The purpose of this work was to plot recrystallization diagrams for pure molybdenum (MCh) and molybdenum microalloyed with iron, cobalt, and nickel. These diagrams make it possible to select the optimal treatment for molybdenum wire.

The chemical composition of the molybdenum wire samples is given in Table 1.

Such alloying provided the highest plasticity with the lowest ratio $\sigma_{0.2}/\sigma_{0}$ [1, 2].

Ingots produced by conventional plant practices were forged to a diam. of 2.5 mm and then drawn into wire 1.2 mm in diam. The total deformation was about 78%.

Fig. 1. Recrystallization diagrams for molybdenum, a) MCh; b) with Fe; c) with Co; d) with Fe and Ni.
TABLE 1

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr</td>
<td>Ni</td>
</tr>
<tr>
<td>----------</td>
<td>---</td>
</tr>
<tr>
<td>0.004</td>
<td>0.0023</td>
</tr>
<tr>
<td>0.003</td>
<td>0.0015</td>
</tr>
<tr>
<td>0.003</td>
<td>0.0015</td>
</tr>
<tr>
<td>0.003</td>
<td>0.0013</td>
</tr>
</tbody>
</table>

In order to obtain an initial equiaxed structure, all the wire was subjected to recrystallization annealing for 1 h at 1200°C in hydrogen (dew point -15°C). This resulted in a uniform and equiaxed structure with grains 7-10 μ in diam.

In order to plot the recrystallization diagrams, the original wire samples, treated as stated above, were drawn with degrees of deformation of 3.5, 6.5, 9.8, 23, 30.5, 60, and 78% and annealed 1 h in hydrogen at 800-1700°C. The temperature at the start of recrystallization was determined by the x-ray method with copper radiation in a back-reflection chamber of the KROS-1 type.

The grain size was determined by means of the Quantimet television analyzing counting microscope. The microhardness was determined with the PMT-3 apparatus under a load of 100 g.

Figure 1 shows the recrystallization diagrams for molybdenum annealed 1 h.

The overall character of the diagrams is similar to that of the well-known diagrams [4-6].

The initial recrystallization temperature decreases with increasing deformation in all cases. The critical degree of deformation, at which the grains are largest, is about 10%. In all cases the grain size at the critical degree of deformation begins to increase sharply at 1250-1300°C.

Comparison of the recrystallization diagrams for the different types of molybdenum shows that microalloying leads to slowing down of recrystallization. Thus, at 1300°C and 9.8% deformation the grain size of MCh molybdenum reaches 146 μ, while in the molybdenum with 0.1% Fe it does not exceed 80 μ, and in the molybdenum alloyed with Fe and 0.015% Ni it is 75 μ. At higher annealing temperatures and larger deformation the grain size of the microalloyed molybdenum is also smaller than in the MCh molybdenum.

The various microalloying elements have different effects on the recrystallization process. Combined alloying with minute amounts of iron and nickel sharply slows down the recrystallization processes. The addition of cobalt reduces the grain size at large degree of deformation. Microalloying with nickel accelerates recrystallization, leading to substantial grain growth and a reduction of the initial recrystallization temperature. This agrees with the data in [6]. Such molybdenum has a high brittleness, making it difficult to use for any practical purpose, and therefore the recrystallization diagram was not plotted.

On the curves of the variation of microhardness with annealing temperature (Fig. 2) one can discern three sections:

1) a reduction of microhardness, probably due to relaxation processes;

2) an increase of microhardness due to polygonization processes in the range of 1100-1200°C;

Fig. 2, Variation of microhardness with annealing temperature (ε = 9.8%). 1) MCh; 2) with 0.1% Fe; 3) with 0.01% Co; 4) with 0.015% Fe and 0.015% Ni.

Fig. 3, Microstructure of molybdenum wire alloyed with 0.01% Co (ε = 9.8%; annealed at 1100°C), (x 1700). Reduced by one-third in reproduction.