Textures and Microstructures, 1991, Vols 14–18, pp. 745–750
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Printed in the United Kingdom

ORIGINS OF MISORIENTATION TEXTURE (MESOTEXTURE)

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Characteristics of the misorientations between grains - "mesotexture" - are discussed. It is shown that a computer simulation approach is a useful way to probe both the relationship between microtexture and mesotexture and the form of the mesotexture.

INTRODUCTION

The term grain "mesotexture" (literally, "texture between" grains) has been introduced to complement the term grain "microtexture" which refers to local texture measured on a grain-by-grain, spatially specific basis (1-4). The "macrotexture", that is, the averaged global texture measured usually by conventional X-ray diffraction is the sum of all the component microtextures. Recent interest in microtextures, on a scale of perhaps a hundred grains or so, has been fostered largely by the development of electron back-scatter diffraction (EBSD) and other techniques which allow microtexture populations of grains larger than 1μm to be measured rapidly with minimal specimen preparation (4).

Where microtextures are obtained from contiguous grains, the misorientation between them can also be computed from the relationship:-

$$R12 = A1^{-1}A2 \qquad (1)$$

where A1 and A2 are the absolute orientations of two neighbouring grains expressed as 3x3 rotation matrices and R12 is the rotation matrix which specifies the misorientation between them. It has been observed that misorientation populations are frequently non-random in character - ie a mesotexture exists. The purpose of this paper is to discuss the origins of mesotexture, and particularly to show, by computer simulations, how it is related to microtexture.

CHARACTERISTICS OF MESOTEXTURE

A misorientation between neighbouring grains is usually described by an angle and axis of misorientation which may be obtained from the rotation matrix (eg 5). Hence mesotexture can be categorised into one of three groups:-

1. Angle mesotexture, eg a low/high angle classification (eg 6);
2. Axis mesotexture, eg a higher than average proportion of low-index axes which relates either to the crystal geometry (eg 7) or the specimen geometry (eg 8).
3. Combined angle and axis mesotexture, which is conveniently classified by the coincident site lattice (CSL) geometry (eg 9).

Figure 1 shows an example of this kind of mesotexture taken from a sample population of about 200 grains in annealed nickel which had an almost random microtexture (1). On this frequency histogram the CSLs are arranged according to ascending Σ-value.

SIMULATION OF MISORIENTATION

From equation 1 it is clear that the misorientation and orientations of a grain pair are inextricably linked. Where the grain sample population is arranged in more than one dimension, connectivity relationships have to be considered in addition to equation 1. For the meeting of grains (usually three) at a line, the following relationship obtains:-

$$R12\ R23\ R31 = I \qquad (2)$$

where I is the identity matrix. Equation 2 refers to the meeting of three grains at a triple grain junction as depicted in figure 2.

A useful approach to the study of mesotexture form and its relationship to the parent microtexture involves computer simulation of chosen microtextures followed by application of algorithms derived from equations 1 and 2 in order to obtain the related mesotexture. It is intuitively obvious that where the microtexture is very sharp the mesotexture will be similarly well-defined.

We will consider first the case of two grains having ideal textures for a well-known case - transformation of the $\{111\}\langle 11\bar{2}\rangle$ component of the bcc rolling texture to the $\{110\}\langle 001\rangle$ Goss texture upon annealing as occurs in silicon iron (eg 10). The misorientation between these two exact orientations is 3° away from a Σ=9 CSL, and so it is not surprising that this CSL is observed in experimental mesotextures (11). Furthermore each variant of the form of the two textures gives the same Σ=9 misorientation. This is not the case for ideal textures which have higher multiplicities. For example, the misorientation between the two texture variants $(210)[\bar{1}23]$ and $(10\bar{2})[\bar{2}3\bar{1}]$ is an exact Σ=5 CSL but the misorientation between $(210)[\bar{1}23]$ and $(10\bar{2})[231]$ is 0.4° from Σ=35b.

In a real microstructure there is a spread of orientation around the main texture component(s). The simulation procedure consists therefore of selecting an angular tolerance away from the ideal texture for the orientation of the rolling direction and rolling plane. An example of the absolute orientation of a grain which is <15° away from (111)<$\bar{2}$11> expressed in matrix form is:-

$$\begin{matrix} -.830 & .436 & .348 \\ -.092 & -.693 & .715 \\ .550 & .537 & .640 \end{matrix}$$

Datafiles of orientations which are within the selected tolerance of the orientations under consideration can be collated by use of a random number generator and appropriate algorithms (2). Mesotextures can then be obtained by suitable combinations of the microtextures. For the case of the (111)[$\bar{2}$11] rolling texture to (011)[100] Goss texture transformation quoted above (15° tolerance), the following CSL proportions were recorded from the simulations:-Σ=9 14%, Σ=27b 9%, Σ=35b 4%, Σ=33b 2%, Σ=15 1%, and Σ=7 1%. All of these CSLs are misoriented on a 210 axis except for Σ=33b which is misoriented on 740, which is only 3° away from 210.

The results of this simulation highlight the important point that the lowest-angle solution of a misorientation may not be the most significant physically.

TWINNING

If we progress now from a mesotexture simulation of a bcc material to one of an fcc material, we need to incorporate twinning into the simulation procedure, since it is now known that multiple twinning is an essential feature in the development of texture, particularly where the stacking-fault energy is low (eg 12). An example is the {011}<211> (rolling texture) to {311}<112> (annealing texture) change which occurs in some austenitic steels during recrystallisation (2,13). The mesotexture of the recrystallisation interface has been simulated including twinning up to the second generation in the new grains. Figure 3 shows a histogram which represents the mesotexture when grains having textures within 10° of (011)[2$\bar{1}$1] recrystallise to (311)[$\bar{1}$12], including the effect of the four primary twin variants, 60°/111, 60°/1$\bar{1}$1, 60°/$\bar{1}$1$\bar{1}$ and 60°/1$\bar{1}\bar{1}$. One of the twinning interactions represents the "maximum growth rate orientation" for fcc, 40°/111 (ie close to Σ=7). Presumably in the real microstructure this variant is selected in preference to the other three. When secondary twinning is also included the most populous Σ-values are 3,5,7,9,11,15,17b,23,25b,27b,29b and 35b. This is in very good agreement with experimental measurements (2).

The CSLs in the mesotexture are all characterised by being misoriented on either a 210 or a 331 axis. There is a simple multiplication rule for triple-grain junction combinations of CSLs which are misoriented on a common axis as illustrated in figure 2; but in addition other combinations can give Σ-values which are close to exact CSLs. For example, two Σ=27b boundaries can conjoin on a 210 axis to give a third boundary which is 2.6° from Σ=7. In fact it turns out that the Σ-values in this mesotexture can all be mutually regenerated by such interactions. Where the boundaries at a triple grain junction do not join in a rational axis, equation 2 applies, for example:-

21.5°/704 702 108 + 20.8°/654 551 519 → 14.5°/910 414 016
near Σ=33a near Σ=21a low angle

CONCLUDING REMARKS

This paper shows that the geometrical characteristics of a mesotexture can be predicted from simulation of the spread of the microtexture. Twinning has a marked effect on the mesotexture, and a simulation procedure can be used to monitor these effects.

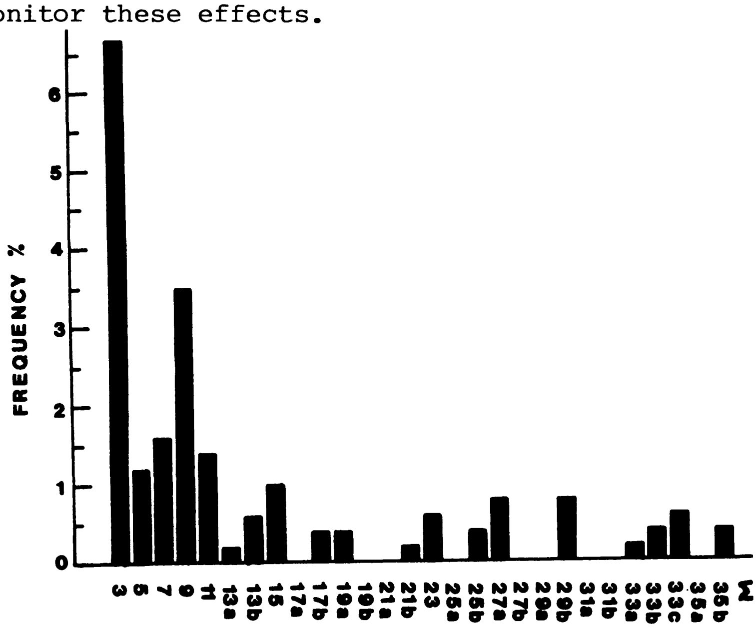

Figure 1 Mesotexture from annealed nickel.

REFERENCES

1. J. Furley and V. Randle, submitted to Mat.Sci.Tech.
2. V. Randle, Proc. Microstructure and Mechanical Processing, Inst. of Met., (1990) in press.
3. V. Randle, Proc. Roy. Soc., in press.
4. D.J. Dingley and V. Randle, (review), submitted to J.Mat.Sci.
5. P.H. Pumphrey and K.M. Bowkett, Scripta Met., 5, 365 (1971).
6. T. Watanabe, Y. Suzuki, S. Tanii and H. Oikawa, Phil. Mag.Lett., 62, 9 (1990).
7. V. Randle and B. Ralph, J.Mat.Sci., 23, 934 (1988).
8. F. Haessner, J. Pospiech and K. Sztwiertnia, Mat.Sci. Eng., 57, 1 (1983).
9. V. Randle and A. Brown, Phil.Mag., 59A, 1075 (1989).
10. W.B. Hutchinson, Acta Met., 37, 1047 (1989).
11. R. Shimizu, J. Harase and D.J. Dingley, Acta Met.Mat., 38, 973 (1990).
12. G. Gottstein, Acta Met., 32, 1117 (1984).
13. M.J. Dickson and D. Green, Mat.Sci.Eng., 4, 304 (1969).

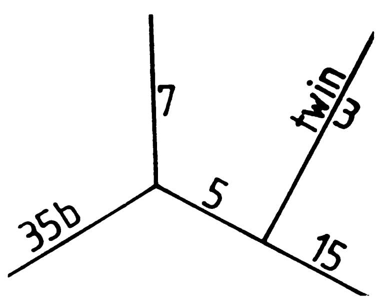

Figure 2 Schematic example of grain junctions showing the interrelationship between Σ-values.

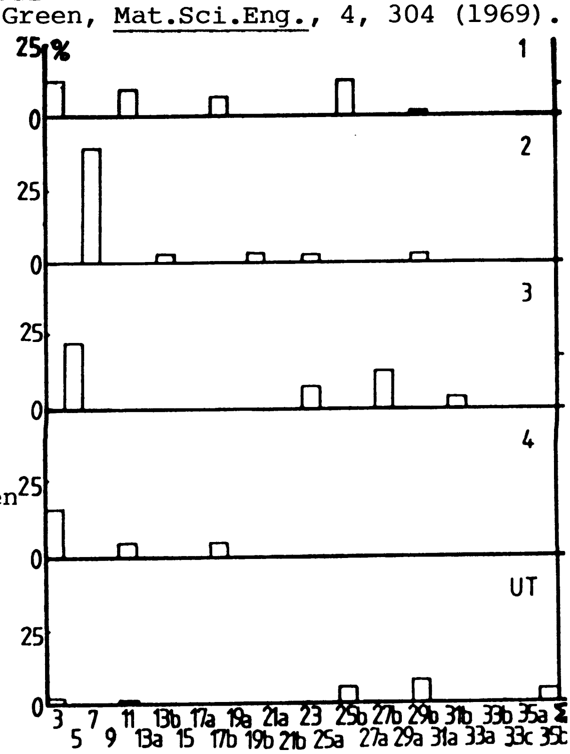

Figure 3 Mesotexture for a simulated texture change including the four primary twin variants of the new texture.