phys. stat. sol. (a) 11, K29 (1972)

Subject classification: 10.1 and 17; 21.1

Ural Polytechnical Institute, Sverdlovsk

On the Connection of Exo-Electron Emission with the Processes of Recovery and Recrystallization

By

R.I. MINTS, V.I. KRYUK, G.I. ROSENMAN, and V.P. MELEKHIN

The existing physical models of exo-electron emission mechanisms are based on the ideas of the determining role either of the processes of creation and annihilation of deformation defects or the processes of sorption and surface oxidation (1). The extent of the influence of both factors on the exo-emission depends on the experimental conditions (ambient medium, purity of material, etc). However, in any case, deformation is the determining factor for the beginning of exo-emission and the role of the chemical processes becomes apparent only by the creation of defects on the surface and in the subsurface layers of solids.

In accordance with the role of structural processes it is of great interest to examine the interdependence of exo-electron emission with the processes occurring during annealing of deformed materials. In this case the study of the kinetics of exo-emission makes it possible to find out whether its limiting stage is connected with the processes proceeding in a volume of a deformed solid.

In this paper Cu-Al alloys containing 2.3, 4.5, and 7.4 wt% Al were chosen as the object for investigating the interdependence between exo-electron emission and the annealing processes of deformed materials. The choice of the material was determined by the fact that the increase of the Al content in Cu and the resulting decrease of energy of the packing defect formation (Fig. 1) provides the following regularities in annealing after deformation of the given alloys (2, 3):
1. The shift of the temperature of the beginning of recrystallization into the high-temperature region.

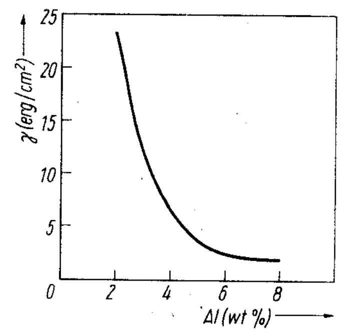

Fig. 1. The formation energy of packing defects for Cu-Al alloys (8)

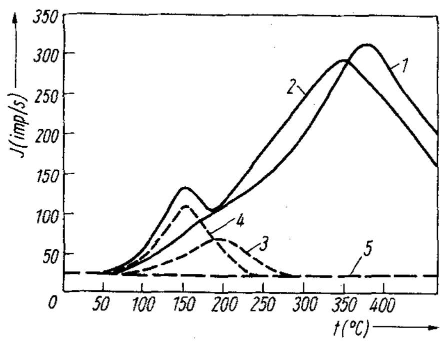

Fig. 2

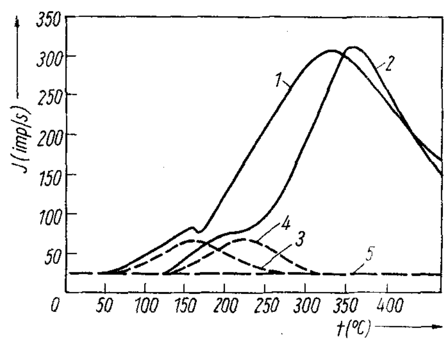

Fig. 3

Fig. 2. Exo-electron emission of Cu (1) and Cu+2.3% Al (2). Dashed lines show the low-temperature peaks for Cu (3) and Cu+2.3% Al (4), curve (5) gives the background

Fig. 3. Exo-electron emission of Cu+4.5% Al (1) and Cu+7.4% Al (2). Dashed lines show the low-temperature peaks for Cu+4.5% Al (3) and Cu+7.4% Al (4), curve (5) gives the background

2. The growth of the value of the effective activation energy of recovery and recrystallization.

The tensile experiments with subsequent annealing were carried out in a vacuum of 10^{-5} Torr. The specimens were deformed at a rate of 2.5 mm/min, the deformation degree amounted to 25%. The exo-electron emission during the annealing process at linear heating was recorded by a secondary electronic multiplier according to the experimental technique described in paper (5) in detail.

Fig. 2, 3 show the results. It is seen from the curves that two processes are involved which take place within different temperature intervals. The maximum of exo-emission for the studied alloy lies within the limits 140 to 170 $^{\circ}$C. The increase of the Al content leads to a rise of the temperature of emission beginning (Table 1).

The alloying also influences the kinetics of exo-emission what is confirmed by calculations of the activation energy of the processes (Table 1), carried out in accordance with the methods by Balarin and Zetzsche (6). The discovered tendency of a shift of the beginning of emission for the high-temperature peak into the high-

Table 1

materials / parameters of exo-emission glow curves	temperature of beginning of the high-temperature peak (°C)	activation energy (eV)		part of low-temperature peak exo-electrons to the whole emission (%)
		low-temperature peak	high-temperature peak	
Cu	80	0.52	0.52	6.1
Cu + 2.3% Al	105	0.59	0.69	6.5
Cu +4.5% Al	120	0.68	0.72	6.6
Cu + 7.4% Al	175	0.76	1.03	8.2

temperature region and also the growth of the effective activation energy for the low- and high-temperature peaks shows the interdependence of exo-electron emis- with the processes of recovery and recrystallization for which analogues regularities are characteristic (2, 3).

It is known that the release of the accumulated energy of deformation occurs during annealing of the pre-deformed materials. It is shown in paper (7) that for Cu this heat release process proceeds in two stages corresponding to the recovery and recrystallization, the part of energy, released at the recovery amounts to (depending on the extent of pre-deformation) 3 to 10% of the total accumulated energy and grows with the decrease of the formation energy of packing defects (4). In the case under consideration the exo-emission intensity for the high-temperature process is 3 to 5 times that for the low-temperature process.

The calculations carried out showed that the ratio of the part of the emitted electrons in the region of the low-temperature peak (of recovery) to the whole emission amounts to 6.1% of that for Cu and with the increase of the Al concentration up to 7.4% amounts to 8.2%. Taking into consideration this circumstance one can suppose that the emission of electrons is connected with the release of the stored energy at annealing.

The closeness of the obtained exo-emission activation energies to those for recovery and recrystallization of the Cu alloys (2, 3) shows apparently the coincidence of the limiting kinetics stages of the annealing and exo-emission processes.

References

(1) F.R. BROTZEN, phys. stat. sol. 22, 9 (1967).

(2) W. KÖSTER, W. ULRICH, I.K. CHOSH, and S.Z. REINIGER, Metallk. 55, 777 (1964).

(3) S.S. GORELIK, The Recrystallisation of Metals and Alloys, Metallurgia, Moscow 1967 (p. 281).

(4) L.M. KLERBROW, M.E. HARGREAVES, and M.H. LORETTO, Growth and Recrystallization of Metals, Metallurgia, Moscow 1966 (p. 69).

(5) Investigation of the Surface of Compound Materials with the Exo-Electron Emission Method, Collected Papers of the Ural Polytechnical Institute, Sverdlovsk 1969.

(6) M. BALARIN and A. ZETZSCHE, phys. stat. sol. 2, 1670 (1962).

(7) R. KANA, Ed., Physical Metallurgy, Vol. 3, Mir, Moscow 1968 (p. 377).

(8) A. HOVA, Direct Observation of Defects in Crystals, Metallurgia, Moscow 1964 (p. 198).

(Received March 23, 1972)