Microstructural Investigation on Severe Cold work and Treated Copper Drawn Wires

Adnan A.Ugla, Khalid A. M. ,Talib H. A. , Sadiq M. I. and Fadhil A.H.

Mechanical Engineering Department

College of Engineering

Thi-Qar University

Abstract

The aim of this work is to study the microstructure of severe cold work copper wires, which its already processed at Ur Foundation (Nasyeria) which in Ur are cold drawn from 10 mm to 2 mm in diameter, then at final process it will be treated automatically by treated box by 200^{o} C (semi treatment). Our work dealing with taken the final drown wire (2 mm in dia.) and doing a laboratory treatment by 200^{o} C, 300^{o} C, 400^{o} C, and 500^{o} C, one hour at this temperature and the furnace cooled. The result which concluded that the Ur treatment is hot full treatment but a stress relief one with almost same wire property. While the treated wires show a recrystallized structure with inclination by 45^{0} angle for this structure. The high treated temperature shows grain growth and demises the 45^{0} angle structure.

المستخلص

تهدف هذه الدراسة إلى التعرف على البنية البلورية للأسلاك النحاسية بعد إجراء عمليات السحب على البارد ولنسبة سحب أكثر من ٩٠% وما ينشأ عن ذلك خلال إجراء المعاملة الحرارية التي تبدأ من الاسترجاع (Recovery) وصولاً إلى إعادة التبلور و التي من خلالها يمكن التعرف على تأثيرها في استخدامات هذه الأسلاك. حيث تم استخدام أسلاك نحاسية مسحوبة من قطر ١٠ ملم و لغاية ٢ ملم و خلال أكثر من عشرة مراحل سحب على البارد ثم في نهاية المطاف أخذت عينات من تلك الأسلاك و أجريت عليها معاملة حرارية بدرجات حرارية ٢٠٠ْ م، ٣٠٠ْ م، ٤٠٠ْ م ، و ٥٠٠ْ م داخل الفرن و لفترة ساعة واحدة ثم تركت تبرد في داخل الفرن الحراري عند تلك الدرجة الحرارية وتم مقارنة البنية البلورية لتلك الأسلاك مع السلك الذي يجرى عليه معاملة حرارية بدرجة ٢٠٠ْ م بعد سحبه داخل وحدة المعالجة الحرارية المرفقة مع ماكنة السحب. كل عمليات السحب أجريت في شركة اور (الناصرية) اما المعاملة الحرارية فاجريت في مختبرات كلية الهندسة-جامعة ذي قار. كانت النتائج قد بينت ان بنية السلك في نهاية عمليات السحب الى قطر ٢ملم دون اي معاملة حرارية لا توجد اي حدود بلورية وكانت البنية محطمة نهائياً نتيجة السحب العالي بحدود ٩٦% CW. اما السلك المعامل في شركة أور فانه يبين ذات البنية التي حصلنا عليها دون المعاملة الحرارية، اما السلك المعامل في المختبر بدرجة حرارة ٢٠٠ْ م فانه يبين بداية اعادة بناء و تبلور بزاوية اقل من 45^{0}. اما السلك المعامل بدرجة حرارة 400^{o} C فانه أعيدت حبيباته إلى الوضع الطبيعي.

1. Introduction

High quality wires have been widely used as electrical wires in microelectronics, telecommunication, network and transportation. Several approaches have been developed to manufacture copper wires, such as continuous casting and rolling, dipping and upward casting. However, the electrical conductivity and elongation of the copper wires with polycrystals fabricated by these approaches are limited due to transverse grain boundaries in the rods. Besides, fabrication of fine Cu wires without breaking is another challenge and many efforts to solve the problem have been made [1-4].

2. Effect of Cold Work on Recrystallization of Copper Wire During Drawing Process

Recrystallization is the rearrangement of the atoms or molecules of the solid into an entirely new set of crystals. This results in drastic changes in the properties such as tensile strength and ductility. For cold-worked metals and alloys recrystallization usually occurs at temperatures of about 0.3 T_m in pure metals and of about 0.5 T_m in alloys [5]. Recrystallization results in the formation and growth of new grains. Distorted elongated grains disappear, and new grains are formed. During the period of grain growth, the layer recrystallized grains grow at the expense of the smaller ones (figure 1) [6]. The temperature of recrystallization depends on the degree of deformation of cold –worked metal. The greater the degree of work hardening is, the lower the temperature of recrystallization is. Also, the purer the metal is, the lower the recrystallization temperature is. There is a value of strain, called the critical strain, below which there is no recrystallization (figure 2) [6]. At this critical strain a few recrystallized grains form and grow extremely large. This technique is some times used to grow single crystals (table1).

Table (1). Recrystallization and melting temperatures of some metals, ^{o}C[6].

metal	recrystallization	melting	Metal	recrystallization	melting
Al	150	660	Ni	620	1452
Cd	50	321	Pt	450	1710
Cu	200	1083	Ag	200	960.5
Fe	450	1535	Ta	1020	3000
Pb	0	327	Sn	0	232
Mg	150	651	W	1210	3400

Cold work processes are accompanied by a marked decreases in ductility and a slight decrease in density and in electrical conductivity. The cold work distorts the equated microstructure of metals, causes the formation of crystal defects, particularly dislocations, and frequently results in elongated grains in the direction of deformation. The percent of cold work (CW) can be calculated from reduction in thickness or in area as follows:

$\% CW = 100(d_o^2 - d^2)/d_o^2$ or $\%CW = 100(A_o - A)/A_o$

Where d_o is the initial thickness, d is the thickness after deformation, A_o is the initial cross-section area, and A is the cross-section area after deformation [7-8].

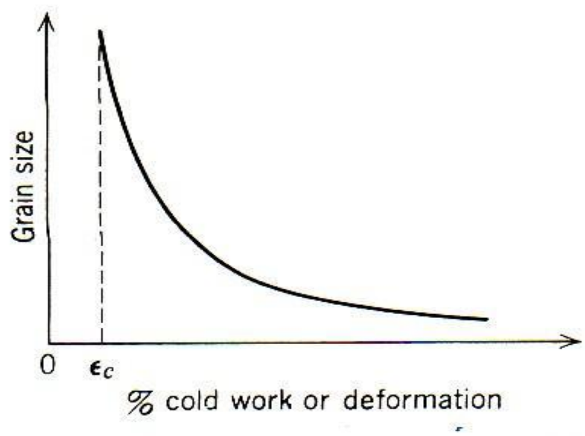

Figure (1). Effect of cold work on recrystallized grain is the critical strain below which there is no recrystallization [5].

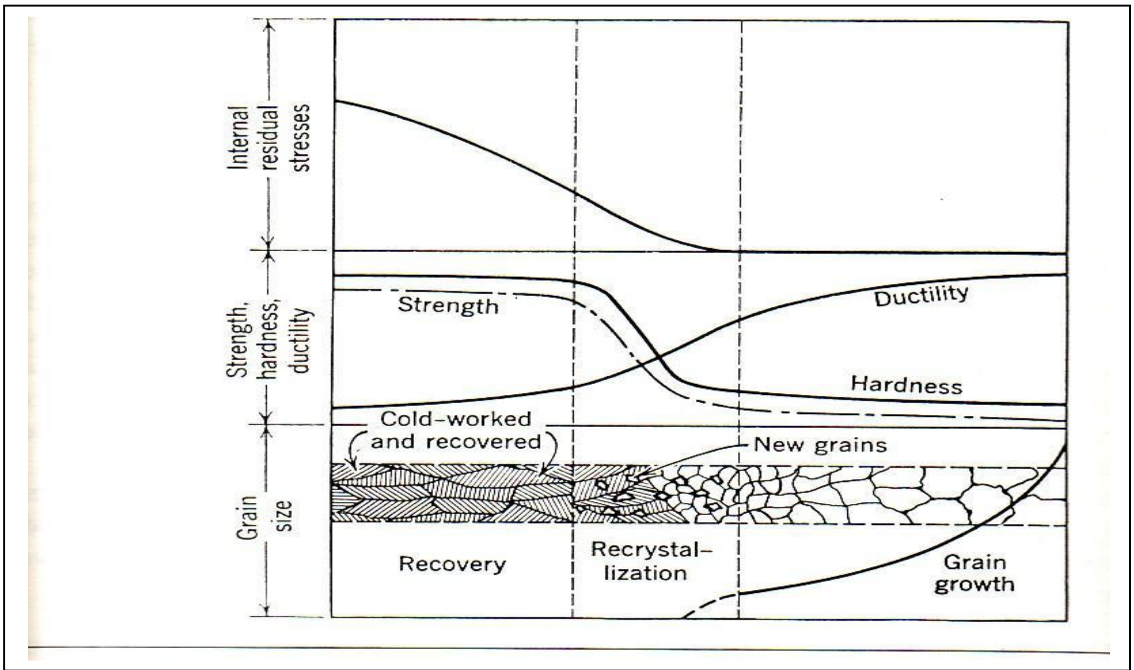

Figure (2). Effect of annealing on cold – worked metal[5].

3. Experimental work

Twelve specimens were taken. Two specimens drawn to 2mm diameter without treatment, two specimens treated by Ur process, eight specimens (2mm diameter) heated to 200^o C, 300^o C, 400^o C, and 500^oC which staying one hour at each temperature and finally furnace cooled. Optical microstructures were reveals by well preparation (grinding and polishing) for these twelve specimens and then examined by optical microscope.

4. Results and discussion

From the samples microstructure for the different treated drowns copper wires. The cold drawing is reach 100% cold worked samples. Which calculated by the below formula:

$\%CW = 100(A_o\text{-}A)/ A_o$

Where : A_o = original area mm^2

A = final area mm^2

This type of cold work will increase the wire hardness to duplicate [9]. The structure of this wires was shown in figure 3-a.The destroyed lamellar structure wasshown clearly in figure 3-b.

Figure 2 points out the Ur treated process which showed clearly the lamellar structure with out any recrystallization process as in (a) and (b). Figures 5 and 6 represent the samples which were full treated at 200 C^0. From these figures, it can be clearly shown the organized oriented at 45^0 angles of the started recrystallized grains with lamellar structure. The recrystallization process which accumulated in , 45^0angles, is likely happens as Lüder bands in tensile yielding, which may can explain due to well- defined yielding, the unlocking of dislocation that occurs at the upper yield point is a localized phenomenon. The unlocked dislocation move at a very high speed, because the stress required to unlock is much higher than the stress required to move them, until they are stopped at grain boundaries [9]. For this reason that drawing will done by more than one stage (in this work about ten stages from 10mm to 2mm in diameter). The clearly etched figure 5 and 6 showing that the high energy inclined lines (by 45^o) due to the dislocation moving clearly appear by the treatment process (200^oC) which is in recrystalization temperature. And by increasing the treatment temperature these inclined lines will disappear and by 400^{o}C and 500^{o}C, figures 8 and 9 shows horizontal lines (energy lines).

5. Conclusions

The main conclusion from this work is that the severe cold work [more than 96% CW] will lead to make easy the dislocation movement at or near the grain boundaries in destroyed structure. This will be preferred to make growth at 45^{o} angles. And this phenomenon is likely to the slipping process in tensile testing for metals (Lüder bands).

6. References

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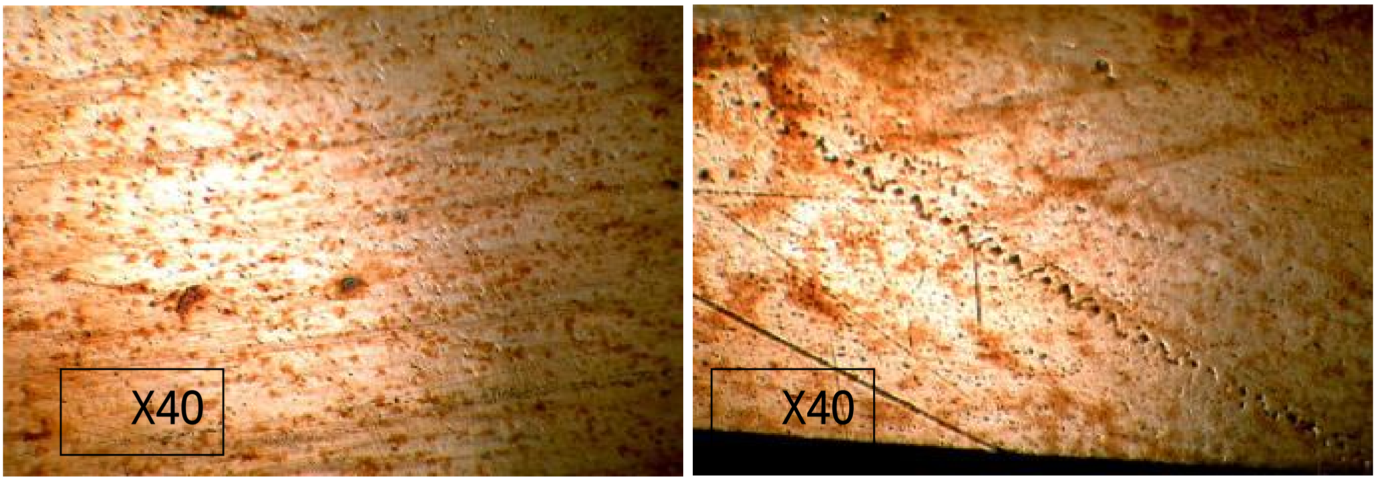
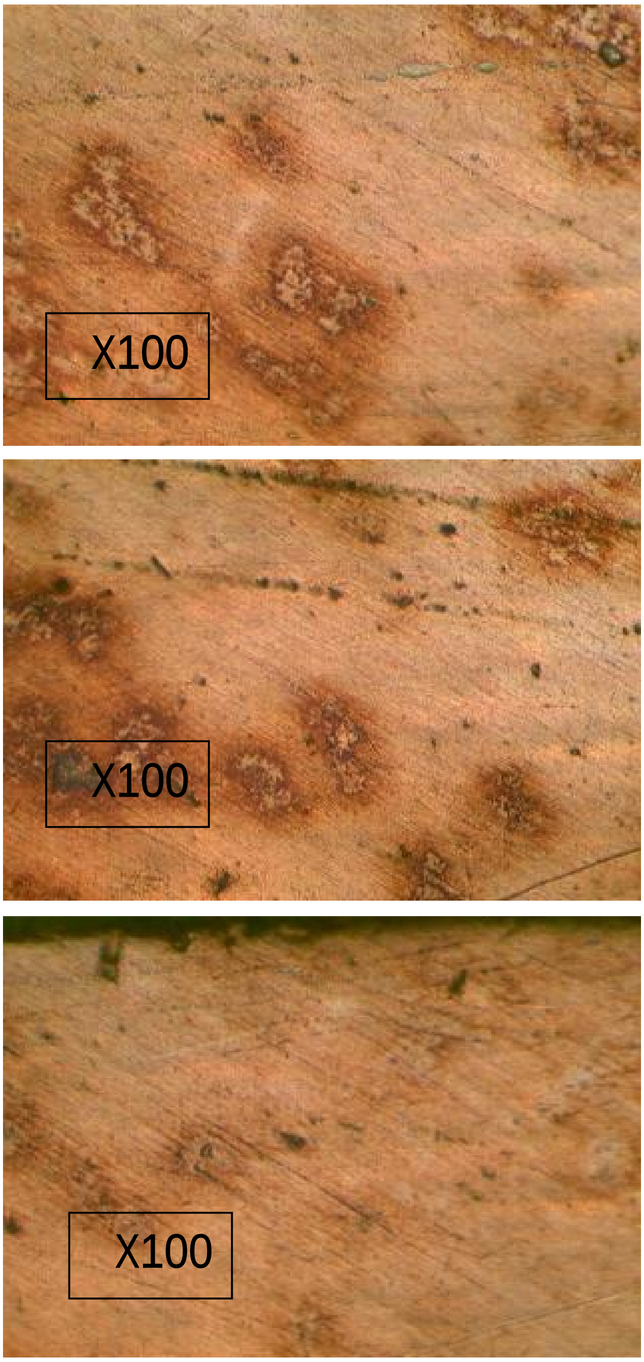
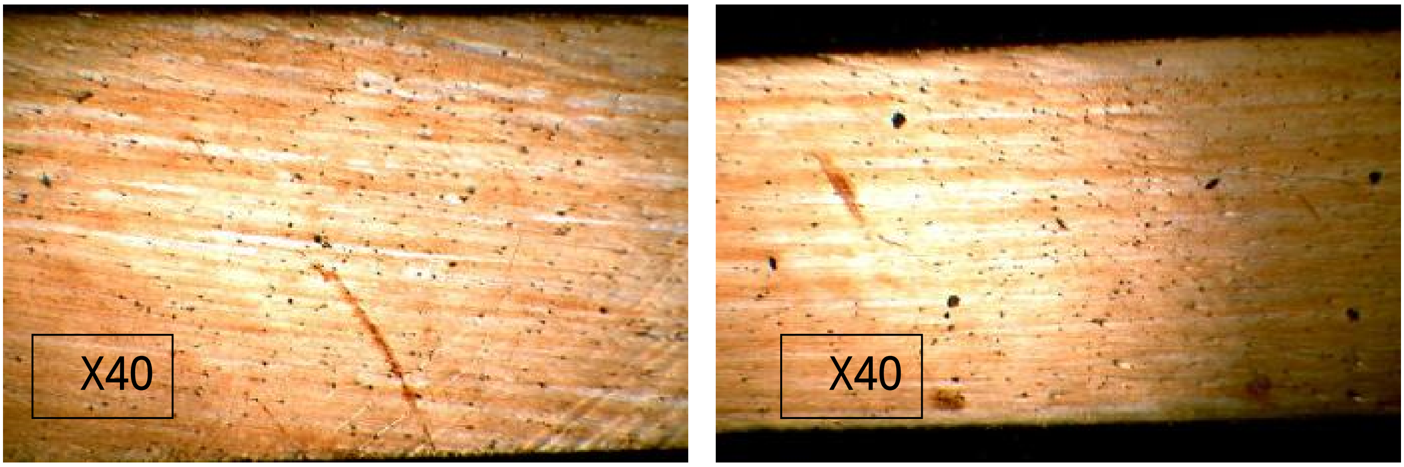


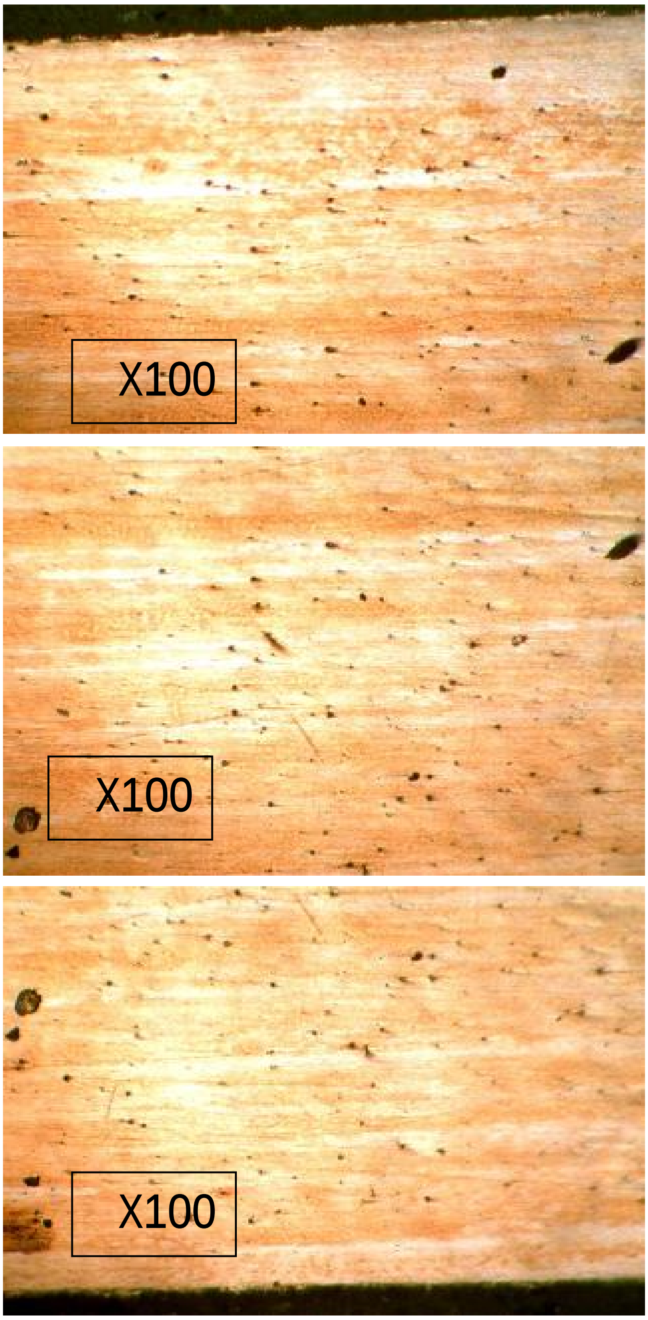
a

b



Figurer (3). Optical Microstructure for severe drawing wire (96% CW).





Figure(4).Lamellar structure for Ur treating process.

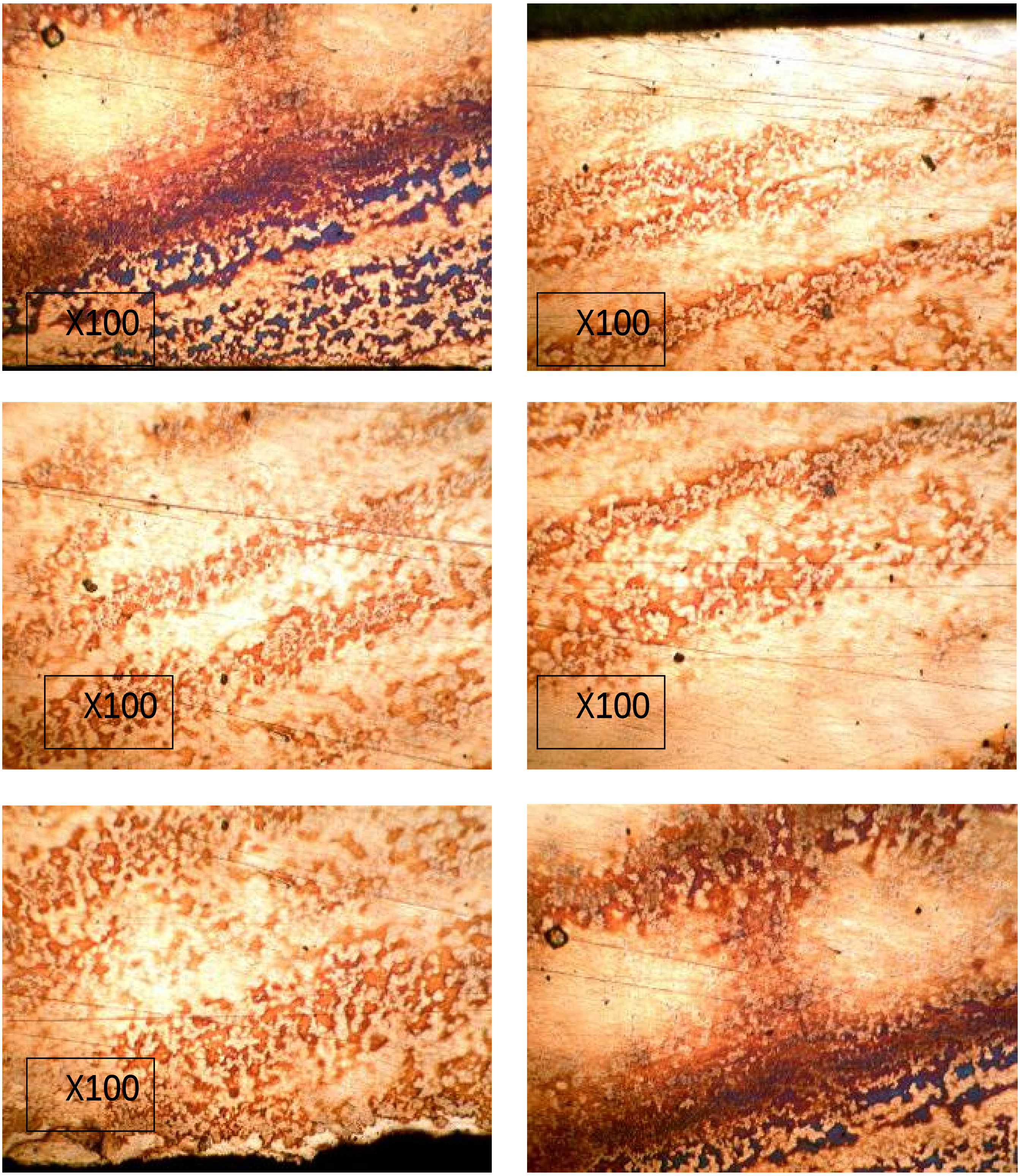


Figure (5). Lamellar recrystallized growth for the wire from the top surface to the down surface laboratory treated at 200 ^{o}C.

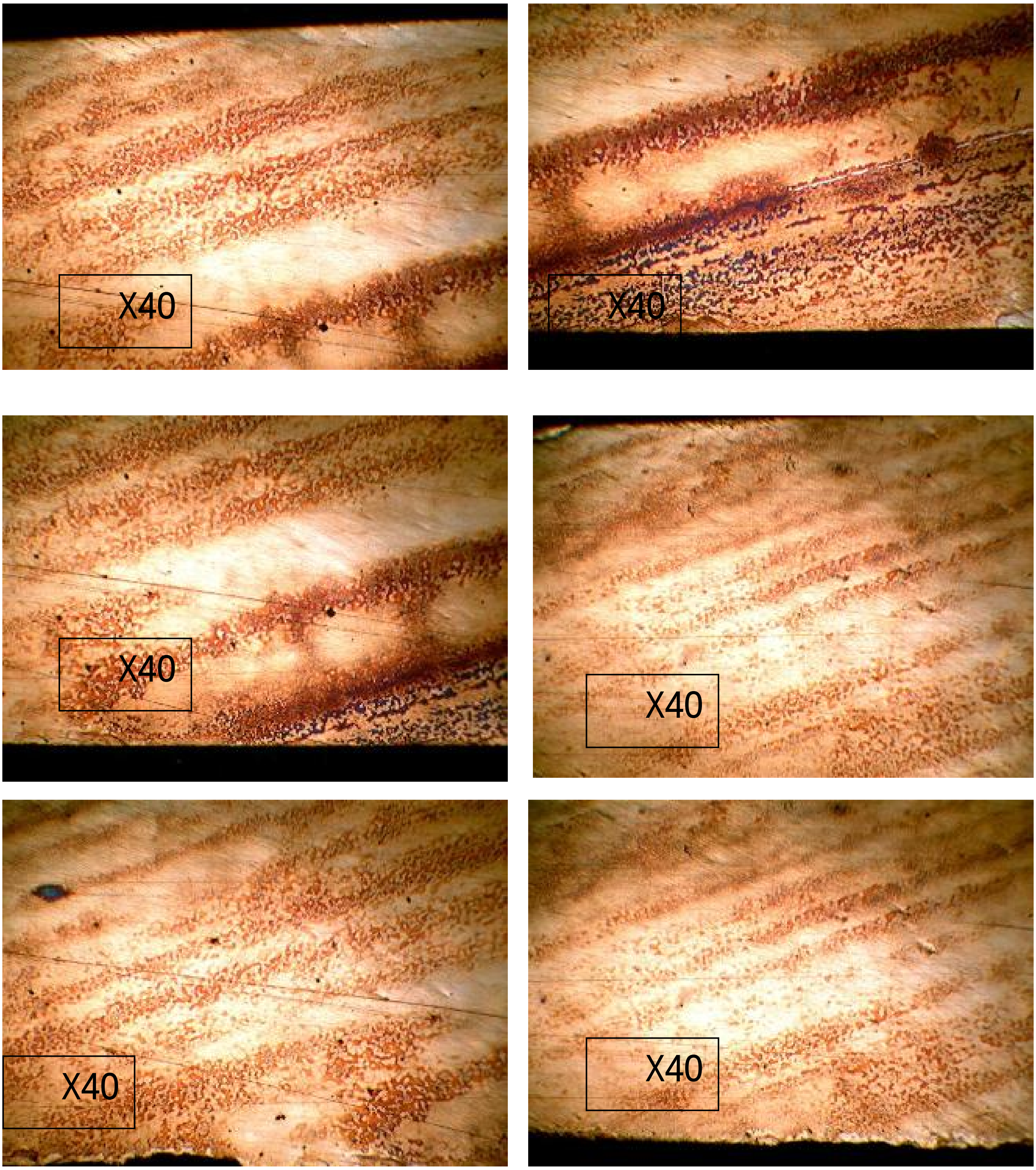


Figure (6). Another region for treated wire at 200^o C.

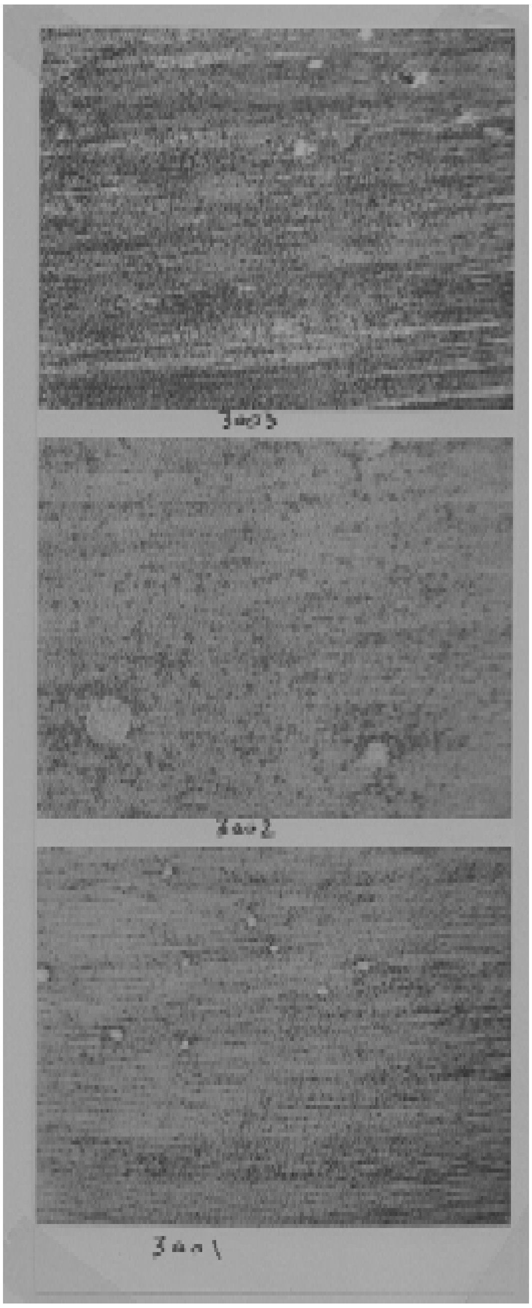
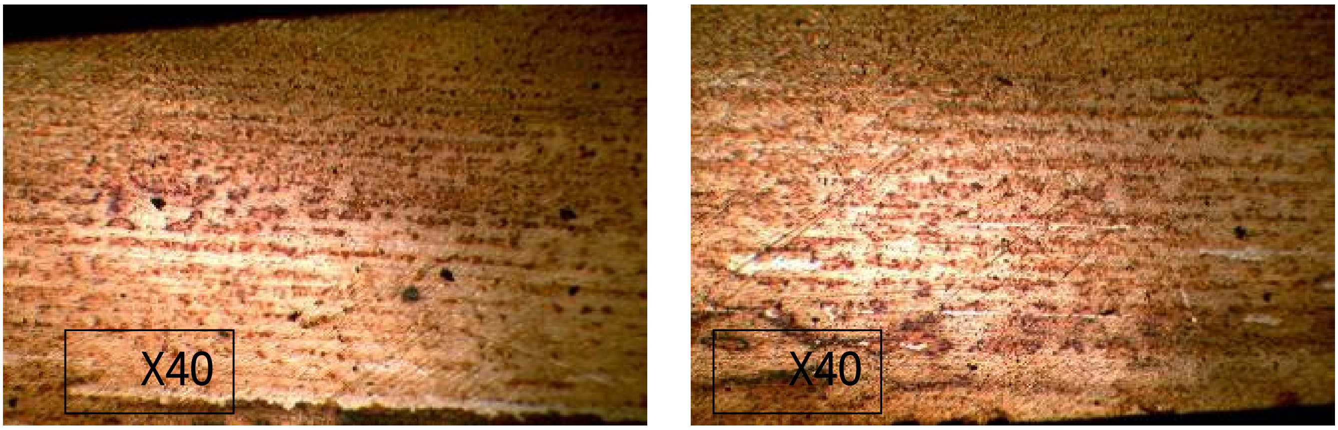


Figure (7). Lamellar growth in parallel lines, which shows the wire treated at 300 C°, X100 .



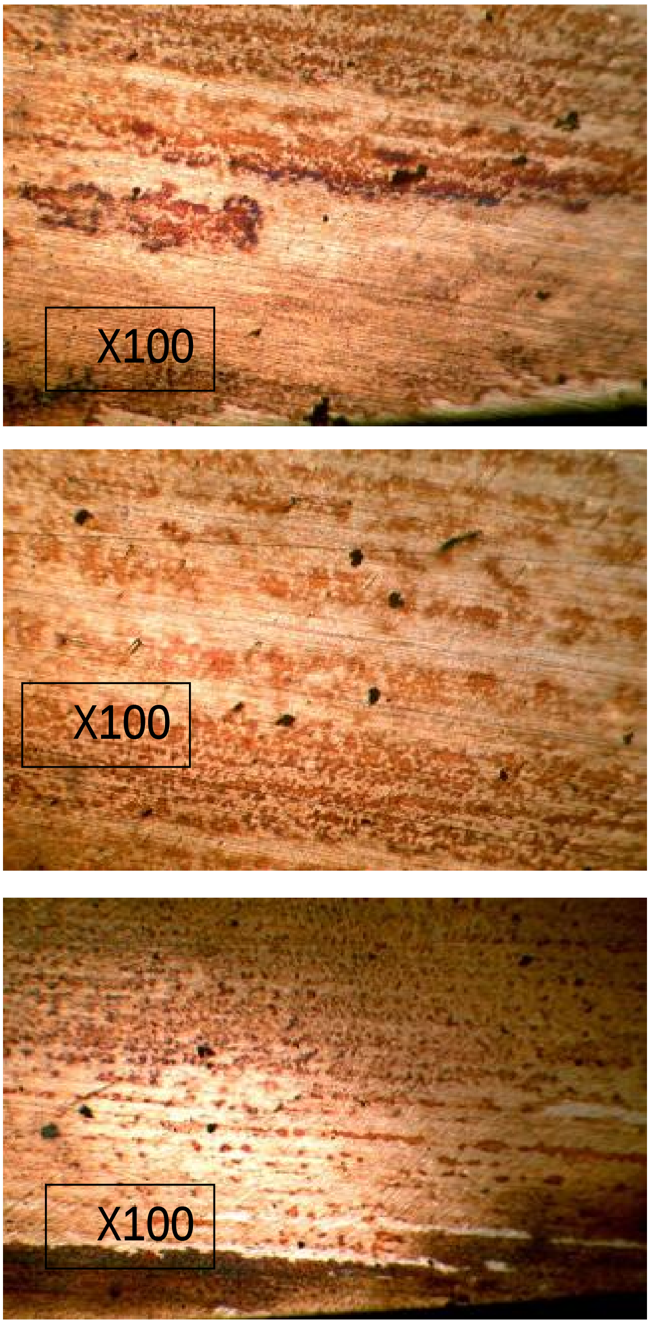
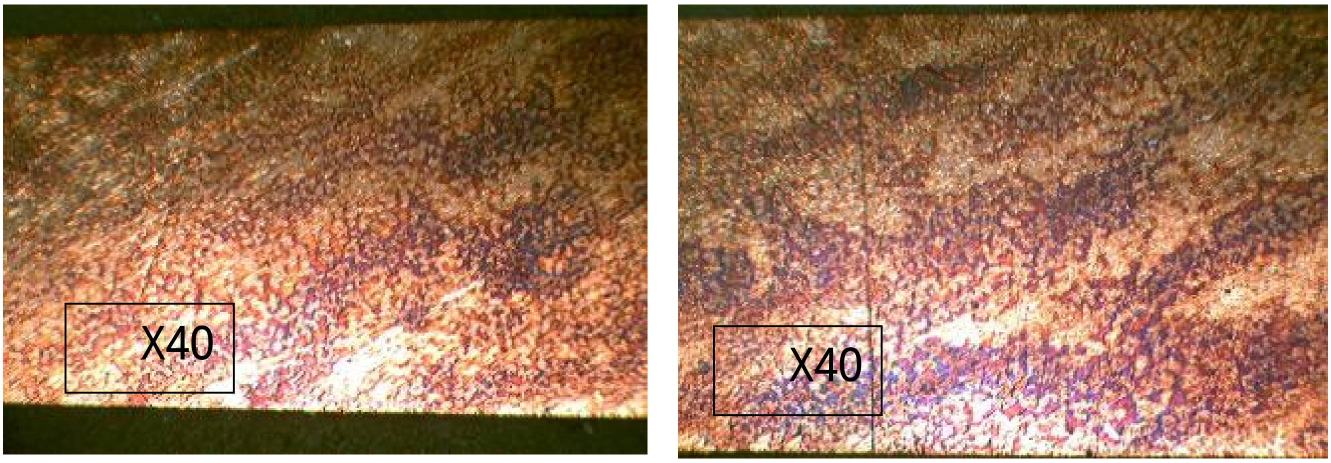


Figure (8). Microstructure of treated wire at 400^{o} C, shows lamellar growth in parallel lines.



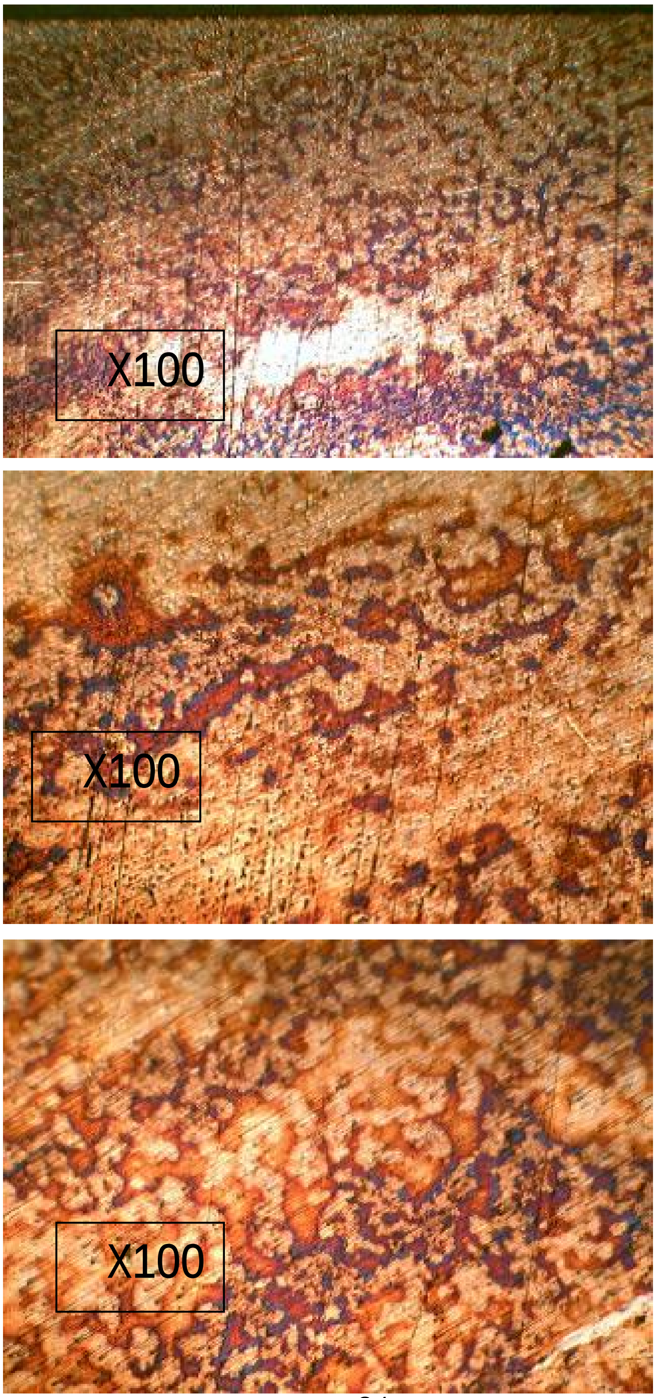


Figure (9). Microstructure of treated wire at 500^o C, which shows the grain growth to new organized structure .