890, USA

4 福州大学 化学学院 福州 350108

5 上海大学 材料研究所 上海 200072

Supplemental Materials for

{111}/{111} Near Singular Boundaries in a High Purity Aluminum Processed by Accumulative Roll-Bonding Followed by Recrystallization Annealing

WANG Xingyu [1], WANG Weiguo [1,2], Gregory S Rohrer [3], CHEN Song [1,2], LIN Yan [1,2], YU Zhiyang [4], ZHOU Bangxin [5]

1 School of Materials Science and Technology, Fujian University of Technology, Fuzhou 350118, China

2 Institute of Grain Boundary Engineering, Fujian University of Technology, Fuzhou 350118, China

3 Department of Materials Science and Engineering, Carnegie Mellon University, Pittsburgh, PA15213-3890,USA

4 School of Chemistry, Fuzhou University, Fuzhou 350108, China

5 Materials Institute, Shanghai University, Shanghai 200072, China

表 T1 样品 A 和样品 B 中以 8 个低 Miller 指数晶轴为旋转轴的晶界数量及其比例统计

Table T1 Grain boundary statistics after-partitioning according to the eight low Miller index rotation axes in the sample A and sample B

Grain boundary	Sample A			Sample B		
	BN	LF / %	NF / %	BN	LF / %	NF / %
<001>	376	0.65	0.65	561	0.90	0.91
<011>	2851	4.74	4.94	3550	5.69	5.79
<012>	2249	3.82	3.90	3875	6.25	6.32
<013>	1912	3.29	3.32	2990	4.78	4.87
<111>	8848	16.15	15.34	8460	14.55	13.79
<112>	6264	10.71	10.86	7137	11.44	11.64
<113>	2383	4.01	4.13	3969	6.37	6.47
<122>	17508	30.44	30.36	13341	21.79	21.75

Note: BN—grain boundary number，LF—length fraction, NF—number fraction

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作者简介 王星宇，男，2000 年生，硕士生

通讯作者 王卫国，wang_weiguo@vip.163.com，主要从事金属和无机非金属材料晶界工程研究

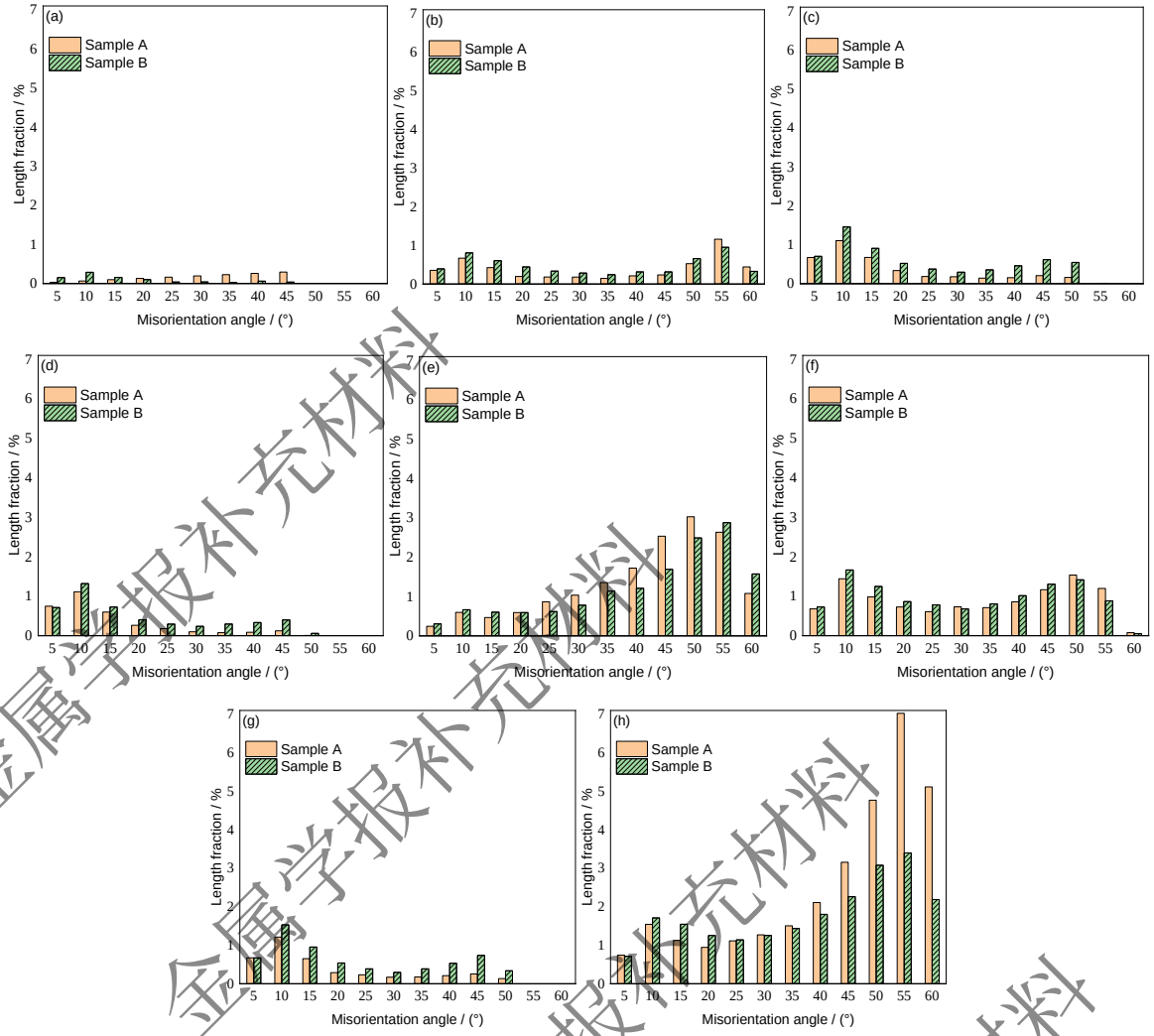

图 F1 样品 A 和样品 B 固定旋转轴晶界取向差分布图

Fig.F1 Misorientation distributions of grain boundaries with specific rotation axis for sample A and sample B

(a) rotation around <001> (b) rotation around <011 > (c) rotation around <012>

(d) rotation around <013> (e) rotation around <111> (f) rotation around <112>

(g) rotation around <113> (h) rotation around <122>

表 T2 样品 A 和样品 B 大角度晶界中的{111}/{111}-NSB 定量统计

Table T2 Statistics of the {111}/{111}-NSBs within the HAGB in sample A and sample B

Sample	Misorientation *[u v w]/θ*	P_i / %	M_i	W_i / °	F_i / %	$F=\sum F_i$ / %
A	<111>/15°	0.47	1.88	1.46	0.25	8.23
	<111>/20°	0.59	1.34	2.00	0.30	
	<111>/30°	1.03	2.02	2.26	0.54	
	<111>/35°	1.36	1.56	2.20	0.70	
	<111>/45°	2.53	1.80	2.23	1.32	
	<111>/50°	3.03	1.68	2.08	1.58	
	<111>/55°	2.63	1.38	2.09	1.36	
	<111>/60°	1.08	1.49	2.22	0.56	
	<112>/20°	0.73	1.21	1.95	0.37	
	<122>/20°	0.95	1.22	2.31	0.48	
	<122>/35°	1.50	1.49	2.39	0.77	
B	<111>/15°	0.60	3.10	1.90	0.33	11.96
	<111>/25°	0.62	2.32	2.00	0.33	
	<111>/30°	0.78	2.04	2.25	0.41	
	<111>/35°	1.14	1.12	2.00	0.58	
	<111>/40°	1.21	1.87	2.47	0.63	
	<111>/45°	1.69	1.44	2.16	0.87	
	<111>/50°	2.49	1.81	2.06	1.30	
	<111>/55°	2.88	2.13	2.32	1.51	
	<111>/60°	1.57	2.78	2.27	0.85	
	<112>/15°	1.25	1.69	2.38	0.64	
	<112>/20°	0.86	1.28	2.43	0.44	
	<112>/30°	0.68	1.64	1.72	0.36	
	<122>/15°	1.55	1.51	2.20	0.80	
	<122>/20°	1.14	1.77	1.84	0.60	
	<122>/30°	1.25	1.38	2.05	0.65	
	<122>/35°	1.44	1.30	2.15	0.74	
	<122>/40°	1.80	1.20	2.13	0.92	

Note: *[uvw]*—rotation axis; *θ*—rotation angle; *i*—the *i*th group grain boundaries with a given misorientaion; P_i—length fraction of the *i*th group grain boundaries; M_i—multipes of random distribution; W_i—full width at half maximum of weighted Gaussian misorientation distribution; F_i—length fraction of {111}/{111}-NSB from the *i*th group grain boundaries

表 T3 样品 A 和样品 B 小角度晶界(LAGB)中的{111}/{111}-NSB 定量统计

Table T3 Statistics of the {111}/{111}-NSBs within the LAGB in sample A and sample B

Sample	Misorientation *[u v w]/θ*	P_i / %	M_i	W_i / (°)	F_i / %	$F = \sum F_i$ / %
A	<013>/5°	0.75	1.66	2.17	0.39	1.70
	<111>/5°	0.24	1.53	2.58	0.12	
	<122>/5°	0.74	2.01	2.01	0.39	
	<122>/10°	1.54	1.31	1.96	0.80	
B	<012>/5°	0.70	1.98	2.42	0.37	4.75
	<012>/10°	1.46	1.83	2.17	0.76	
	<013>/5°	0.71	2.42	2.03	0.38	
	<013>/10°	1.32	1.26	2.30	0.67	
	<111>/5°	0.31	1.96	2.34	0.16	
	<113>/5°	0.67	1.80	2.46	0.35	
	<113>/10°	1.53	1.61	2.26	0.79	
	<122>/5°	0.71	2.19	1.88	0.38	
	<122>/10°	1.71	1.70	1.99	0.89	

表 T4 随机选取的 20 个 Taylor 取向晶粒与其相邻晶粒形成{111}/{111}-NSB 的详细信息

Table T4 Information related to the formation of 11 {111}/{111}-NSBs between randomly located 20 grains of Taylor orientation and their adjacent grains

{111}/{111}-NSB No.	The orientation of grains		The orientation of adjacent grains		Misorientation [uvw]/θ
	(φ1,Φ,φ2)	Miller indexed	(φ1,Φ,φ2)	Miller indexed	
1	(90°,27°,47°)	{4 4 11}<-6 -5 4>	(235°,12°,57°)	{1 -1 -7}<2 -5 1>	[-11-1]/45.7°
2	(88°,28°,47°)	{3 3 8}<-4 -4 3>	(178°,43°,9°)	{0 1 1}<11 1 -1>	[-111]/56.7°
3	(92°,26°,45°)	{113}<-3 -3 2>	(25°,40°,81°)	{4 -9 12}<3 -12 -10>	[11-1]/43.9°
4	(89°,26°,51°)	{5 4 13}<-11 -9 7>	(188°,43°,5°)	{1 -11 -12}<10 2 -1>	[-111]/53.8°
5	(92°,29°,46°)	{3 3 8}<-4 -4 3>	(47°,34°,67°)	{7 3 11}<-5 -14 7>	[-111]/29.5°
6	(94°,31°,44°)	{3 3 7}<-11 -10 9>	(65°,34°,57°)	{10 -3 6}<6 10 5>	[11-1]/19.5°
7	(92°,26°,50°)	{5 4 13}<-11 -9 7>	(157°,32°,14°)	{2 8 13}<-9 -7 6>	[1-1-1]/37.7°
8	(88°,28°,52°)	{5 4 12}<-4 -4 3>	(37°,41°,75°)	{3 -4 6}<2 -6 -5>	[11-1]/36.6°
9	(277°,28°,44°)	{3 3 8}<9 7 -6>	(357°,45°,6°)	{1 10 10}<10 -1 0>	[11-1]/55.6°
10	(94°,27°,45°)	{4 4 11}<-6 -5 4>	(48°,32°,72°)	{3 1 5}<-1 -2 1>	[11-1]/26.3°
11	(94°,27°,48°)	{4 4 11}<-6 -5 4>	(244°,34°,36°)	{-2 4 -1}<0 1 4>	[-111]/52.6°

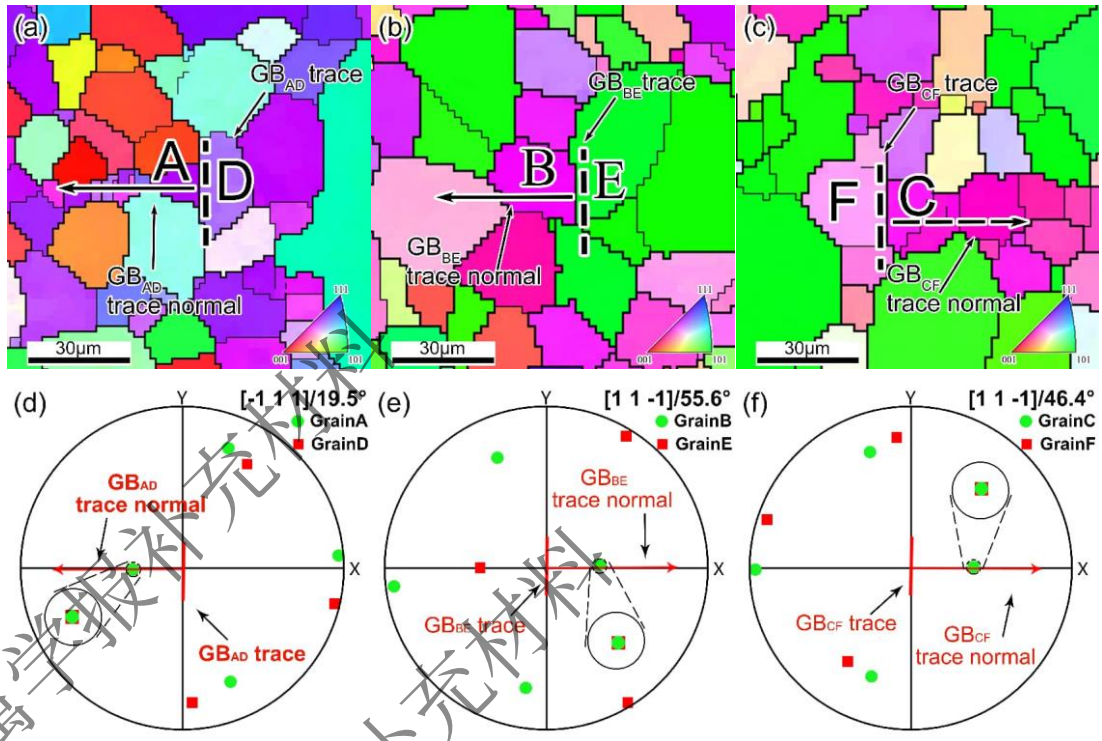

图 F2 Taylor 取向晶粒与其相邻晶粒间形成{111}/{111}-NSB 的显微组织 OIM 图和{111}重叠极图晶界迹线分析

Fig.F2 {111}/{111}-NSB (GB_{AB}, GB_{CD} and GB_{EF}) formed between Taylor-oriented grains (A, B, and C) and their adjacent grains (D, E, and F)

(a-c) OIM images (d-f) {111} overlapped pole figure grain boundary trace analyses

表 T5 对应图 F2 的 3 个 Taylor 取向晶粒与相邻晶粒形成{111}/{111}-NSB 的相关信息

Table T5 Information related to the formation of {111}/{111}-NSBs between 3 Taylor-oriented grains and their adjacent grains corresponding to Fig.F2

Grain boundary	Orientations of grains A, B, and C		Orientations of grains D, E, and F		Misorientation
	(φ1, Φ, φ2)	Miller indexed	(φ1, Φ, φ2)	Miller indexed	[*uvw*]/*θ*
GB_{AD}	A:94°,31°,44°	{3 3 7}<-11 -10 9>	D:65°,34°,57°	{6 -3 10}<5 -10 -6>	[-111]/19.5°
GB_{BE}	B:277°,28°,44°	{3 3 8}<9 7 -6>	E:357°,45°,6°	{1 10 10}<10 -1 0>	[1 1 -1]/55.6°
GB_{CF}	C:94°,27°,48°	{4 4 11}<-6 -5 4>	F:244°,34°,36°	{-2 4 -1}<0 1 4>	[1 1 -1]/46.4°

表 T6 随机选取 9 个 Taylor 取向晶粒与 9 个 Goss 取向晶粒之间的取向差统计

Table T6 Statistics of misorientations between randomly located 9 Taylor-oriented grains and randomly located 9 Goss-oriented grains

Goss-oriented grains Euler angle (φ1, Φ, φ2)	Taylor-oriented grains Euler angle (φ1, Φ, φ2)								
	80 °,22 °,40 °	80 °,22 °,45 °	80 °,27 °,45 °	85 °,22 °,40 °	85 °,22 °,45 °	85 °,27 °,45 °	90 °,22 °,40 °	90 °,22 °,45 °	90 °,27 °,45 °
80 °,90 °,40 °	<11-1>/54.5 °	<11-1>/57.4 °	<-2-23>/58.0 °	<-111>/58.7 °	<-232>/59.1 °	<-233>/59.1 °	<-2-3-2>/57.6 °	<-233>/55.4 °	<2-3-4>/55.2 °
80 °,90 °,45 °	<11-1>/57.4 °	<-111>/60.0 °	<2-2-3>/60.4 °	<-111>/58.7 °	<-111>/56.0 °	<-223>/56.2 °	<1-1-1>/54.6 °	<2-3-3>/52.0 °	<-233>/52.2 °
80 °,90 °,50 °	<23-3>/60.6 °	<-111>/57.4 °	<2-2-3>/58.0 °	<-322>/56.1 °	<-111>/53.1 °	<-223>/53.7 °	<1-1-1>/51.8 °	<-111>/49.0 °	<-233>/49.5 °
85 °,85 °,45 °	<23-3>/54.3 °	<22-3>/56.5 °	<-1-12>/57.2 °	<22-3>/58.0 °	<22-3>/60.4 °	<-101>/58.0 °	<2-2-3>/59.0 °	<-223>/56.5 °	<-1-12>/57.2 °
85 °,90 °,40 °	<11-1>/50.4 °	<11-1>/53.1 °	<-2-23>/53.7 °	<11-1>/54.5 °	<11-1>/57.4 °	<-2-23>/58.0 °	<-1-11>/58.5 °	<-233>/59.1 °	<-233>/59.1 °
85 °,90 °,45 °	<23-3>/53.5 °	<11-1>/56.0 °	<-2-23>/56.2 °	<1-1-1>/57.4 °	<-111>/60.0 °	<-223>/60.4 °	<1-1-1>/58.7 °	<-111>/56.0 °	<-223>/56.2 °
85 °,90 °,50 °	<23-3>/56.9 °	<-2-33>/59.1 °	<-2-33>/59.1 °	<-2-33>/60.6 °	<-111>/57.4 °	<-223>/57.8 °	<3-2-2>/56.1 °	<-111>/53.1 °	<-223>/53.7 °
90 °,90 °,40 °	<23-3>/46.6 °	<11-1>/49.0 °	<-2-23>/49.5 °	<1-1-1>/50.4 °	<11-1>/53.1 °	<22-3>/53.7 °	<-1-11>/54.5 °	<11-1>/57.4 °	<22-3>/58.0 °
90 °,90 °,45 °	<23-3>/49.8 °	<-2-33>/52.0 °	<-2-33>/52.2 °	<-2-33>/53.5 °	<11-1>/56 °	<22-3>/56.2 °	<-1-11>/57.4 °	<-111>/60.0 °	<-223>/60.4 °