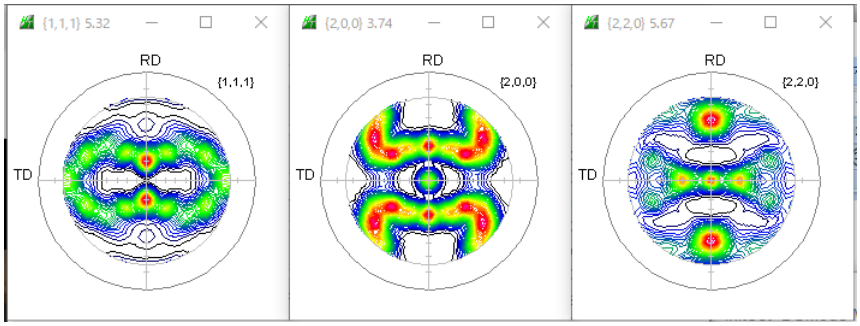
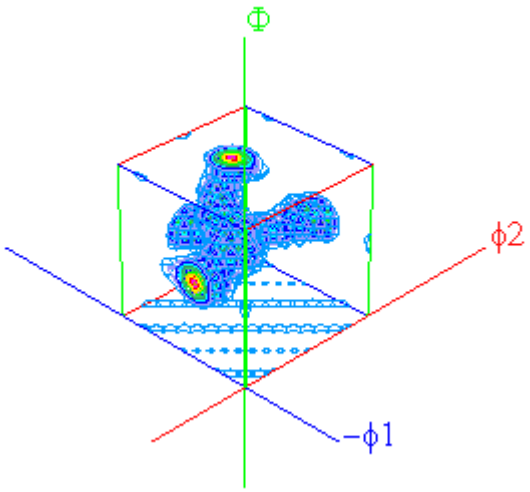
ＧＰＯＤＧＦＤｉｓｐｌａｙの応用

特許公報　構造用アルミニウム合金板及びその製造方法

ＪＰ６４１２１０３をシュミレーション





２０２２年０７月１９日

ＨｅｌｐｅｒＴｅｘ　Ｏｆｆｉｃｅ

概要

特許請求範囲に結晶方位を扱った申請があります。以前はＸＲＤを用いていたが、
最近は，ＥＢＳＤ利用が目立っています。しかし、圧延版などの場合、材料の広い範囲データが
必要になり、ＸＲＤが利用されています。
今回は、構造用アルミニウム合金板及びその製造方法に適用されている特許公報を扱ってみます。

ＸＲＤ結晶方位に関する請求範囲

製造した構造用アルミニウム合金板では、Brass 方位、S 方位、及び、Copper 方位という 3 種類の結晶方位のうち、少なくとも 1 種類の結晶方位の方位密度が、ランダム比で 20 以上であり、かつ、Cube 方位、CR 方位、Goss 方位、RW 方位、及び、P 方位という 5 種類の結晶方位の方位密度が、ランダム比ですべて 10 以下である集合組織

解説

結晶方位を扱う場合、方位密度とＶｏｌｕｍｅＦｒａｃｔｉｏｎ（ＶＦ％）があります。
ＶＦ％はＸＲＤの場合、体積分率（体積率)、ＥＢＳＤの場合、面積率と表現されています。
結晶方位とＶＦ％の関係は、ｅｕｌｅｒ角度（φ1, Φ,φ２）の広がりを同一とし、
同じＶＦ％の場合

Goss:RW:Cube:Copper:Brass:P:CR:S=４：４：４：２：２：２：２：１

の関係があります。

今回は、結晶方位でシュミレーションを行ってみます。

	ＶＦ％	比率	密度
Ｂｒａｓｓ	２５	２	５０
Ｓ	３４	１	３４
Ｃｏｐｐｅｒ	２５	２	５９
Ｃｕｂｅ	２	４	８
ＣＲ	５	２	１０
Ｇｏｓｓ	２	４	８
ＲＷ	２	４	８
Ｐ	５	２	１０

シュミレーション

対称性

Ｂｒａｓｓ｛１１０｝＜１１２＞

（１１０）［１－１２］　（５４．７４，９０．０，４５．０）

（０１１）［２－１１］　（３５．２６，４５．０，０．０）

（１０１）［－１－２１］（３５．２６，４５．０，９０．０）

Ｓ｛２３１｝＜３４６＞

（２３１）［３－４６］　（５２．８７，７４．５０，３３．６９）

（２１３）［－３－６４］（５８．９８，３６．７０，６３．４３）

（１３２）［６－４３］　（２７．０３，５７．６９，１８．４３）

Ｃｏｐｐｅｒ｛１２１｝＜１１１＞

（１２１）［１－１１］　（３９．２３，６５．９１，２６．５７）

（１１２）［－１－１１］（９０．０，３５．２６，４５．０）

Ｃｕｂｅ｛１００｝＜００１＞

（００１）［１００］　　（０．０，０．０，０．０）

（０１０）［１００］　　（０．０，９０．０，０．０）

（０１０）［００１］　　（９０．０，０．０，０．０）

（００１）［０－１０］　（９０．０，０．０，０．０）

（００１）［０－１０］　（０．０，０．０，９０．０）

（１００）［０－１０］　（０．０，９０．０，９０．０）

（１００）［００１］　　（９０．０，９０．０，９０．０）

（００１）［－１００］　（９０．０，０．０，９０．０）

ＣＲ｛０１０｝＜１０３＞

（０１０）［１０３］　　（７１．５７，９０．０，０．０）

（００１）［１－３０］　（７１．５７，０．０，０．０）

（０１０）［３０１］　　（１８．４３，９０．０，０．０）

（００１）［３－１０］　（１８．４３，０．０，０．０）

（１００）［０－１３］　（７１．５７，９０．０，９０．０）

（００１）［－３－１０］（７１．５７，０．０，９０．０）

（１００）［０－３１］　（１８．４３，９０．０，９０．０）

（００１）［－１－３０］（１８．４３，０，０，９０．０）

Ｇｏｓｓ｛１１０｝＜００１＞

（１１０）［００１］　　（９０．０，９０．０，４５．０）

（０１１）［１００］　　（０．０，４５．０，０．０）

（１０１）［０－１０］　（０．０，４５．０，９０．０）

ＲＷ｛００１｝＜１１０＞

（００１）［１－１０］　（４５．０，０．０，０．０）

（０１０）［１０１］　　（４５．０，９０．０，０．０）

（００１）［－１－１０］（４５．０，０．０，９０．０）

（１００）［０－１１］　（４５．０，９０．０，９０．０）

Ｐ｛１１０｝＜１１１＞

（１１０）［1－１１］　（３５．２６，９０．０，４５．０）

（（０１１）［1－１１］　（５４．７４，４５．０，０．０）

（１０１）［－1－１１］　（５４．７４，４５．０，９０．０）

測定される結晶方位の値は測定Ｓｔｅｐに影響受ける方位があります。

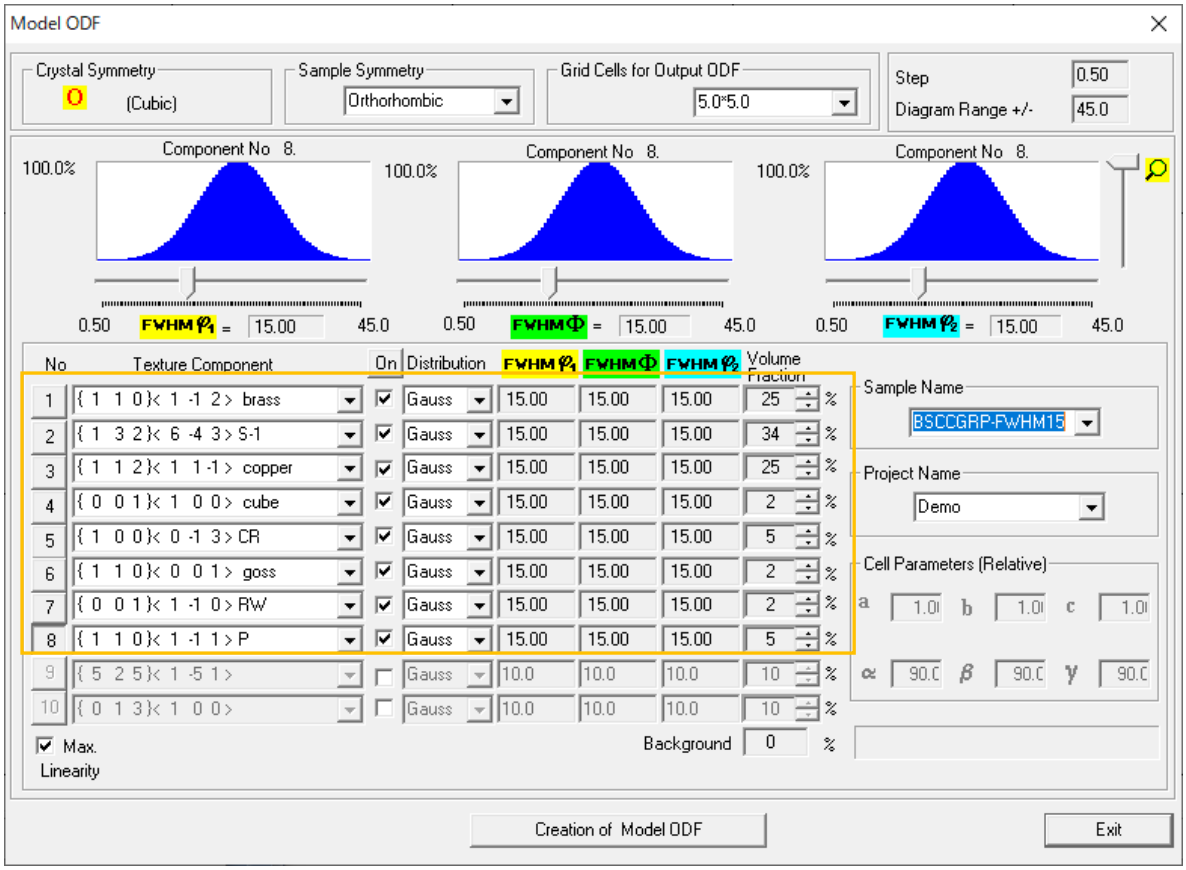
Ｓｔｅｐ＝５．０で方位のシフトがない場合

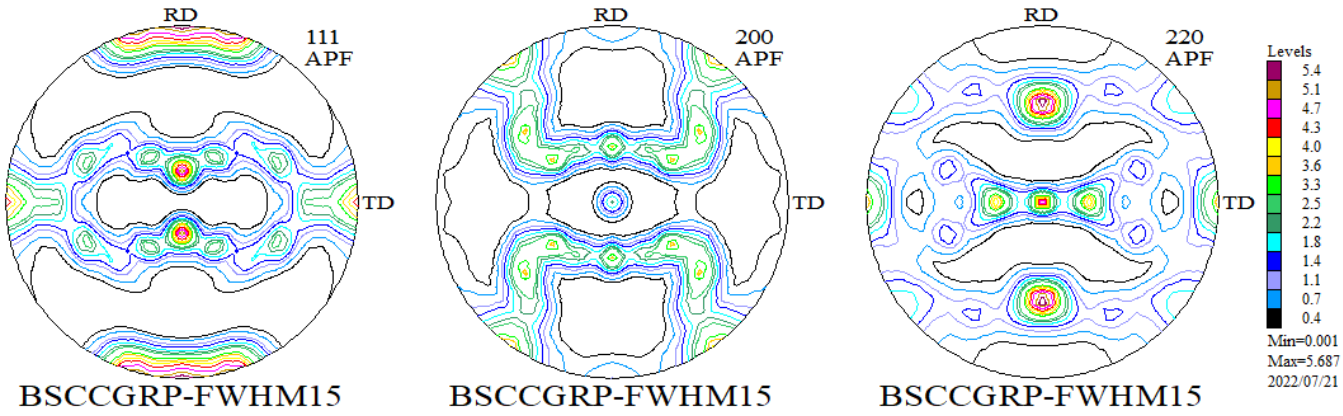
Ｇｏｓｓは全て同一の値が測定されるが、他の方位は等価方位により格子点から外れる為、

異なった値で、正しい値より少ない値を示します。

本資料では、結晶方位の値は等価方位の最大値を採用します（正しい値に近づける)。

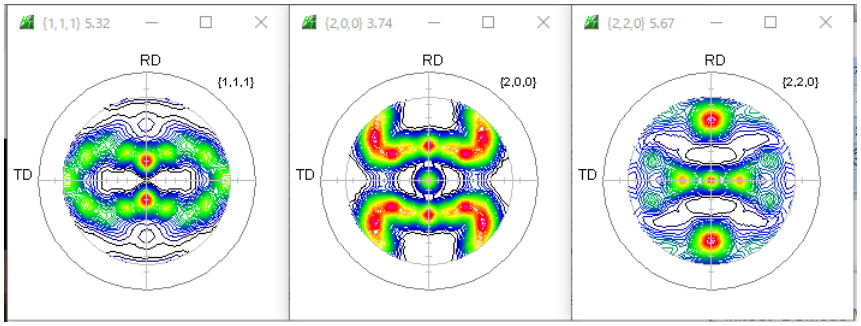
ＦＷＨＭ＝１５ｄｅｇでＯＤＦ図作成





極点図の測定では測定間隔５度が一般的であるが、間隔を狭くすれば、正しい強度測定が可能になるが測定時間が長くなり、ＯＤＦ図表示もスピードが遅くなります。

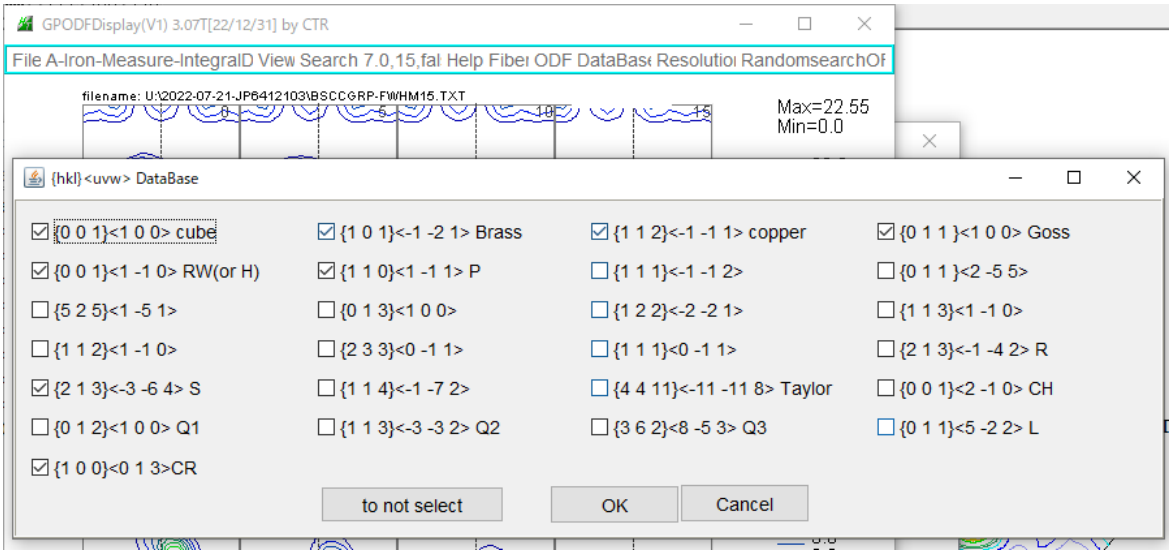
以降、この極点図から反射極点図を作成し、各種ＯＤＦで解析を行い、方位密度の確認



法密度の計算をＧＰＯＤＦＤｉｓｐｌａｙソフトウエアで実施

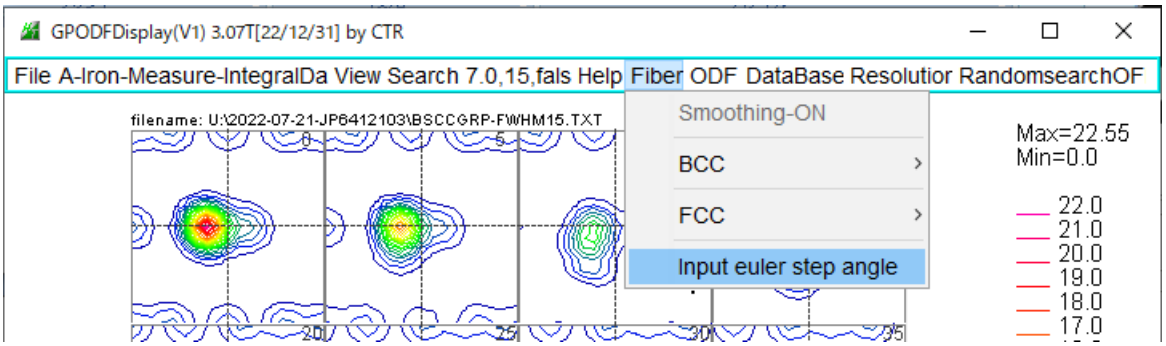
従来は、調べる方位を指定して

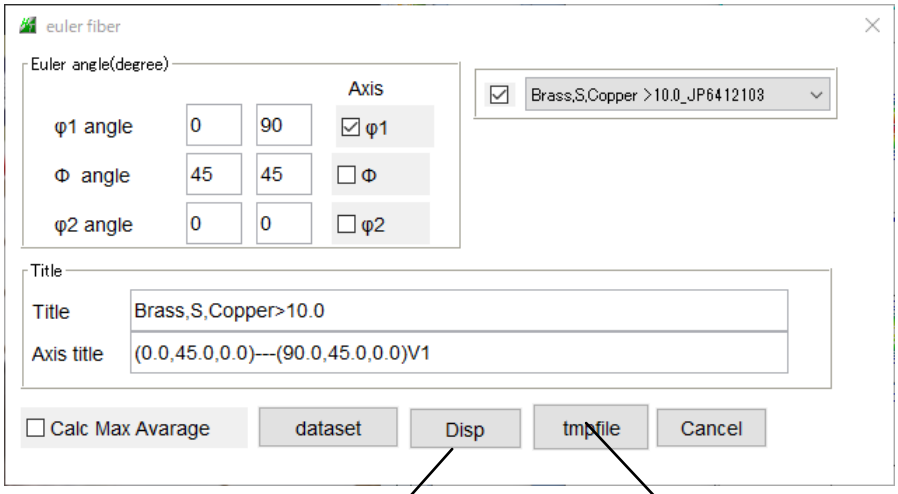
各方位の最大値を計算

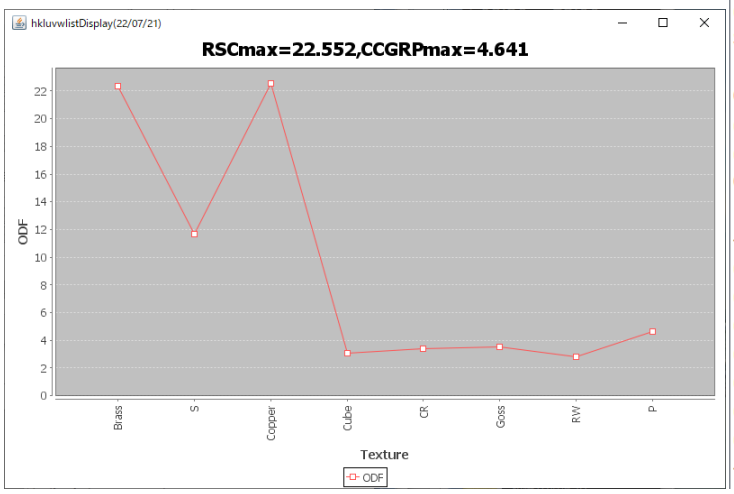


MaxOrientation	φ1	Φ	φ2	ODF
{1 1 2}<-1 -1 1> copper	90.0	35.26	45.0	22.55
{1 0 1}<-1 -2 1> Brass	35.26	45.0	90.0	22.36
{1 3 2}<6 -4 3> S	27.03	57.69	18.43	11.67
{1 1 0}<1 -1 1> P	35.26	90.0	45.0	4.64
{0 1 1}<1 0 0> Goss	0.0	45.0	0.0	3.53
{0 1 0}<1 0 3> CR	71.57	90.0	0.0	3.41
{0 0 1}<1 0 0> cube	0.0	0.0	0.0	3.06
{0 0 1}<1 -1 0> RW(H)	45.0	0.0	0.0	2.8
MAXODF=22.55	MINIODF=0.0 (Weight=0 Cycle=10)			

ＧＰＯＤＦＤｉｓｐｌａｙによる専用の計算







U:\2022-07-21-JP6412103\BSCCGRP-FWHM15.TXT

Brass,S,Copper>10.0

Brass

(110)[1-12]	(54.74,90.0,45.0)	22.363
(011)[2-11]	(35.26,45.0,0.0)	22.134
(101)[-1-21]	(35.26,45.0,90.0)	22.134

Brass max=22.3632

S

(231)[3-46]	(52.87,74.5,33.69)	11.591
(213)[-3-64]	(58.98,36.7,63.43)	10.903
(132)[6-43]	(27.03,57.69,18.43)	11.674

S max=11.6742

Copper

(121)[1-11]	(39.23,65.91,26.57)	21.794
(121)[1-11]	(90.0,35.26,45.0)	22.552

Copper max=22.5523

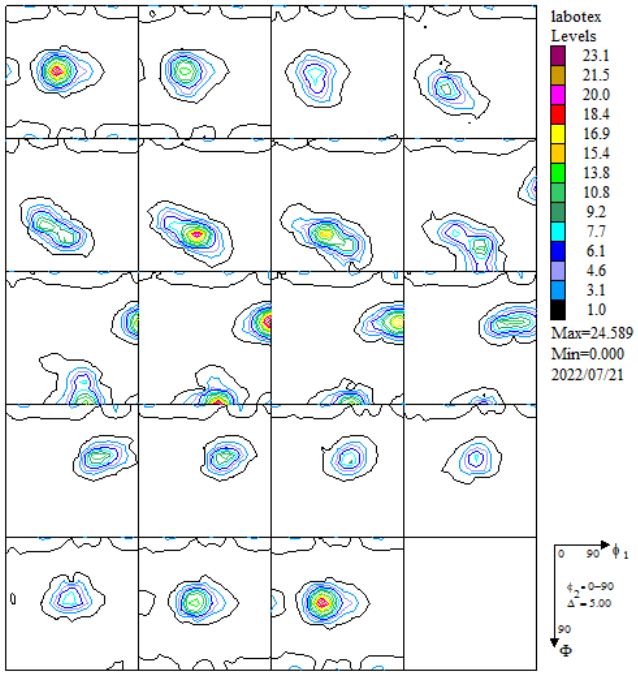
{001}<100>

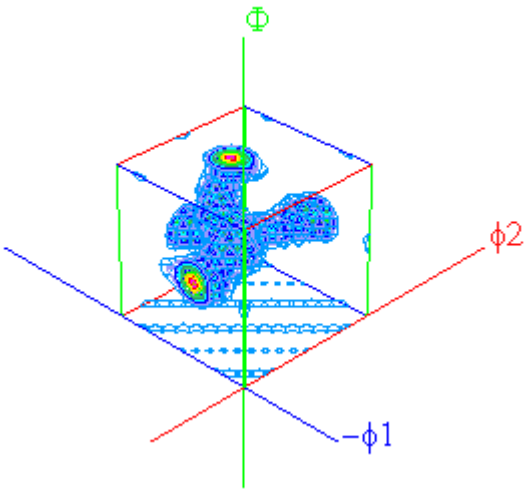
(001)[100]	(0.0,0.0,0.0)	3.057
(010)[100]	(0.0,90.0,0.0)	2.927
(010)[001]	(90.0,0.0,0.0)	3.057
(001)[0-10]	(0.0,0.0,90.0)	3.057
(001)[0-10]	(0.0,90.0,90.0)	2.927
(100)[001]	(90.0,90.0,90.0)	2.927
(001)[-100]	(90.0,0.0,90.0)	3.057

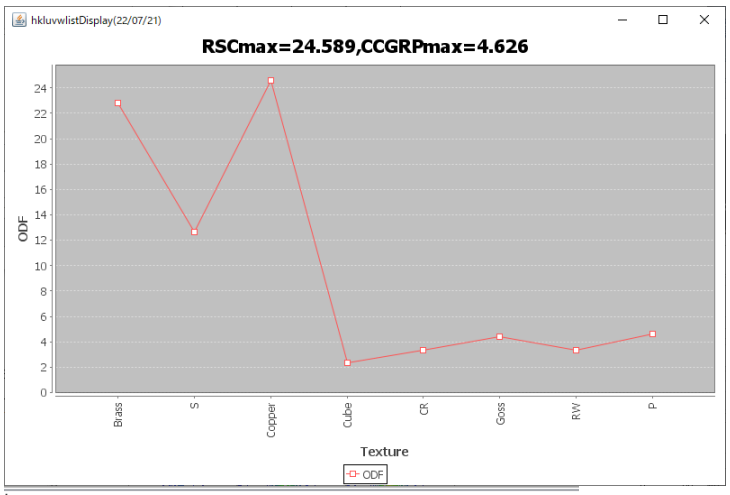
{001}<100> max=3.05654

以降、反射極点図から各種 ODF で解析を行い、Brass,S,Copper>10 の評価を行ってみます。

Ｌａｂｏ Ｔｅｘで解析







U:\2022-07-21-JP6412103\TXT2\LaboTex\CW\RSC.TXT

Brass,S,Copper>10.0

Brass

(110)[1-12]	(54.74,90.0,45.0)	22.31
(011)[2-11]	(35.26,45.0,0.0)	22.782
(101)[-1-21]	(35.26,45.0,90.0)	22.782

Brass max=22.7822

S

(231)[3-46]	(52.87,74.5,33.69)	11.37
(213)[-3-64]	(58.98,36.7,63.43)	12.303
(132)[6-43]	(27.03,57.69,18.43)	12.619

S max=12.6192

Copper

(121)[1-11]	(39.23,65.91,26.57)	21.504
(121)[1-11]	(90.0,35.26,45.0)	24.589

Copper max=24.5889

{001}<100>

(001)[100]	(0.0,0.0,0.0)	2.31
(010)[100]	(0.0,90.0,0.0)	2.292
(010)[001]	(90.0,0.0,0.0)	2.327
(001)[0-10]	(0.0,0.0,90.0)	2.31
(001)[0-10]	(0.0,90.0,90.0)	2.292
(100)[001]	(90.0,90.0,90.0)	2.291
(001)[-100]	(90.0,0.0,90.0)	2.327

{001}<100> max=2.32726

CR

(010)[103]	(71.57,90.0,0.0)	3.357
(010)[301]	(18.43,90.0,0.0)	3.357
(001)[3-10]	(18.43,0.0,0.0)	3.289
(001)[1-30]	(71.57,0.0,0.0)	3.3
(001)[1-30]	(71.57,90.0,90.0)	3.357
(100)[0-31]	(18.43,90.0,90.0)	3.357
(001)[-1-30]	(18.43,0.0,90.0)	3.289
(001)[-3-10]	(71.57,0.0,90.0)	3.3

CR max=3.3567

Goss

(110)[001]	(90.0,90.0,45.0)	4.319
(011)[100]	(0.0,45.0,0.0)	4.418
(011)[100]	(0.0,45.0,90.0)	4.418

Goss max=4.41758

RW

(001)[1-10]	(45.0,0.0,0.0)	3.378
(010)[101]	(45.0,90.0,0.0)	3.358
(001)[-1-10]	(45.0,0.0,90.0)	3.378
(100)[0-11]	(45.0,90.0,90.0)	3.358

RW max=3.37801

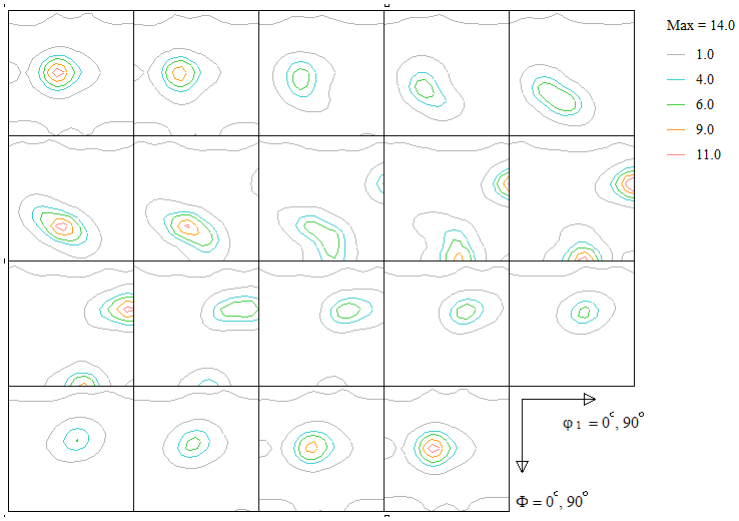
P

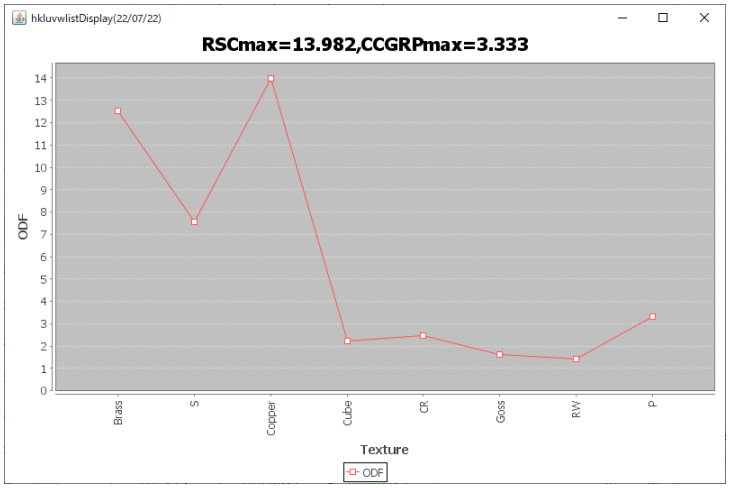
(110)[1-11]	(35.26,90.0,45.0)	4.452
(011)[1-11]	(54.26,45.0,0.0)	4.626
(101)[-1-11]	(54.74,45.0,90.0)	4.626

P max=4.62635

BSCmax 24.589 CCGRPmax 4.626

ＴｘＴｏｏｌｓで解析





U:\2022-07-21-JP6412103\TXT2\TexTools\RSC.HODF

Brass,S,Copper>10.0

Brass

(110)[1-12]	(54.74,90.0,45.0)	12.333
(011)[2-11]	(35.26,45.0,0.0)	12.524
(101)[-1-21]	(35.26,45.0,90.0)	12.524

Brass max=12.5244

S

(231)[3-46]	(52.87,74.5,33.69)	7.461
(213)[-3-64]	(58.98,36.7,63.43)	7.553
(132)[6-43]	(27.03,57.69,18.43)	7.377

S max=7.5526

Copper

(121)[1-11]	(39.23,65.91,26.57)	12.258
(121)[1-11]	(90.0,35.26,45.0)	13.982

Copper max=13.9818

{001}<100>

(001)[100]	(0.0,0.0,0.0)	2.136
(010)[100]	(0.0,90.0,0.0)	2.056
(010)[001]	(90.0,0.0,0.0)	2.22
(001)[0-10]	(0.0,0.0,90.0)	2.136
(001)[0-10]	(0.0,90.0,90.0)	2.056
(100)[001]	(90.0,90.0,90.0)	2.058
(001)[-100]	(90.0,0.0,90.0)	2.22

{001}<100> max=2.22

CR

(010)[103]	(71.57,90.0,0.0)	2.015
(010)[301]	(18.43,90.0,0.0)	2.019
(001)[3-10]	(18.43,0.0,0.0)	2.467
(001)[1-30]	(71.57,0.0,0.0)	2.111
(001)[1-30]	(71.57,90.0,90.0)	2.015
(100)[0-31]	(18.43,90.0,90.0)	2.019
(001)[-1-30]	(18.43,0.0,90.0)	2.467
(001)[-3-10]	(71.57,0.0,90.0)	2.111

CR max=2.4672

Goss

(110)[001]	(90.0,90.0,45.0)	1.536
(011)[100]	(0.0,45.0,0.0)	1.617
(011)[100]	(0.0,45.0,90.0)	1.617

Goss max=1.6173

RW

(001)[1-10]	(45.0,0.0,0.0)	1.432
(010)[101]	(45.0,90.0,0.0)	1.37
(001)[-1-10]	(45.0,0.0,90.0)	1.432
(100)[0-11]	(45.0,90.0,90.0)	1.37

RW max=1.4322

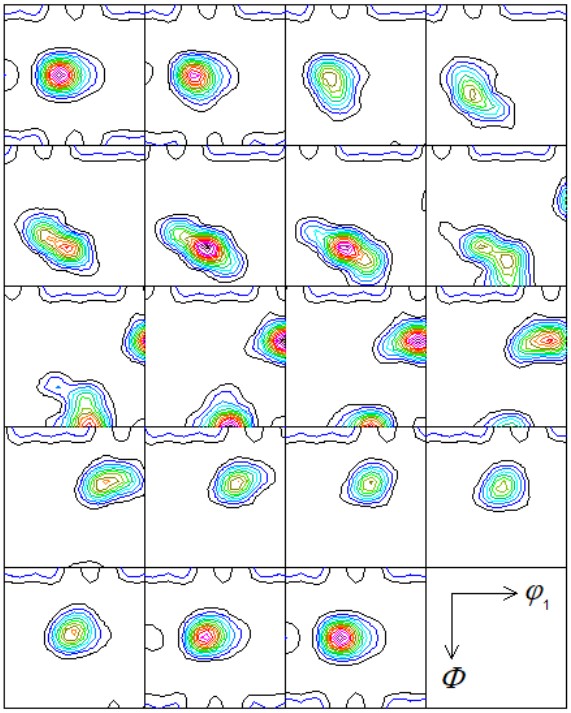
P

(110)[1-11]	(35.26,90.0,45.0)	3.007
(011)[1-11]	(54.26,45.0,0.0)	3.333
(101)[-1-11]	(54.74,45.0,90.0)	3.333

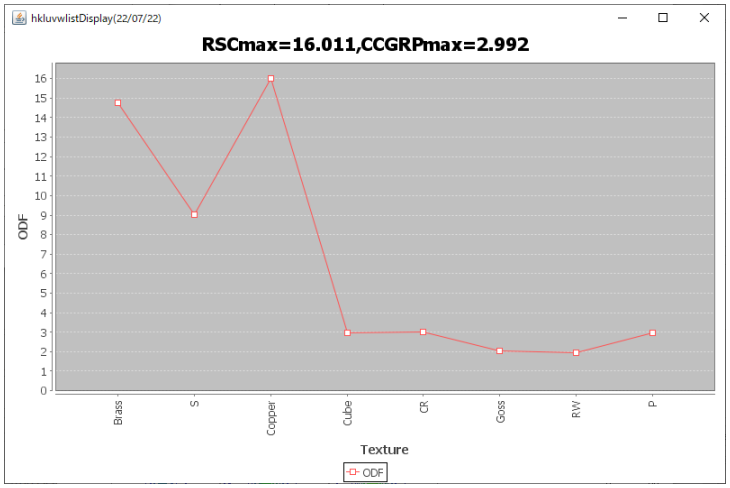
P max=3.3333

BSCmax 13.982 CCGRPmax 3.333

Ｓｔａｎｄａｒｄ ＯＤＦで解析



Contour Levels: 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0



U:\2022-07-21-JP6412103\TXT2\StandardODF\ODF15

Brass,S,Copper>10.0

Brass

(110)[1-12]	(54.74,90.0,45.0)	14.778
(011)[2-11]	(35.26,45.0,0.0)	14.778
(101)[-1-21]	(35.26,45.0,90.0)	14.778

Brass max=14.77773380279541

S

(231)[3-46]	(52.87,74.5,33.69)	8.688
(213)[-3-64]	(58.98,36.7,63.43)	9.017
(132)[6-43]	(27.03,57.69,18.43)	8.724

S max=9.016656875610352

Copper

(121)[1-11]	(39.23,65.91,26.57)	15.531
(121)[1-11]	(90.0,35.26,45.0)	16.011

Copper max=16.010786056518555

{001}<100>

(001)[100]	(0.0,0.0,0.0)	2.966
(010)[100]	(0.0,90.0,0.0)	2.966
(010)[001]	(90.0,0.0,0.0)	2.966
(001)[0-10]	(0.0,0.0,90.0)	2.966
(001)[0-10]	(0.0,90.0,90.0)	2.966
(100)[001]	(90.0,90.0,90.0)	2.966
(001)[-100]	(90.0,0.0,90.0)	2.966

{001}<100> max=2.966090679168701

CR

(010)[103]	(71.57,90.0,0.0)	2.992
(010)[301]	(18.43,90.0,0.0)	2.992
(001)[3-10]	(18.43,0.0,0.0)	2.992
(001)[1-30]	(71.57,0.0,0.0)	2.992
(001)[1-30]	(71.57,90.0,90.0)	2.992
(100)[0-31]	(18.43,90.0,90.0)	2.992
(001)[-1-30]	(18.43,0.0,90.0)	2.992
(001)[-3-10]	(71.57,0.0,90.0)	2.992

CR max=2.991719961166382

Goss

(110)[001]	(90.0,90.0,45.0)	2.034
(011)[100]	(0.0,45.0,0.0)	2.034
(011)[100]	(0.0,45.0,90.0)	2.034

Goss max=2.034358501434326

RW

(001)[1-10]	(45.0,0.0,0.0)	1.939
(010)[101]	(45.0,90.0,0.0)	1.939
(001)[-1-10]	(45.0,0.0,90.0)	1.939
(100)[0-11]	(45.0,90.0,90.0)	1.939

RW max=1.9387567043304443

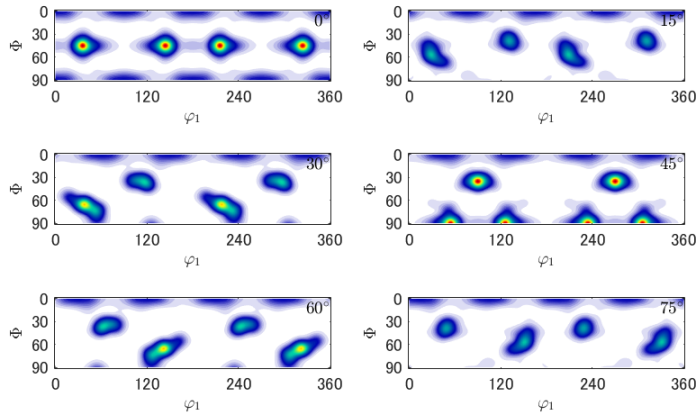
P

(110)[1-11]	(35.26,90.0,45.0)	2.968
(011)[1-11]	(54.26,45.0,0.0)	2.968
(101)[-1-11]	(54.74,45.0,90.0)	2.968

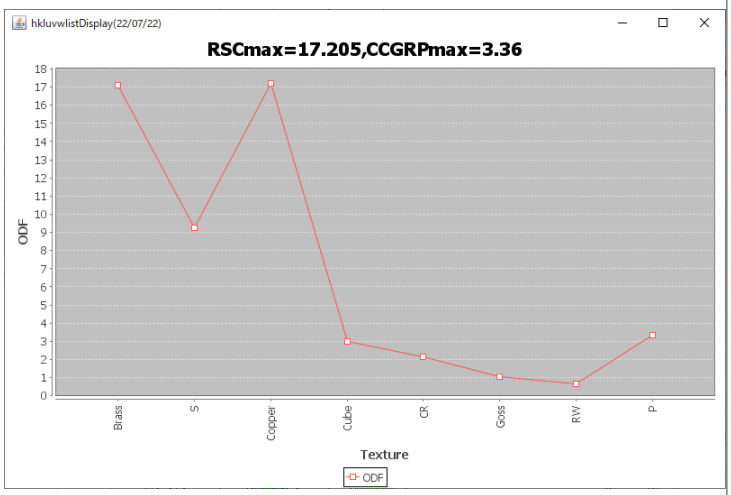
P max=2.967557191848755

BSCmax 16.011 CCGRPmax 2.992

ＭＴＥＸで解析（FWHMはｄｅｆａｕｌｔ）



Radially symmetric portion:
kernel: de la Vallee Poussin, halfwidth 5°
center: 4951 orientations, resolution: 5°
weight: 1



U:\2022-07-21-JP6412103\TXT2\MTEX\MTEXODF.txt

Brass,S,Copper>10.0

Brass

(110)[1-12]	(54.74,90.0,45.0)	17.092
(011)[2-11]	(35.26,45.0,0.0)	17.092
(101)[-1-21]	(35.26,45.0,90.0)	17.092

Brass max=17.09224

S

(231)[3-46]	(52.87,74.5,33.69)	9.103
(213)[-3-64]	(58.98,36.7,63.43)	9.239
(132)[6-43]	(27.03,57.69,18.43)	8.984

S max=9.238567499999998

Copper

(121)[1-11]	(39.23,65.91,26.57)	16.534
(121)[1-11]	(90.0,35.26,45.0)	17.205

Copper max=17.205115

{001}<100>

(001)[100]	(0.0,0.0,0.0)	2.97
(010)[100]	(0.0,90.0,0.0)	2.97
(010)[001]	(90.0,0.0,0.0)	2.97
(001)[0-10]	(0.0,0.0,90.0)	2.97
(001)[0-10]	(0.0,90.0,90.0)	2.97
(100)[001]	(90.0,90.0,90.0)	2.97
(001)[-100]	(90.0,0.0,90.0)	2.97

{001}<100> max=2.96997

CR

(010)[103]	(71.57,90.0,0.0)	2.146
(010)[301]	(18.43,90.0,0.0)	2.146
(001)[3-10]	(18.43,0.0,0.0)	2.146
(001)[1-30]	(71.57,0.0,0.0)	2.146
(001)[1-30]	(71.57,90.0,90.0)	2.146
(100)[0-31]	(18.43,90.0,90.0)	2.146
(001)[-1-30]	(18.43,0.0,90.0)	2.146
(001)[-3-10]	(71.57,0.0,90.0)	2.146

CR max=2.1464999999999996

Goss

(110)[001]	(90.0,90.0,45.0)	1.053
(011)[100]	(0.0,45.0,0.0)	1.053
(011)[100]	(0.0,45.0,90.0)	1.053

Goss max=1.05311

RW

(001)[1-10]	(45.0,0.0,0.0)	0.629
(010)[101]	(45.0,90.0,0.0)	0.629
(001)[-1-10]	(45.0,0.0,90.0)	0.629
(100)[0-11]	(45.0,90.0,90.0)	0.629

RW max=0.62892

P

(110)[1-11]	(35.26,90.0,45.0)	3.36
(011)[1-11]	(54.26,45.0,0.0)	3.36
(101)[-1-11]	(54.74,45.0,90.0)	3.36

P max=3.36011

BSCmax 17.205 CCGRPmax 3.36

まとめ

数値を集計すると

	Brass	S	Copper	Cube	CR	Goss	RW	P
LaboTex	22.78	12.62	24.59	1.33	3.36	4.42	3.38	4.63
TexTools	12.52	7.55	13.98	2.22	2.47	1.62	1.43	3.33
StandardODF	14.78	9.02	16.01	2.97	2.99	2.03	1.94	2.97
MTEX	17.09	9.24	17.21	2.99	2.15	1.05	0.63	3.36

概ね、予測された値が計算されている。