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MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

ON THE PLASTIC DEFORMATION OF HIGH PURITY IRON AND Cu-Zn BRASSES

NABIL FAT-HALLA*, SALAH EL GEMAE* AND MOHAMMED A. ABDOU*

ABSTRACT

Deformation characteristics of high purity iron was studied through both tension and rolling. The surfaces of the deformed specimens were observed by optical microscopy at magnifications up to 2000. Slip characteristics were studied for the tensile specimens up to 17% strain and for the cold rolled specimens up to about 72% reduction in thickness. Increasing the per cent of deformation gradually increased the dislocations density. It was observed that in case of tension the dislocations took the form of regular rows of parallel lines, which was not the case in the rolled specimens. α/β brass bicrystals made by the solid state diffusion technique, have been used to clarify the slip characteristics in both α - and β -brass. The change of the slip traces morphology in α -iron (bcc) and β - brass (bcc) was attributed to the different constraint conditions in each case.

INTRODUCTION

The establishment of the dislocation theory |1-3| has undoubtedly put forward the interpretation of the plastic deformation of metals and alloys. On the light of this theory, phenomena such as, onset of plastic yielding, yield drop, increase and decrease of work hardning rates, and effect of hardening methods in crystals on mechanical properties could be clarified |4|. However, the observation of slip characteristics of metals and alloys with different crystal structures is of great importance. Inspite of the common general features of the deformation behaviour of bcc family |4|, or fcc family of metals |4| or alloys it seems that each metal or alloy in the same family has its own or special characteristics which finally throw the light on more details of the phenomena.

The aim of the present work was to study the deformation behaviour of some bcc and fcc metals and alloys through the observation of dislocations configurations, and the slip traces in order to better understand the plastic deformation characteristics as a first step towards the improvement of its mechanical properties.

* Associate professors,
Mechanical Department, Faculty of Engineering, AL Azhar University

Experimental Procedure

The materials used in the present investigation were α- high-purity iron and cu-Zn brass with the analysis shown in Table 1 measured in weight %.

Table 1: Chemical composition

Material	Elements						
	C	N	Si	S	P	Mn	Fe
α-Iron	0.005	<0.001	0.004	0.005	0.001	trace	Balance
	Zn	Fe	Pb	Sn	Cu		
α-Brass	29.9	0.001	0.001	0.001	Balance		
β-Brass	47.4	<0.001	0.004	<0.00	Balance		

The iron was forged to strips 10x30 mm^2 and then hot rolled to 4 mm thickness at a temperature of 1373K. After annealing of the strips at 1213K for 3.6 ks some samples were deformed by tension at a strain rate of 10^{-3} s^{-1} to plastic strains between 8 and 17%. The rest of the starting material were cold rolled on a laboratory cold mill with successive thickness reduction of 8,27,45 and 72%. The structural changes associated with cold deformation were examined by optical microscopy.

α(fcc)/β(bcc) brass two phase bicrystals made by the solid state diffusion technique |5| was used, in the present investigation, to study its plastic deformation in tension at a strain rate of 10^{-3} /s through the observation of the slip traces by optical microscopy. The use of bicrystals allowed easily observations owing to the large grain (crystal) size available. Additionally, comparison between bcc iron and bcc β-brass could be analyzed and discussed.

Results and Discussion

Since the main purpose of the present investigation is to study the slip characteristics it is of special interest to detect the dislocation strength, slip planes and slip directions in each used metal or alloy. Table 2 delineates the lattice parameters |6| for α-brass and β-brass for specific composition. The strength of the Burger's vector was calculated for the α-iron and β-brass using the formula; a/2 |111|, also for the α-brass using the formula a/2 |110|. The results are given in Table 2.

Table 2. Lattice Parameters and Burger's vectors for α-iron, α-brass, β-brass

	α-iron (bcc)	α-brass (fcc)	β-brass (bcc)
Lattice Parameter (a)	2.8664 A°	3.6932 A°	2.9539 A°
Burger's vector (b)	2.48 A°	2.61 A°	2.58 A°

Fig.1 shows the microstructure of the as-rolled high purity iron after thickness reduction of 27% the photograph, also, exhibits elongated grains. The dislocations configuration of specimens rolled to 8,27 and 45% are shown in Fig.2(a) to (c) respectively. It can be, clearly observed from

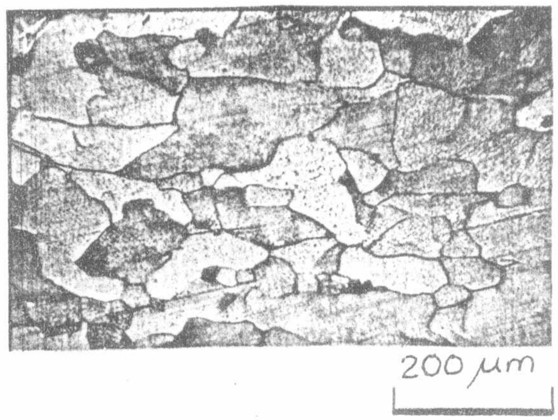


Fig1. The structure of high purity iron after deformation by rolling (ε = 27%).

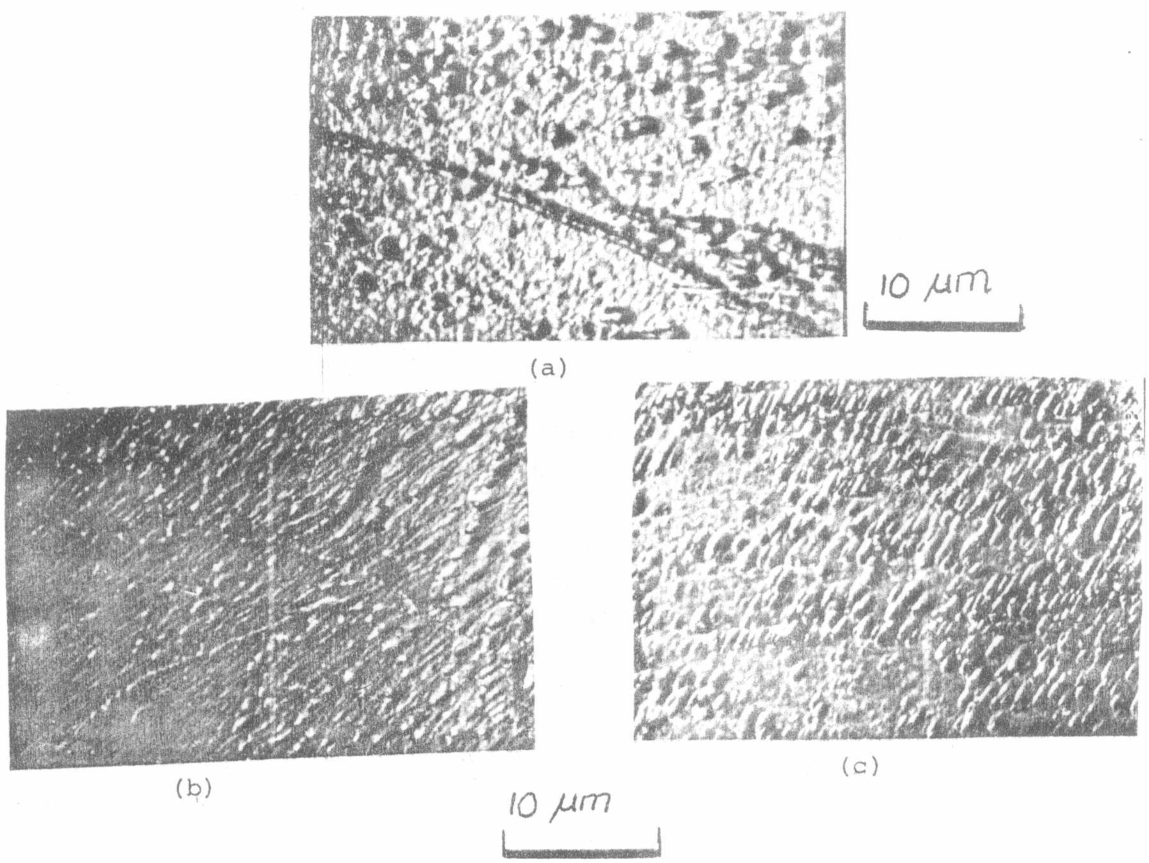
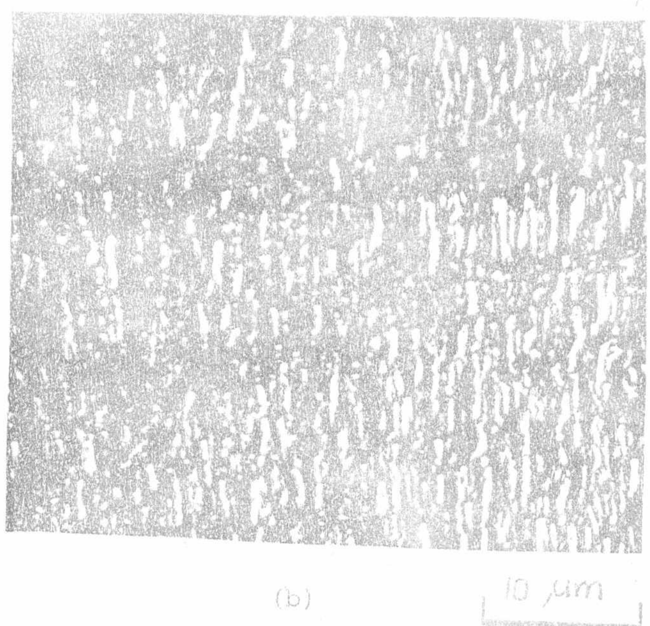


Fig.2 Dislocations structure of high purity iron after deformation by rolling

a) ε = 8% b) 27% c) 45%.

(a)



(b)

Fig.3 Dislocations structure of high purity iron after deformation by tension

a) $\varepsilon = 8\%$

b) $\varepsilon = 17\%$

the photos that; (i) dislocations are more or less randomly distributed, and (ii) dislocations density increases monotonically with strain (Cf.Fig .2 (a) and (c)). On the other hand, the dislocations configuration for a sample specimen tensile tested at room temperature, up to a strain of 8%, shows more uniform distribution of dislocations as illustrated in Fig.3(a,b) A comparison between Fig.2(a) and Fig.3(a) clarify the difference in the dislocations configurations in both the deformation techniques.

Before getting into the results of the slip characteristics of the three phases used in the present investigation it is of importance to review the slip systems expected during their deformation. The α-brass of the composition used (about 30 wt%Zn) is known to deform in tension on invariable slip system of the form {111} < 110> |7,8|. This characteristic of slip for the α-brass might result in straight and well defined slip traces. On the other hand, β-brass is known to deform on {hkℓ} <110> |9,10|. The operative slip plane is reported to be between {110 }and {112} owing to the test temperature and orientation |10 |. The variation of the slip plane in this alloy frequently occurs since the critical resolved shear stress (CRSS) is more or less close to each other for the planes under consideration. The easiness with which the slip plane is changed, however, do affect the slip traces characteristics in this alloy. The slip traces are expected to be fine and wavy. Finally, the α-iron (bcc) deform by slip in any of the <111> directions. The slip planes are numerous. They include the {110} , {112} and {123} planes |11|. The slip lines (traces) that are seen on the crystal surface generally are very wavy. This indicates that the dislocations which produce slip are not confined to unique slip planes.

Fig.4 exhibits the slip traces as observed by optical microscopy on the surface of high purity-iron specimens (bcc) at high magnification. As was expected, the slip traces are more or less wavy, however, since the magnification is about 2000, the slip lines may seem to be straight. A recent research |12 | on (bcc) α-iron with some traces confirmed the present observations. On the other hand, the slip traces observed on the surface of α/β brass bicrystals as tensioned at room temperature are shown in Fig.5. It can be noticed from Fig.5 that , (i) for the α -brass the slip traces are straight and well defined, additionally, double slip can be seen, however, the slip systems corresponds always with {111} <110> . On the surface of the β-phase curved slip traces can be observed. It seems that for bicrystals, the operative slip system near the phase boundary differs from that system operative in the interior of β-phase. It is of special interest to the present research to compare the slip traces on α-iron and β-brass, both having bcc crystal structure. The wavy slip traces observed in Fig.4 was not observed in Fig.5 on the surface of the β-brass. These results can be plausibly interpreted due to different constraint conditions in both cases. In the α-iron grains, each grain is surrounded by neighbouring grains everywhere, however, in case of bicrystals, only one neighbouring crystal do exist. The constraints on plastic deformation offerred by surrounding conditions play an important role on the slip characteristics.

CONCLUSIONS

1- Change of dislocations configurations due to increased plastic strains in tension and rolling for high purity α-iron has been studied. In -

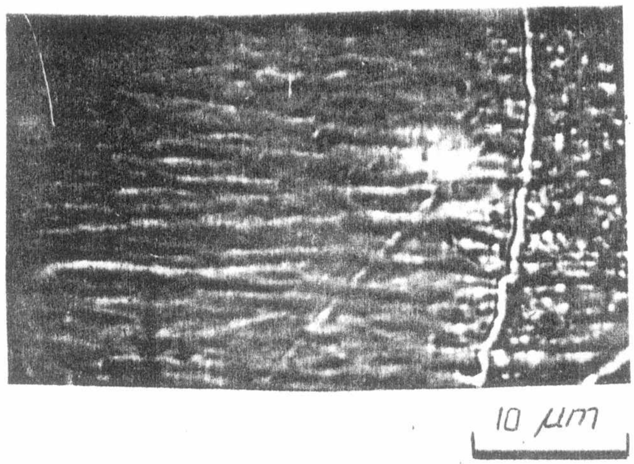


Fig.4 Slip characteristics of high purity iron after deformation by tension, (ε = 17%)

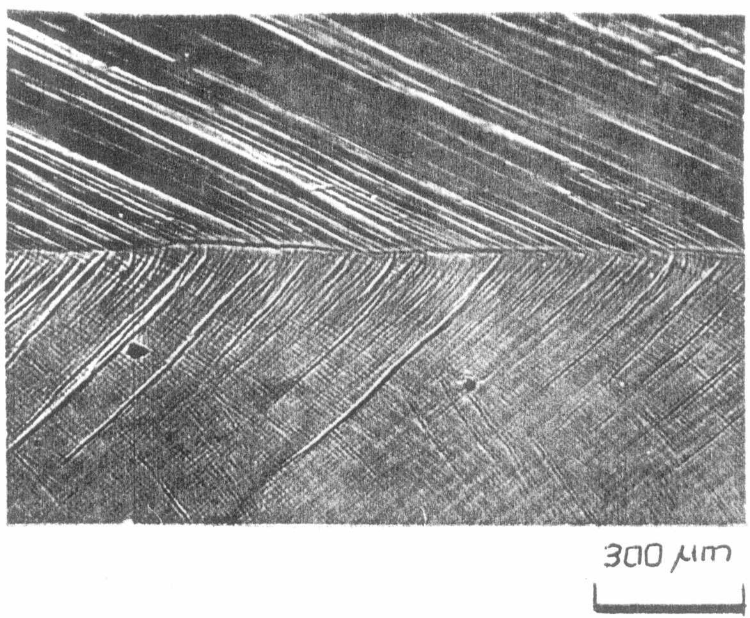


Fig.5 Slip characteristics of α - and β -brass deformed by tension (ε =10%)

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addition slip characteristics for, α-brass and β-brass have been presented and discussed.

2- A comparison was made between the slip characteristics of α-iron (bcc) and β-brass (bcc). The discrepancy in the behaviour was referred to the different constraints in each case.

ACKNOWLEDGEMENT

The present authors wishes to express their thanks to Eng.Mahmoud Nour EL Deen for helping in development and printing of photographs.

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