INVESTIGATION OF MICRO-CRACK PROPAGATION IN THE NICKEL BASED ALLOY 80A DURING HOT FORMING BY 3D-EBSD

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INTRODUCTION

During hot forming of deformable materials only narrow deformation windows exist in terms of temperature und strain. If these deformation windows were exceeded, the probability for the initiation of cracks is strongly increased. To initiate cracks in a nickel based alloy 80 A a sample was hot compressed by a hydraulic press at a temperature of 1000°C at a true strain rate of 0.39 1/s to a true strain of 0.59 [1]. Afterwards a 3D-EBSD investigation of this specimen was performed to elucidate both the crack propagation and the structures surrounding the cracks.

EXPERIMENTAL SECTION

Sample preparation:

Compression test [1]

- Cylindrical sample (d = 16mm, h = 24mm) of alloy 80A

C	Al	Si	Ti	Cr	Mn	Co	Ni	Mo
0.06	1,67	0,15	2,52	19,6	0,04	0,06	75,1	0,03

- Solution heat treatment was done at 1200°C for 2 minutes
- Hot compression tests were carried out at a 100 ton hydraulic press (T = 1000°C, average true strain rate 0.39 1/s)
- After the first cracks were visible the compression was stopped (corresponds to a true strain of 0.59)

Serial sectioning for 3D-EBSD [2,3]

- A half of the transversal cross section at half its height was embedded in resin for this investigation (see Fig. 1)
- After the first polishing Vickers indentations were made for measuring the thickness of the removed layer using light microscopy
- At each sectioning step the surface was ground with grinding paper P4000 for 4 minutes, followed by C-polishing for 12 min and silica polishing for 90 min.

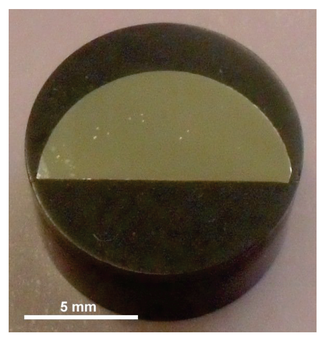

Fig. 1: Embedded cross section with indentations

Results:

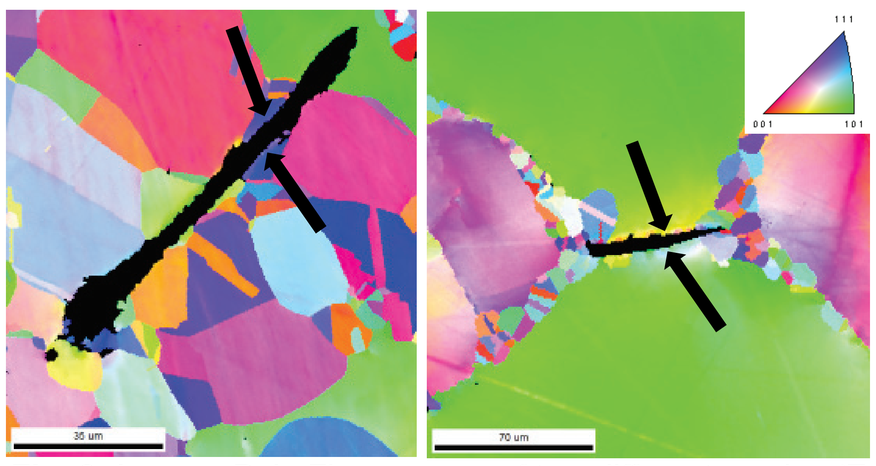

Fig. 2: Inverse Pole Figure maps of two different cracks; (E_0 = 20 keV and I_p = 7 nA)

Figure 2 shows the inverse pole figure maps of two different cracks and it can clearly be seen that the surrounding of the cracks is quite different. The crack shown in the left image propagates in the region of the recrystallized grains, not necessarily along grain boundaries but also across the grains themselves (see arrows). In the right image of Figure 2 the crack is located between unrecrystallized grains with recrystallized grains at the tip of the crack. Additionally, the unrecrystallized grains show a high misorientation density close to the crack (see arrows), which indicates that the formation of cracks did not reduce the stress in its surrounding. From these two 2D-EBSD no clear interpretation about the propagation of the crack and the stopping effect on this propagation can be formulated. For this reason a 3D-EBSD via the serial sectioning method, as described in the sample preparation section, was applied to this specimen. The results of this sectioning along a depth of 35 µm are shown in Figure 3. It can be seen that the crack propagates along high angle grain boundaries. Along the surrounding of the crack the misorientation density is always high except at regions where recrystallized grains have already been formed. Due to the fact that the crack disappears in the region of the recrystallized grains and that the tip of the crack stops also in a region of recrystallized grains it can be concluded that recrystallized grains have a stopping effect on the propagation of cracks in a specimen with rather high fraction of recrystallized grains.

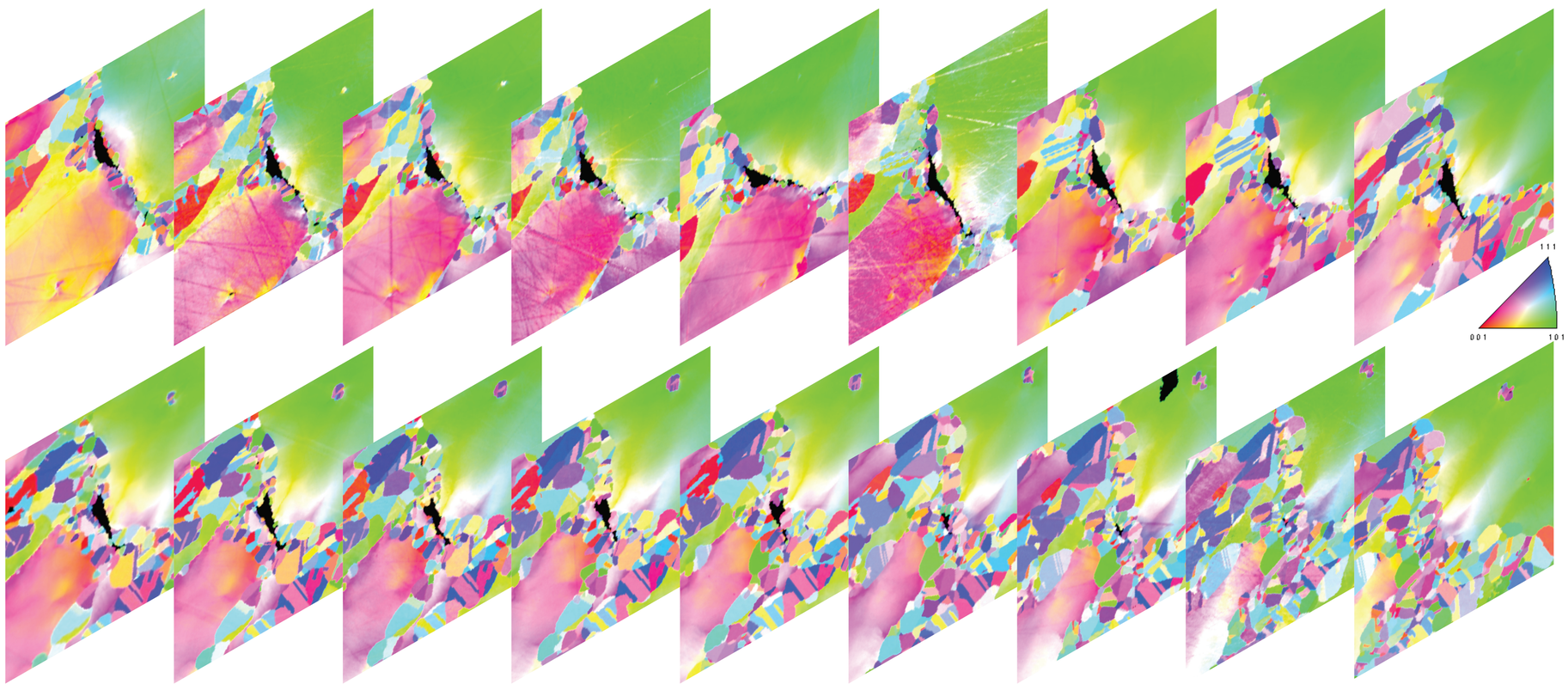

Fig. 3: 3D stack of inverse pole figure maps showing the evolution of a crack along a depth of 35 µm; image width 196 µm (E_0 = 20 keV and I_p = 7 nA)

CONCLUSION

Serial sectioning is a useful method to investigate large specimen areas in 3D. The 3D-EBSD results of a hot compressed specimen of the nickel based alloy 80A, which is partially recrystallized, proves that the recrystallization occurred before the cracking and these recrystallized grains have a stopping effect on the propagation of a crack. Generally the cracks propagate along high angle boundaries and have no reducing effect on the stress in the surrounding of the cracks.

INSTRUMENTATION

- SEM Zeiss Ultra 55
- DigiView camera from EDAX- TSL
- TSL OIM Analysis Software 6.1.3

LITERATURE

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