Study on the Effect of Pulse Current on Plasticity of the Pure Ti

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Abstract. The tensile experiments were carried out under different conditions of pulse current on pure titanium. The influence of pulse current density on the actual stress strain curve, elongation and the tensile strength were also analyzed. The experimental results show that pulse current could change material elastic constants and result in a decline in the yield stress of the material. With the pulse current, the tensile strength of Ti decreased by 62.2% while its elongation kept almost unchanged. At the same time, microstructure was also different. With the increase of pulse current density, grain size of Ti tends to be more uniform and equiaxial and a directional arrangement of the grain can be more easily observed.. It showed that intracrystalline defects were decreased gradually with the low quantity of slip system and dislocation, for the electronic wind caused by drift electrons was not strong enough for the dislocation motion.

Introduction

Electro plastic effect is a phenomenon that, with pulse current, the plasticity increases while deformation resistance decreases with the interactions between drift electrons in the metal and the dislocations involved in the deformation process [1]. Electro plastic effect is an important content in the field of materials science, which has been successfully applied in practical production to solve the problems in processing. It can improve the structure and the plasticity of the material which processing performance is very poor. Microstructure is significant to the performance of materials, so the effect of pulse current on microstructure and dislocation morphology is related with many factors such as pulse current density, deformation temperature and deformation rate[2-3]. In this paper, the effect of pulse current on microstructure and dislocation morphology has been analyzed based on the sample of pure titanium.

Experiment Set-up

The experimental material is pure titanium rolling sheet with thickness of 1.2 mm provided by Baoji Metal Materials Company, and the chemical composition is showed in table 1.

Table 1 the composition in weight percent of Ti(Wt-%)

Ti	Fe	C	N	O	H	Others
99.5	0.15	0.07	0.02	0.14	0.0012	<0.02

According to GB/T228–2002 standard “metallic materials tensile testing at ambient temperature” was formed by stamping along the rolling direction specimens with the geometry and final dimensions shown in Figure 1.The LCJ-150 type electronic torsion testing machine is employed to perform the tensile tests at a constant speed of $1.67\times10^{-3}s^{-1}$. During the tensile deformation of titanium specimens, direct current electric field in the loading direction is applied by numerical control bidirectional pulse plating power supply and electric fan is used to cool the temperature of the sample.

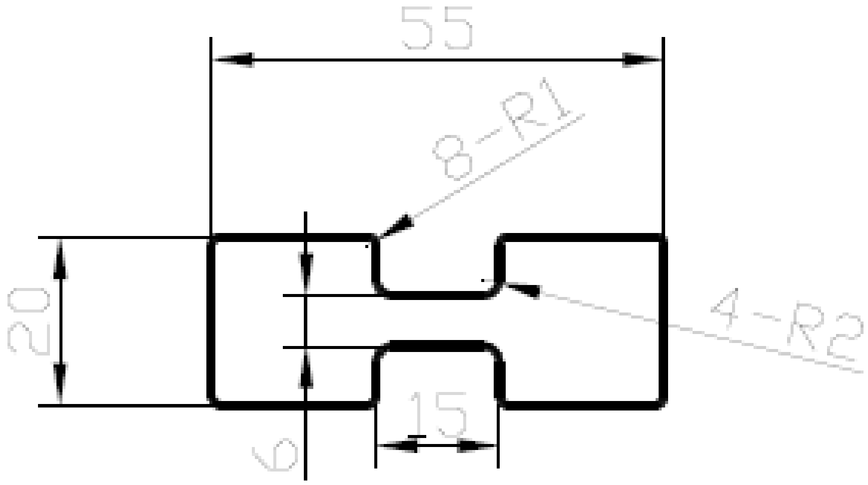


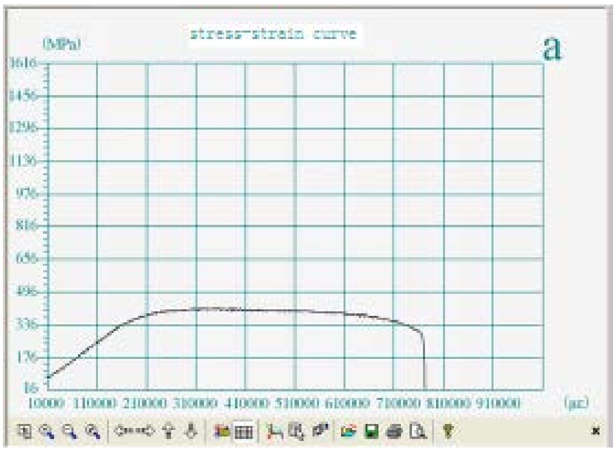
Figure1 Tensile sample

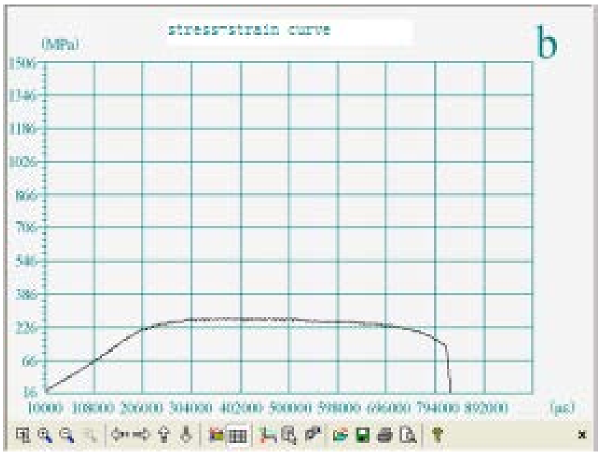
The electron microscope samples were evenly sliced into 0.3 mm and then pasted on glass slide of the ultrasonic cutting machine. The samples were rushed into a circular shape with diameter at most 3mm. With surface mechanical attrition treatment, the samples were ground to about 100μm. The samples were reduced to suitable thickness by ion beam thinner and then observed by the JEM-2100F type transmission electron microscope.

Effect of Pulse Current on the Property

Stress Strain Curve

The experimental result of the stress strain curve for titanium without pulse current is presented in Figure 2a. During the uniaxial tension, pulse current at 10% duty cycle is connected to samples and figure 2b shows the stress strain curve under the condition of $J=5.56\times10^2 A/cm^2$. As can be seen from the figure 2c, without pulse current, the sample changes from elastic deformation into uniform plastic deformation along the cure OAB; while, with pulse current, stress strain curve turns into the curve OA_1B_1. Under the condition of pulse current, compared with a non- marked increase in total strain, the total elongation increases slightly in uniform plastic stage while tensile strength decreases remarkably. Under the condition of the same deformation rate, the sample is in the state of elastic deformation and the slope of its stress strain curve OA_1 is significantly smaller than OA which is the result of curve for samples without pulse current. This phenomenon shows that pulse current could impact the material elastic constants and, to some extent, module and Poisson's ratio. Titanium has no obvious yield point. So it can be assumed that plastic elastic deformation occurs at the point of A after elastic deformation on the curve OA. Compared with curve OAB and OA_1B_1, yield stress with pulse current is less than samples' without pulse current. It indicates that with pulse current, the yield stress of titanium declines remarkably. As presented in Figure 2c, by applying the pulse current, the tensile strength of titanium declines remarkably and the elongation increases little.





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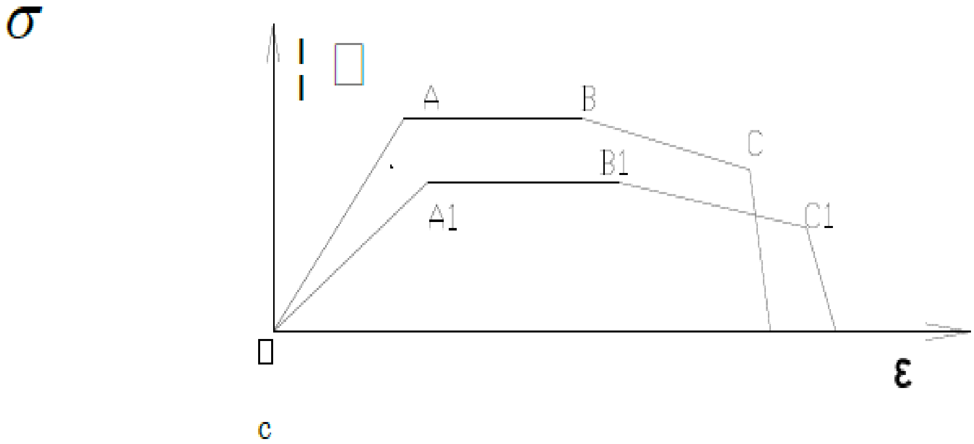


c

Figure 2 Stress-Strain curve

a Stress-Strain curve without pulse current b Stress-Strain curve with pulse current c simplified Stress-Strain curve of a,b

Tensile Strength and Elongation

Formability of sheet metal is closely related with its ability to resist necking during the stretch, which can be improved by pulse current. Figure 3 shows the actual results of the tensile strength and elongation of metallic titanium under pulse current. It can be seen that tensile strength is obviously reduced under the influence of pulse current and it dramatically drops with the increase of pulse current density. Tensile strength drops from 370Mpa to 140Mpa with a decrease of 62.2 percent when applying pulse current density $J=7.64\times10^2 A/cm^2$, but elongation is not improved as expected. The results are consistent with influences when pulse current is applied on stress-strain curve in figure 2, in which the elongation of titanium changes unobviously while tensile strength remarkably decreased.

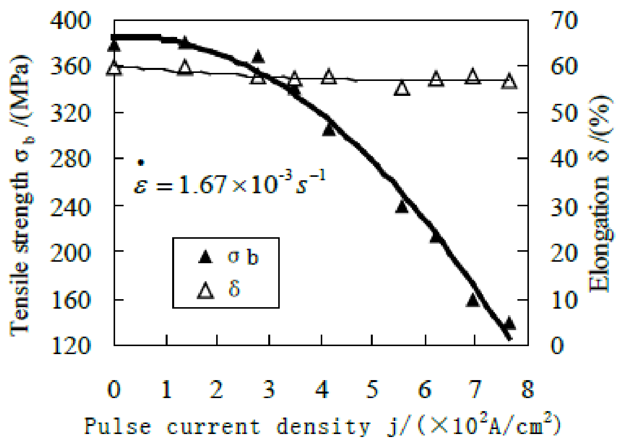
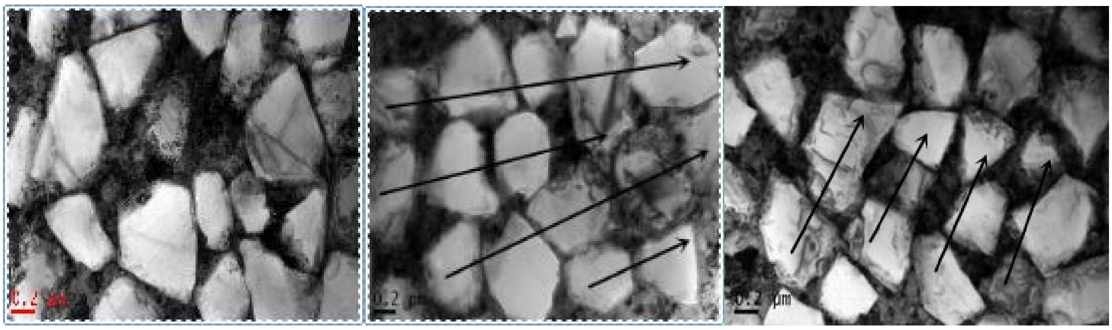


Figure 3 Influence of pulse current on elongation and the tensile strength

Effect of Pulse Current on the Micro Structure

Crystal Texture

The grain structure of titanium under different conditions of pulse current is presented in Figure 4. The research results show that the bigger the pulse current density is, the more directional grain' arrangement is. Without pulse current, the arrangement of crystals is not clearly oriented, and even clutter. Under the condition of pulse current density $J=5.56\times10^2A/cm^2$, crystals are oriented obviously, but the stagger area still destroys the direction of the grain. When pulse current density is $7.64\times10^2A/cm^2$, crystasl are exceedingly directional and grain orientation tends to be paralleled to each other. In addition, it can be observed in Figure 4 that the grain size of titanium presents uniformity with the increase of pulse current density. The grain size is in the range of 0.2~0.8μm and a lot of defects and sub-grains in the crystal can be found without pulse current. The defects in the crystal reduce by applying pulse current. When pulse current density is $7.64\times10^2A/cm^2$, figure 4c shows that the superfine and uniform equiaxed crystals with size of 0.3μm are gained and there are no obvious defects in the area. With the increase of pulse current density, the high angular grains of big size break down and are rearranged, then they transform into low angular subgrains. Wafer-like subgrains elongate horizontally and shrink longitudinally, and finally tend to stability and directionality [4-5].



a b c

Figure 4 Influence of pulse current on crystal texture

a crystal texture without pulse current b crystal texture at $J=5.56\times10^2A/cm^2$ c crystal texture at $J=7.64\times10^2A/cm^2$

Dislocations

Titanium is HCP metal at room temperature and it has six slip systems $\{10\bar{1}0\}\langle 11\bar{2}0\rangle$. The dominant process of superplastic deformation is slip and twining. The dislocations in the glide of titanium after stretching under the condition of pulse current are presented in Figure 5. We can see that slip systems and dislocations are few, for dislocation multiplication and dislocation annihilation reach the dynamic balance by applying pulse current which prevents the formation of dislocation walls and dislocation tangles. Electrons will drift, which carries the external stress called electronic wind acting on dislocations to enhance their mobility. Electronic wind helps dislocations avoid and overcome obstacles to make dislocation slip smoothly. Finally the strength of the metal declines [6-7]. However, under the experimental condition, dislocation walls and dislocation tangles can not be observed with the low number of dislocations in titanium and electronic wind is not strong enough to enhance their mobility. So the elongation does not increase a lot. But electronic wind will help potential slip systems in crystals more conducive to motion and make more slip systems participate in the slip[8]. Electronic wind makes dislocations move only along favorable orientation glide plane, which makes the tensile strength decrease.

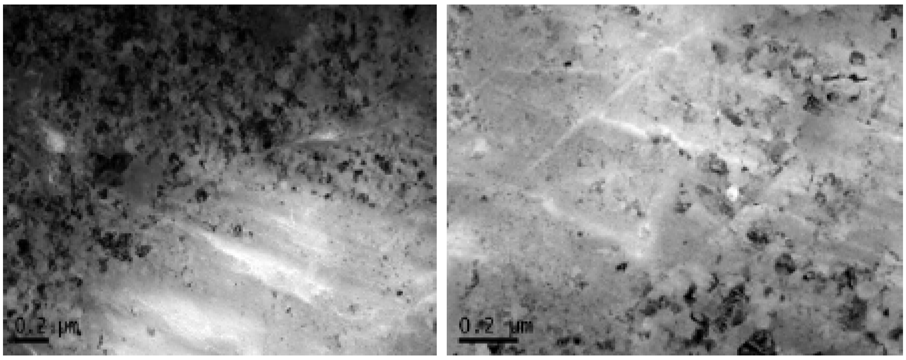


Figure 5 Influence of pulse current on dislocations

Summary

(1)The results show that pulse current has effect on the stress strain curve and elastic constants. The tensile strength of titanium declines remarkably and also the yield stress declines in some degree.In the experiment the tensile strength drops from 370Mpa to 140Mpa with a decrease of 62.2 percent and the elongation increases little.

(2)The grain distribution of titanium is changed by applying pulse current. With pulse current, crystals are exceedingly directional and the grain size presents uniformity. At the same time the defects in the crystal reduce.

(3)Under the experimental condition, slip systems and dislocations are few when applying pulse current.

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