FIZIKA 2 Suppl. 2 (1970) 44.1

THERMAL DECOMPOSITION OF QUENCHED URANIUM RICH BINARY ALLOYS

Dj. Lazarević and M. Gligić

"Boris Kidrič", Institute of nuclear sciences, Beograd

I INTRODUCTION

It has been reported recently (1) that small quantities of some elements influence the radiation growth of uranium in a way which depends on the sort of the alloying addition. For example, silicon and germanium lowered the radiation growth. The opposite effect was found with iron, which enhanced the radiation growth. This peculiarity was not explained yet, though it was related to the ionic radius of the alloying element.

In the present work some results of a study by resistivity method of thermal decomposition of quenched binary uranium alloys with small additions of silicon, iron and aluminium are presented. These results could be related to the solute ionic radius.

II EXPERIMENTAL

Preparation of alloys. The alloys used in the investigation were made of electrolytical uranium produced by Minerais et Metaux, Paris, with the following main impurities: 60 ppm Si; 40 ppm C; 30 ppm Fe; 20 ppm Al; 6 ppm O; 5 ppm Ni; 5 ppm Cu.

The alloys were obtained by melting and homogenisation in an arc furnace and by subsequent homogenisation annealing at 850°C for 24 h.

Forming of specimens. The specimen wires used in experiments were made by swaging to 2 mm at 300°C and occacional recrystallisation annealing, followed by cold swaging to 0.8 mm and more frequent recrystallisation annealing.

Thermal treatment of specimens. All specimens including pure uranium were heated for one hour at 850°C and oil quenched. All the annealing experiments were performed in a special device reported elsewhere (2). The isochronal annealing was performed at 30 min time intervals.

III METHOD OF ANALYSIS

The rate of annealing of a given defect which is migrating by thermal activation is often expected to follow a rate equation of the form (3)

$$-\frac{dn}{dt} = f\,(n,\ q_1,\ q_2,\ \ldots.\ q_n)\ \exp\,(-E/kT), \qquad \text{I}$$

where n represents the total average defect concentration. The q's represent variables independent of t and T, which depend on the previous history of the specimen and involve the spatial distribution of sinks to which the defect must migrate. The kinetics is generally measured by measurement of a macroscopic physical property p. If the relationship between p and n is a single-valued monotonically increasing or decreasing function i.e. if

$$p = p(n) \qquad \text{II}$$

then $\frac{dp}{dt} = F(p,\ q_1,\ q_2,\ \ldots\ q_n)\ \exp\,(-E/kT),$ III

Eq. (III) can be integrated in the form

$$-\int_{p_o}^{p} \frac{dp}{F(p,q_1,q_2,\ldots)} = \int_{0}^{t} \exp(-E/kT)dt = \Theta \qquad \text{IV}$$

where Θ is referred to as the temperature compensated time. For identical specimens (same history prior to annealing treatment) the q's need not be considered. Thus for such specimens p is a function only of the temperature compensated time Θ, i.e.

$$p = p(\Theta) \qquad \text{V}$$

If both isochronal and isothermal data are available for initially identical specimens one could proceed in the following way: if the recovery is associated with a unique process then after the i^{th} isochronal annealing pulse for the measured value of p, p_i, one can write

$$\Delta \Theta_i \equiv \Theta_i - \Theta_{i-1} = \Delta t \exp(-E/kT_i) \qquad \text{VI}$$

The increment of isothermal annealing time, $\Delta \tau_i$, required to produce the same property change increment, p_i, as was observed in the i^{th} isochronal annealing pulse is equal to

$$\Delta \tau_i = \Delta \Theta_i \exp(E/kT_a) \qquad \text{VII}$$

Substituting into Eq. VI one obtains

$$\Delta \tau_i = \Delta t.\exp(E/kT_a) \, . \, \exp(-E/kT_i) \qquad \text{VIII}$$

or

$$l_n \Delta \tau_i = C - E/kT_i \qquad \text{IX}$$

The slope of the curve according to Eq.IX can be used to determine the activation energy .

IV RESULTS AND DISCUSSION

Figures 1, 2 and 3 represent the isothermal resistivity decay curves of binary uranium alloys with iron, aluminium and silicon respectively. Fig. 4 represents the isochronal resistivity decay curves of the same alloys. When combining the isothermal curve with the isochronal curve in a manner outlined in Sec. III one obtains the activation energy. It is determined from the slope of the straight line portion of the curve plotted according to Eq.IX. These curves for alloys with iron, aluminium and silicon are represented in Figs. 5, 6 and 7 respectively. Two curves were obtained for each alloy by using two different isothermal temperatures. It is evident that all the resistivity which recovers by annealing is associated with almost a unique process, the difference in activation energy for two different isothermal temperatures being between 0.1 and 0.3 eV for three alloys

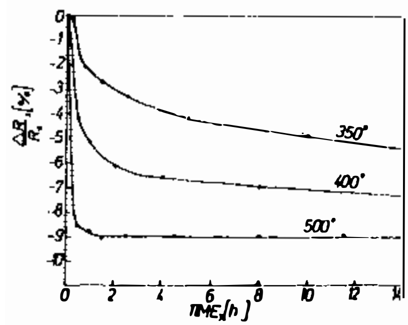

FIG.1

Isothermal decay curves of quenched uranium alloy with 800 ppm of iron

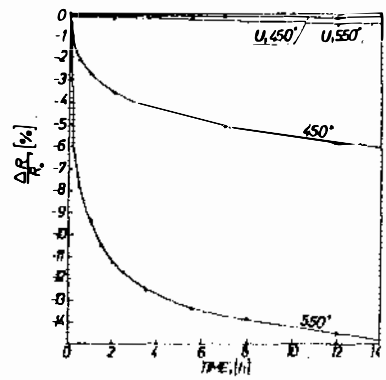

FIG.2

Isothermal decay curves of quenched uranium and uranium alloy with 980 ppm of aluminium

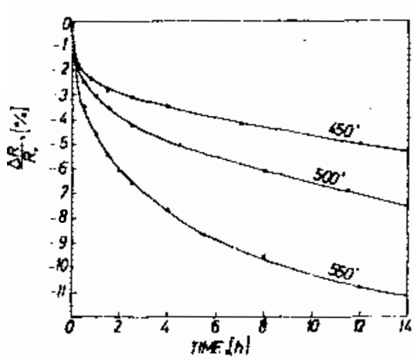

FIG.3

Isothermal decay curves of quenched uranium alloy with 1000 ppm of silicon

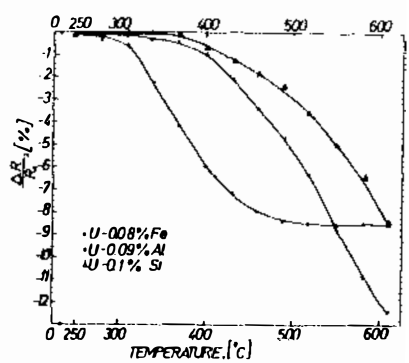

FIG.4

Isochronal decay curves of quenched binary uranium alloys with iron, aluminium and silicon

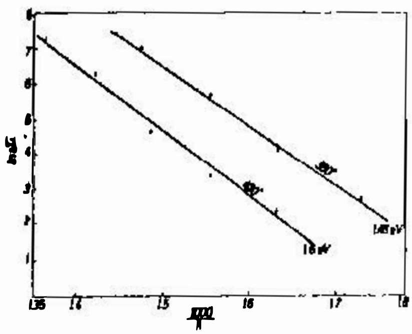

FIG.5

Determination of activation energy for diffusion of iron in uranium

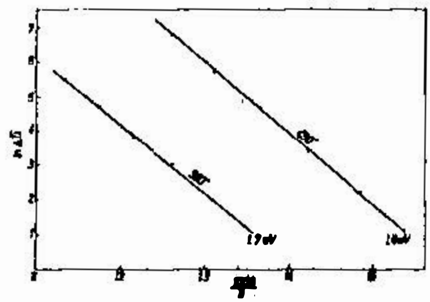

FIG.6

Determination of activation energy for diffusion of aluminium in uranium

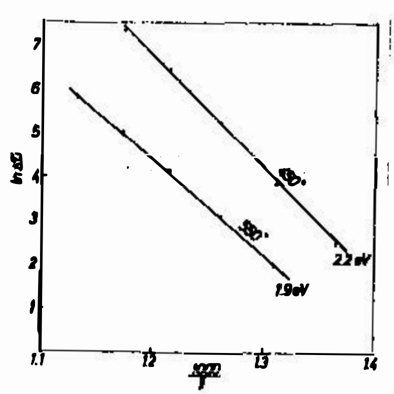

FIG.7

Determination of activation energy for diffusion of silicon in uranium investigated. When comparing activation energies for diffusion of solute atoms with their ionic radii it appears that there is a distinct relationship

Element:	U	Fe	Al	Si
Ionic radius:	0.97/+4/, 0.80/+6/	0.83/+7/ 0.67/+3/	0.55/+3/	0.4/+4/
E/eV/	-	1.53	1.75	2.05
Growth coef. ficient for 1000 MWD/t at 450 °C(1)	750	1650	615	420

One could argue as to whether the resistivity results obtained with such an anisotropic material like uranium are reliable or not. Two reasons support the present results: first, the amount of textures obtained by quenching should be very small and should not differ considerably because of low level of alloying additions. Second, the intention was to compare the migration characteristics of alloying elements investigated in one and the same lattice.

Further experiments will be performed on the line of reaction order determinations and on the influence of the quenching temperature.

Achnowledgements

Authors wish to thank Mrs. R. Topalović and M. Isailović for their valuable technical assistance.

References

1. J. Lehmann et al., Proc.Symp. "Radiation damage in reactor materials", IAEA-SM-120/H-1, Vienna, 1969
2. M. Gligić, Dj. Lazarević, Proc.of the XIII Conference of electronics, telecomunications, automation and nuclear engineering, Subotica, 1969, p. 444
3. C.J. Mechan and J.A. Brinkmann, Phys.Rev., Vol. 103, p. 1193 (1956)