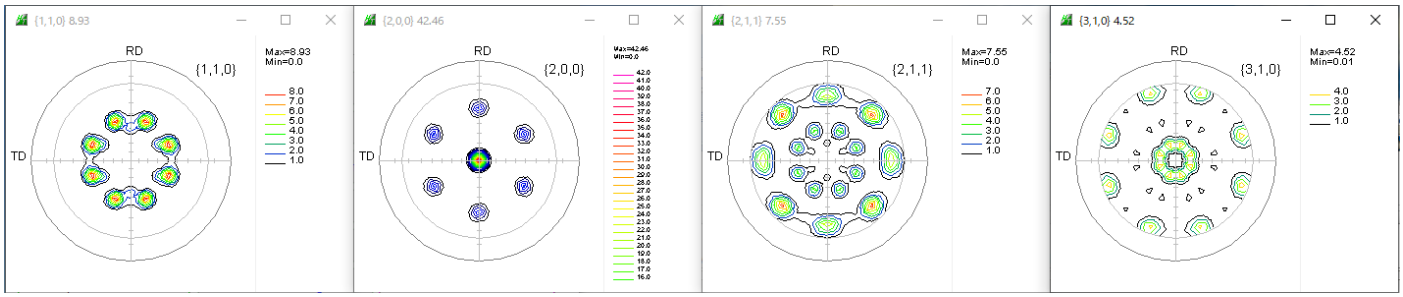
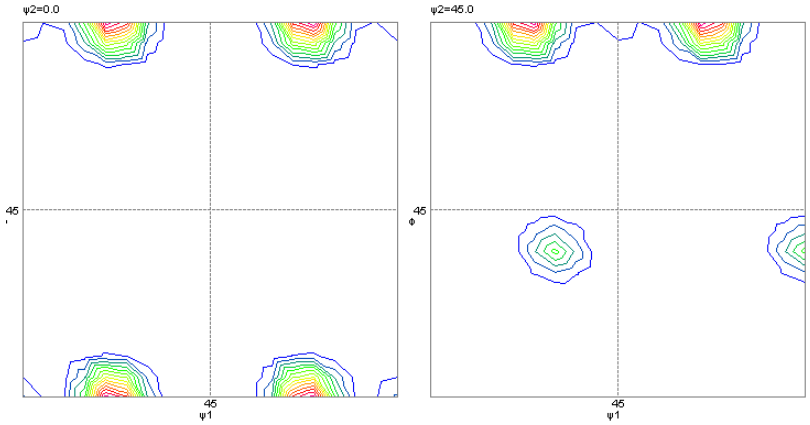
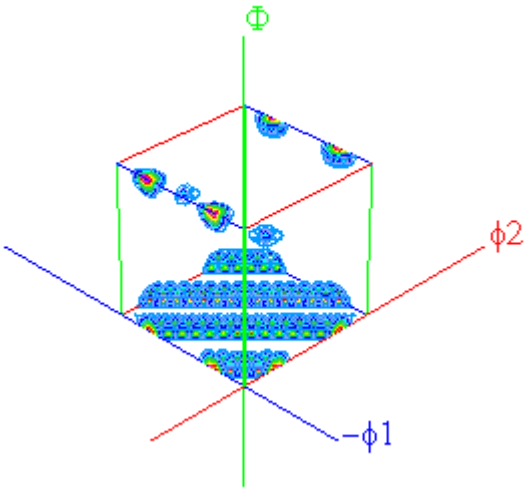
ＧＰＯＤＧＦＤｉｓｐｌａｙの応用

特許公報　無方向性電磁鋼板とその製造方法ならびにモータコアとその製造方法

ＪＰ６２６０８００をシュミレーション







２０２２年０７月２２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、無方向性電磁鋼板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

板厚中心層における｛００１｝＜２５０＞,｛１１１｝＜１１２＞および｛００１｝＜１００＞の
Ｘ線強強度比をそれぞれＳ，ＭおよびＣとしたとき
Ｓ／2Ｍ＞＝１．０、Ｓ＞５Ｃ＞＝１．０

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、｛００１｝＜１００＞の方位密度は｛００１｝＜２５０＞や
｛１１１｝＜１１２＞の方位密度の約２倍になります。
更に、ｅｕｌｅｒ角度がＯＤＦの格子点から外れる｛００１｝＜２５０＞や｛１１１｝＜１１２＞は
対称方位の方位密度が異なった値を示します。この場合最大方位が正しい方位密度に近い値を示します。
ｅｕｌｅｒ角度の問題で｛００１｝＜２５０＞は｛１１１｝＜１１２＞より小さい方位密度を示します。

ｅｕｌｅｒ角度の広がりＦＷＨＭを同一として以下の条件でシュミレーションを行ってみます。

		比率	密度
｛００１｝＜２５０＞	ＶＦ＝７５％	０．４５	３０
｛１１１｝＜１１２＞	ＶＦ＝２０％	０．５	１０
｛００１｝＜１００＞	ＶＦ＝５％	１	５

Ｓ／２／Ｍ＝３０／２／１０＝１．５
Ｓ／５／Ｃ＝３０／５／５＝１．２
を予測

シュミレーション

対称性

｛００１｝＜２５０＞

（００１）［２－５０］　（６８．２０，０．０，０．０）
（０１０）［２０５］　（６８．２０，９０．０，０．０）
（０１０）［５０２］　（２１．８０，９０．０，０．０）
（００１）［５－２０］　（２１．８０，０．０，０．０）
（００１）［－５－２０］（６８．２０，０．０，９０．０）
（１００）［０－２５］　（６８．２０，９０．０，９０．０）
（１００）［０－５２］　（２１．８０，９０．０，９０．０）
（００１）［－２－５０］（２１．８０，０．０，９０．０）

｛１１１｝＜１１２＞

（１１１）［－１－１２］（９０．０，５４．７４，４５．０）
（１１１）［１－２１］　（３０．０，５４．７４，４５．０）

｛００１｝＜１００＞

（００１）［１００］　（０．０，０．０，０．０）
（０１０）［１００］　（０．０，９０．０，０．０）
（０１０）［００１］　（９０．０，９０．０，０．０）
（００１）［０－１０］　（０．０，０．０，９０．０）
（００１）［０－１０］　（０．０，９０．０，９０．０）
（１００）［００１］　（９０．０，９０．０，９０．０）
（００１）［－１００］　（９０．０，０．０，９０．０）

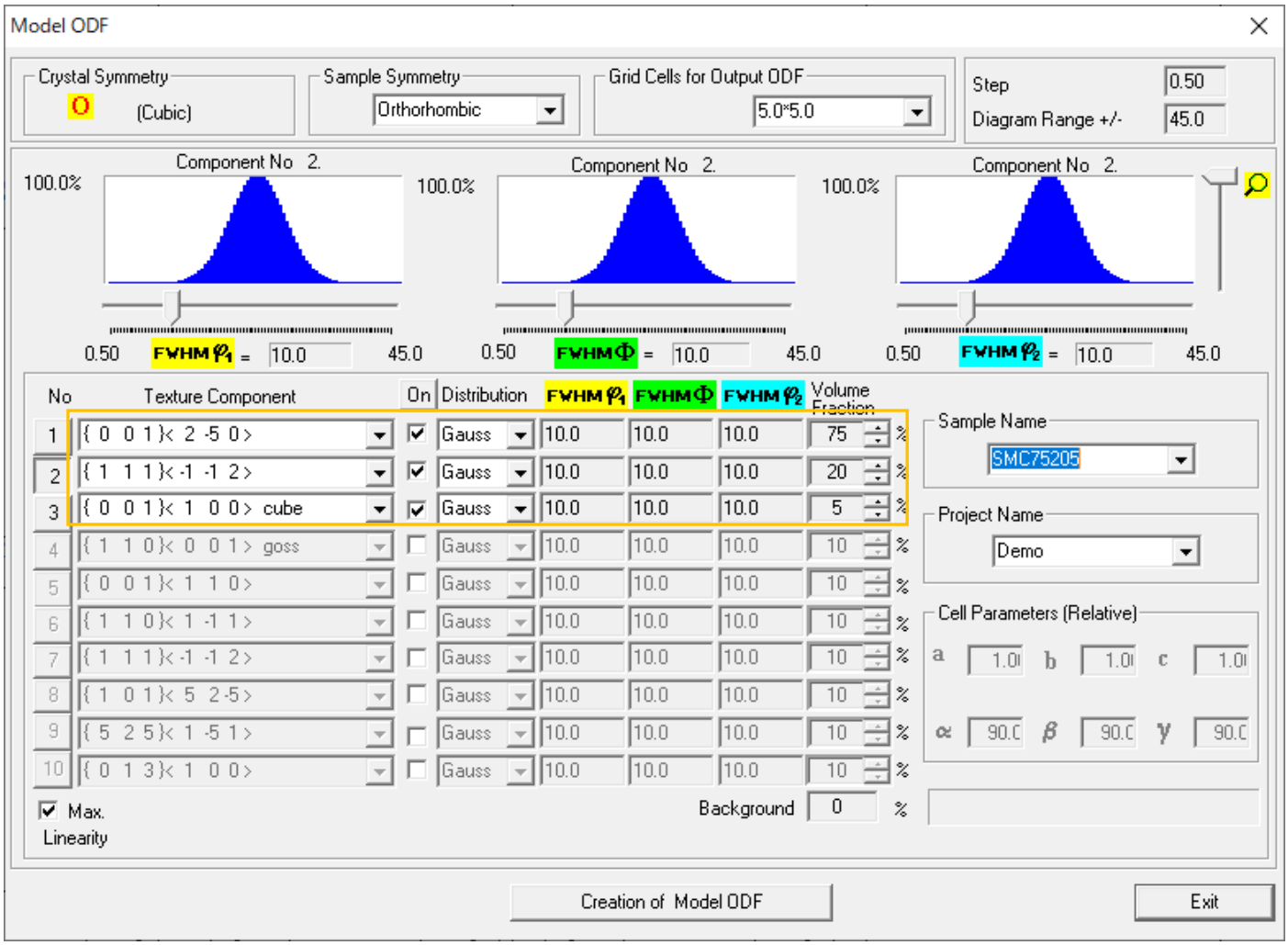
測定される結晶方位の値は測定Ｓｔｅｐに影響受ける方位があります。

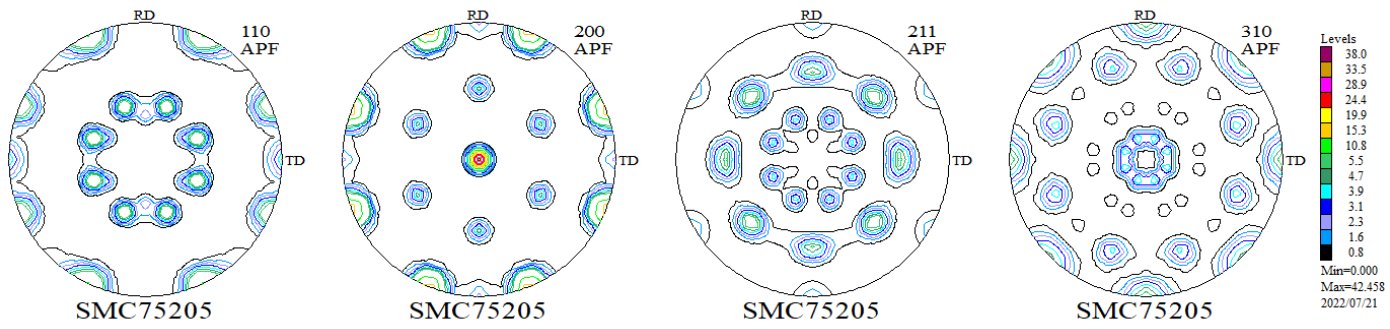
Ｓｔｅｐ＝５．０で方位のシフトがない場合

｛００１｝＜２５０＞はｅｕｌｅｒ角度の問題で｛１１１｝１１２＞より少ない値を示します。

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

シュミレーション



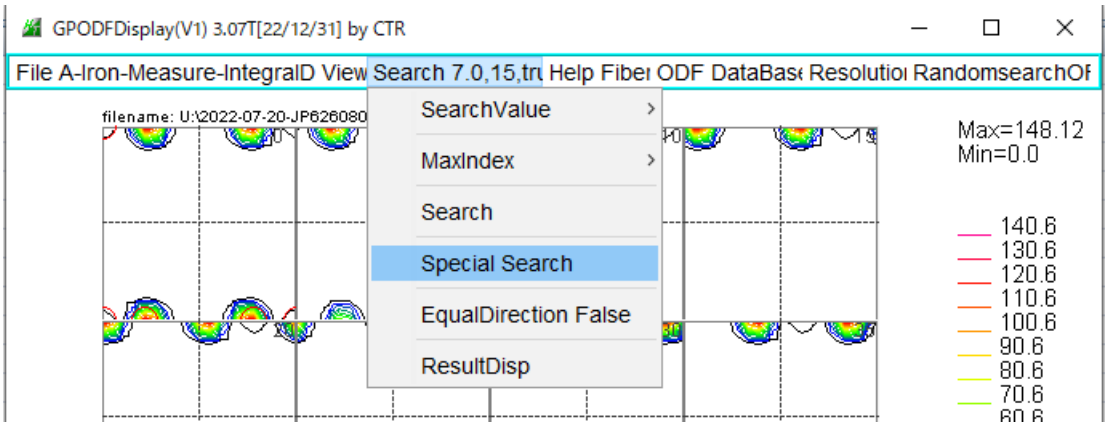


極点図の測定では測定間隔５度が一般的である。間隔を狭くすれば、正しい強度測定が可能になるが
測定時間が長くなり、ＯＤＦ図表示もスピードが遅くなります。

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、Ｓ／２Ｍ，Ｓ／５Ｃを計算する

Ｓ／２Ｍ，Ｓ／５Ｃの計算をＧＰＯＤＦＤｉｓｐｌａｙソフトウエアで実施

従来は、ピークサーチで各方位密度を計算



TextDisplay 1.14S C:¥CTR¥work¥GPODFDisplay¥CALCHKLUVW.TXT

File Help

f1	F	f2	ODF	calcf1	calcF	calcf2	hkluvw	EqualDirection
0.0	0.0	0.0	21.4	0.0	0.0	0.0	(0 0 1)[1 0 0] cube	1
0.0	90.0	0.0	21.4	0.0	90.0	0.0	(0 1 0)[1 0 0] cube	1
0.0	90.0	90.0	21.4	0.0	90.0	90.0	(1 0 0)[0 -1 0] cube	1
21.53	90.0	0.0	148.1	21.8	90.0	0.0	(0 1 0)[5 0 2] 1	
21.53	90.0	90.0	148.1	21.8	90.0	90.0	(1 0 0)[0 -5 2]	1
30.0	54.81	45.0	53.3	30.0	54.74	45.0	(1 1 1)[1 -2 1]	1
68.47	90.0	0.0	148.1	68.2	90.0	0.0	(0 1 0)[2 0 5] 1	
68.47	90.0	90.0	148.1	68.2	90.0	90.0	(1 0 0)[0 -2 5]	1
90.0	0.0	90.0	21.4	90.0	0.0	90.0	(0 0 1)[-1 0 0] cube	1
90.0	54.81	45.0	53.3	90.0	54.74	45.0	(1 1 1)[-1 -1 2]	1
90.0	90.0	0.0	21.4	90.0	90.0	0.0	(0 1 0)[0 0 1] cube	1
90.0	90.0	90.0	21.4	90.0	90.0	90.0	(1 0 0)[0 0 1] cube	1

MAXODF= 148.12 MINIODF= 0.0

各方位の最大値を計算

TextDisplay 1.14S C:¥CTR¥work¥GPODFDisplay¥CALCHKLUVW.TXT

File Help

f1	F	f2	ODF	calcf1	calcF	calcf2	hkluvw	EqualDirection
0.0	0.0	0.0	21.37	0.0	0.0	0.0	(0 0 1)[1 0 0] cube	6
21.53	90.0	0.0	148.12	21.8	90.0	0.0	(0 1 0)[5 0 2] 4	
30.0	54.81	45.0	53.34	30.0	54.74	45.0	(1 1 1)[1 -2 1]	2

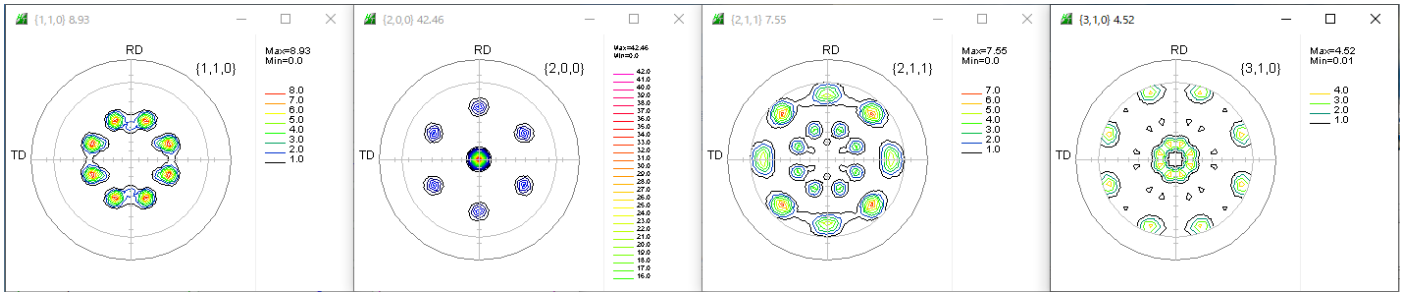
MAXODF= 148.12 MINIODF= 0.0

Ｓ／２Ｍ＝１４８．１２／２／５３．３４＝１．３８８

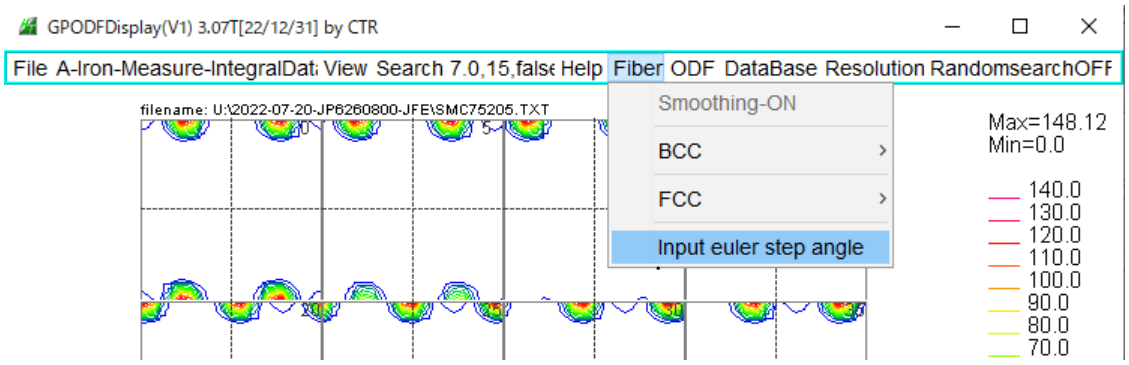
Ｓ／５／Ｃ＝１４８．１２／５／２１．３７＝１．３８６

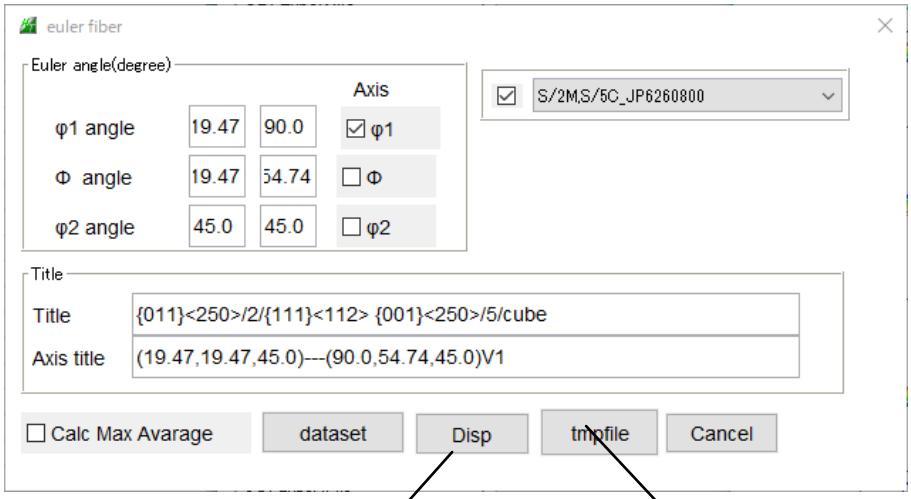
以降反射極点図を用い、各種 ODF ソフトウエアで解析を行いＥｘｐｏｒｔＯＤＦデータを

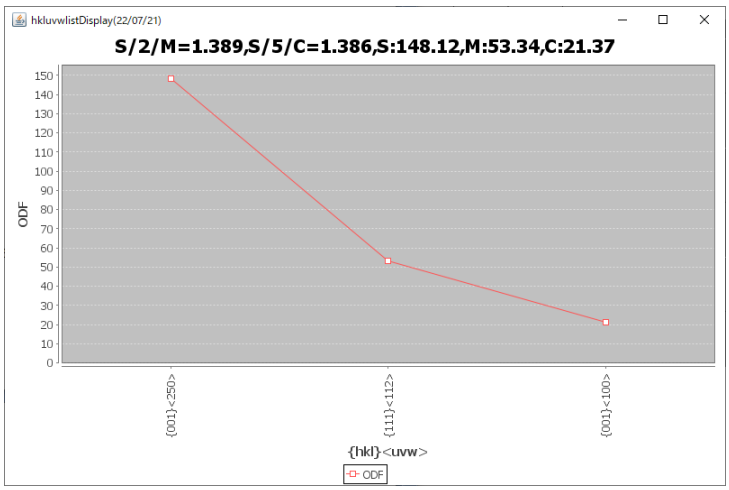
ＧＰＯＤＦＤｉｓｐｌａｙの専用計算を適用します。



ＰＧＰＯＤＦＤｉｓｐｌａｙによる専用計算







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{011}<250>/2/{111}<112> {001}<250>/5/cube

{001}<250>

(001)[2-50]	(68.2,0.0,0.0)	148.12
(010)[205]	(68.2,90.0,0.0)	148.12
(010)[502]	(21.8,90.0,0.0)	148.107
(001)[5-20]	(21.8,0.0,0.0)	148.107
(001)[-5-20]	(68.2,0.0,90.0)	148.12
(100)[0-25]	(68.2,90.0,90.0)	148.12
(100)[0-52]	(21.8,90.0,90.0)	148.107
(001)[-2-05]	(21.8,0.0,90.0)	148.107

{001}<250> max=148.12

{111}<112>

(111)[112]	(90.0,54.74,45.0)	53.337
(111)[1-21]	(30.0,54.74,45.0)	53.337

Copper max=53.3365

{001}<100>

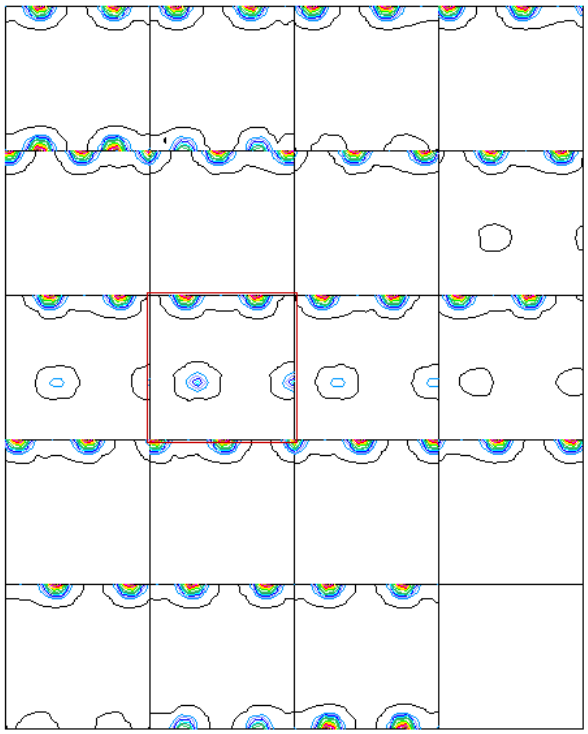
(001)[100]	(0.0,0.0,0.0)	21.372
(010)[100]	(0.0,90.0,0.0)	21.371
(010)[001]	(90.0,0.0,0.0)	21.372
(001)[0-10]	(0.0,0.0,90.0)	21.372
(001)[0-10]	(0.0,90.0,90.0)	21.371
(100)[001]	(90.0,90.0,90.0)	21.371
(001)[-100]	(90.0,0.0,90.0)	21.372

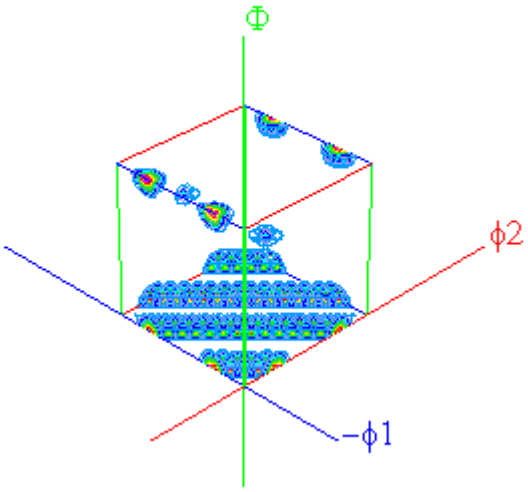
{001}<250> max=21.3724

S/2/M = 1.389　　S/5/C = 1.386

以降、反射極点図から各種 ODF で解析を行い、S/2/M,S/5/C を比較してみます。

Ｌａｂｏ Ｔｅｘで解析





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{011}<250>/2/{111}<112> {001}<250>/5/cube

{001}<250>

(001)[2-50]	(68.2,0.0,0.0)	148.41
(010)[205]	(68.2,90.0,0.0)	147.048
(010)[502]	(21.8,90.0,0.0)	147.048
(001)[5-20]	(21.8,0.0,0.0)	147.546
(001)[-5-20]	(68.2,0.0,90.0)	148.41
(100)[0-25]	(68.2,90.0,90.0)	147.048
(100)[0-52]	(21.8,90.0,90.0)	147.048
(001)[-2-05]	(21.8,0.0,90.0)	147.546

{001}<250> max=148.41

{111}<112>

(111)[112]	(90.0,54.74,45.0)	54.005
(111)[1-21]	(30.0,54.74,45.0)	53.864

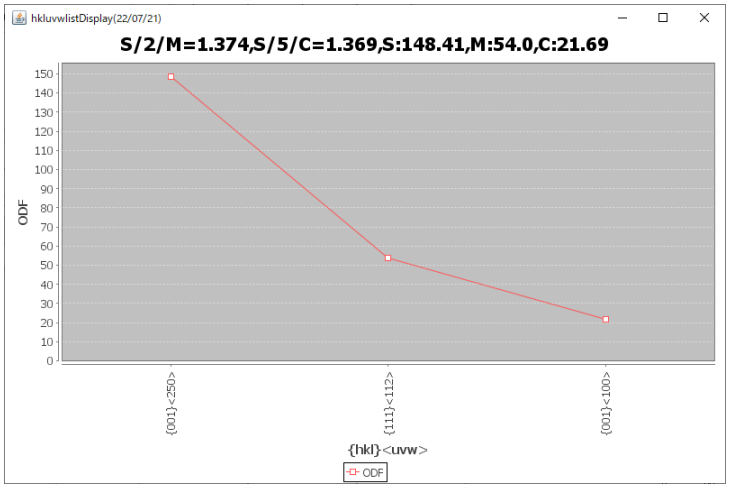
Copper max=54.0046

{001}<100>

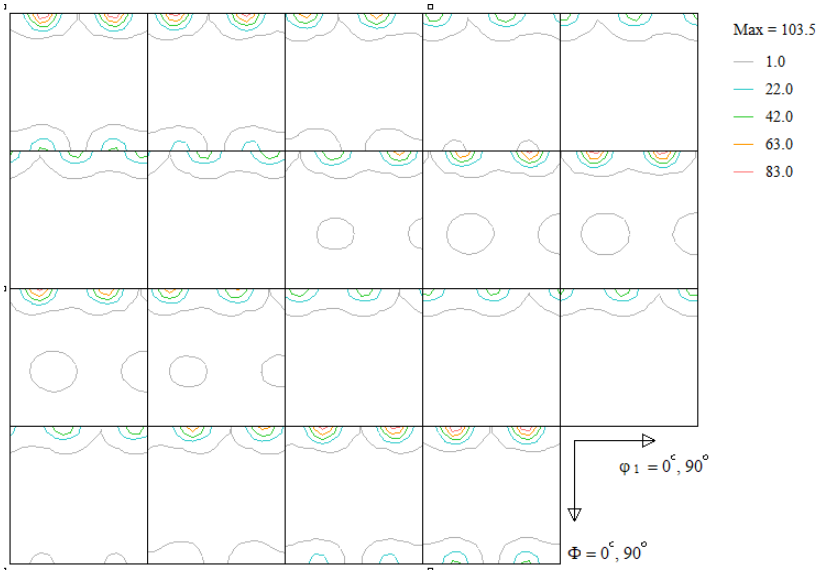
(001)[100]	(0.0,0.0,0.0)	20.489
(010)[100]	(0.0,90.0,0.0)	21.688
(010)[001]	(90.0,0.0,0.0)	19.877
(001)[0-10]	(0.0,0.0,90.0)	20.489
(001)[0-10]	(0.0,90.0,90.0)	21.688
(100)[001]	(90.0,90.0,90.0)	21.677
(001)[-100]	(90.0,0.0,90.0)	19.877

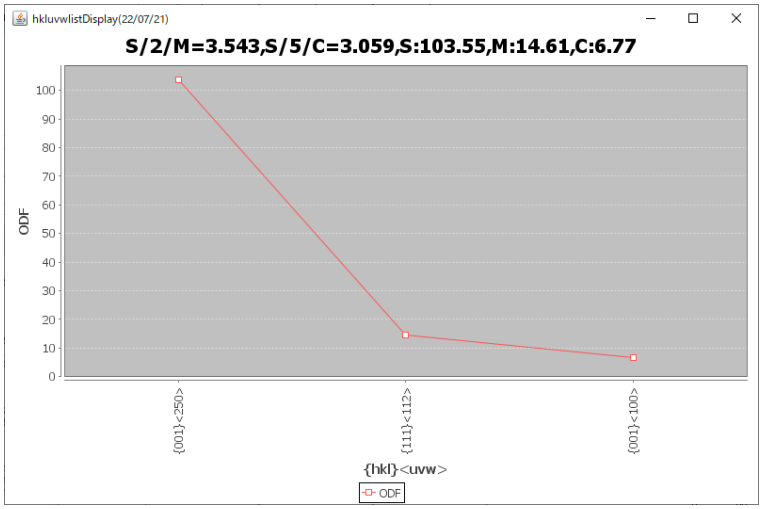
{001}<250> max=21.6876

S/2/M = 1.374　　S/5/C = 1.369



ＴｘＴｏｏｌｓで解析





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{011}<250>/2/{111}<112> {001}<250>/5/cube

{001}<250>

(001)[2-50]	(68.2,0.0,0.0)	102.258
(010)[205]	(68.2,90.0,0.0)	45.892
(010)[502]	(21.8,90.0,0.0)	45.908
(001)[5-20]	(21.8,0.0,0.0)	103.547
(001)[-5-20]	(68.2,0.0,90.0)	102.258
(100)[0-25]	(68.2,90.0,90.0)	45.892
(100)[0-52]	(21.8,90.0,90.0)	45.908
(001)[-2-05]	(21.8,0.0,90.0)	103.547

{001}<250> max=103.5471

{111}<112>

(111)[112]	(90.0,54.74,45.0)	14.615
(111)[1-21]	(30.0,54.74,45.0)	14.553

Copper max=14.6148

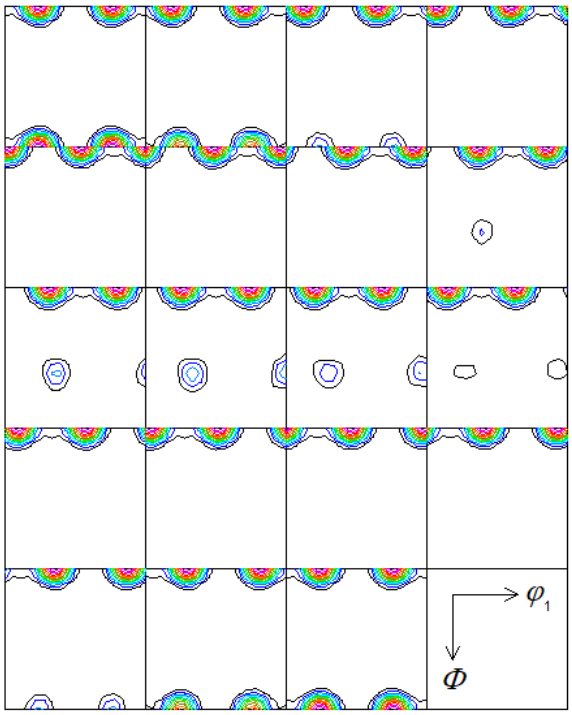
{001}<100>

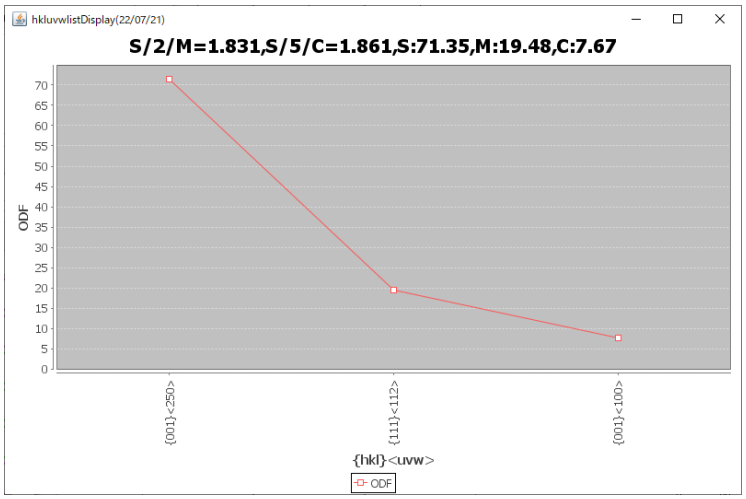
(001)[100]	(0.0,0.0,0.0)	6.593
(010)[100]	(0.0,90.0,0.0)	6.277
(010)[001]	(90.0,0.0,0.0)	6.77
(001)[0-10]	(0.0,0.0,90.0)	6.593
(001)[0-10]	(0.0,90.0,90.0)	6.277
(100)[001]	(90.0,90.0,90.0)	6.274
(001)[-100]	(90.0,0.0,90.0)	6.77

{001}<250> max=6.7704

S/2/M = 3.543　　S/5/C = 3.059

Ｓｔａｎｄａｒｄ ＯＤＦ で解析





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{011}<250>/2/{111}<112> {001}<250>/5/cube

{001}<250>

(001)[2-50]	(68.2,0.0,0.0)	71.347
(010)[205]	(68.2,90.0,0.0)	71.347
(010)[502]	(21.8,90.0,0.0)	71.347
(001)[5-20]	(21.8,0.0,0.0)	71.347
(001)[-5-20]	(68.2,0.0,90.0)	71.347
(100)[0-25]	(68.2,90.0,90.0)	71.347
(100)[0-52]	(21.8,90.0,90.0)	71.347
(001)[-2-05]	(21.8,0.0,90.0)	71.347

{001}<250> max=71.3470458984375

{111}<112>

(111)[112]	(90.0,54.74,45.0)	19.34
(111)[1-21]	(30.0,54.74,45.0)	19.48

Copper max=19.48024559020996

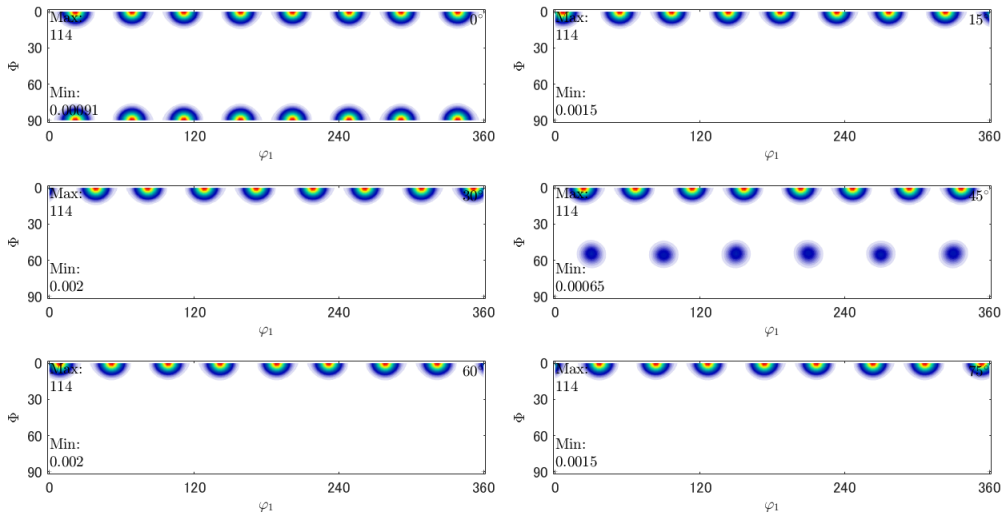
{001}<100>

(001)[100]	(0.0,0.0,0.0)	7.668
(010)[100]	(0.0,90.0,0.0)	7.668
(010)[001]	(90.0,0.0,0.0)	7.668
(001)[0-10]	(0.0,0.0,90.0)	7.668
(001)[0-10]	(0.0,90.0,90.0)	7.668
(100)[001]	(90.0,90.0,90.0)	7.668
(001)[-100]	(90.0,0.0,90.0)	7.668

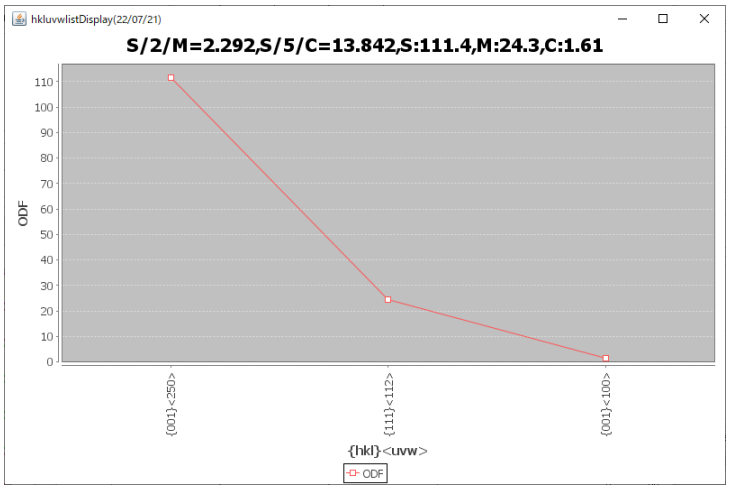
{001}<250> max=7.667993545532227

S/2/M = 1.831 S/5/C = 1.861

ＭＴＥＸで解析（FWHMはｄｅｆａｕｌｔ）




```
Radially symmetric portion:
  kernel: de la Vallee Poussin, halfwidth 5°
  center: 4930 orientations, resolution: 5°
  weight: 1
```



U:\2022-07-20-JP6260800-JFE\TXT2\MTEX\MTEXODF.txt

{011}<250>/2/{111}<112> {001}<250>/5/cube

{001}<250>

(001)[2-50]	(68.2,0.0,0.0)	111.4
(010)[205]	(68.2,90.0,0.0)	111.4
(010)[502]	(21.8,90.0,0.0)	111.4
(001)[5-20]	(21.8,0.0,0.0)	111.4
(001)[-5-20]	(68.2,0.0,90.0)	111.4
(100)[0-25]	(68.2,90.0,90.0)	111.4
(100)[0-52]	(21.8,90.0,90.0)	111.4
(001)[-2-05]	(21.8,0.0,90.0)	111.4

{001}<250> max=111.40015

{111}<112>

(111)[112]	(90.0,54.74,45.0)	24.304
(111)[1-21]	(30.0,54.74,45.0)	24.018

Copper max=24.303635

{001}<100>

(001)[100]	(0.0,0.0,0.0)	1.61
(010)[100]	(0.0,90.0,0.0)	1.61
(010)[001]	(90.0,0.0,0.0)	1.61
(001)[0-10]	(0.0,0.0,90.0)	1.61
(001)[0-10]	(0.0,90.0,90.0)	1.61
(100)[001]	(90.0,90.0,90.0)	1.61
(001)[-100]	(90.0,0.0,90.0)	1.61

{001}<250> max=1.60957

S/2/M = 2.292　　S/5/C = 13.842

まとめ

数値を集計すると

	{001}<250>	{111}<112>	{001}<100>	S/2/M	S/5/C
LaboTex	148.41	54	21.69	1.374	1.369
TexTools	103.55	14.61	6.77	3.543	3.059
StandardODF	71.35	19.48	7.67	1.831	1.861
MTEX	111.4	24.3	1.61	2.292	13.842

Ｃｕｂｅの値がばらつき、計算結果に反映しています。

解析ＯＤＦソフトウエアを固定した評価が必要