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DISCUSSION

J. Narayan[1]—If the vacancies are present in the form of divacancies or loops (≤ 10 Å) which cannot be detected by TEM, then the relaxation will change (probably increase gradually to one). You have not accounted for that in your equation. How well are relaxations around point defects in molybdenum known?

H. I. Jang and J. Moteff (authors' closure)—Tewordt[2] has shown that the lattice relaxation around a vacancy in copper is approximately –0.5 atomic volume. Since a similar value has been reported in the literature for vacancies in molybdenum,[3] it was assumed that the relaxation results on copper apply also to molybdenum. The relaxation around simple clusters of vacancies (divacancy, trivacancy, . . .) in copper are also approximately –0.5 atomic volume per vacancy (see Ref *6* of paper). The possible presence of vacancies in the form of small loops is unlikely, or at least not significant, as there is no evidence that vacancies in molybdenum are mobile at 70°C. Even if a significant number of small loops were present, whether the relaxation will increase gradually to one would still be in question because the Keating-Goland equation only holds for the loop sizes with $C >> 4r_0$ where C and r_0 are the radii of the loop and the atom, respectively. For all these reasons, we had to make the assumption that the vacancies are present in the form of simple point defects and the relaxation is –0.5 atomic value.

J. A. Sprague[4]—In the recovery curve for the specimen irradiated to 5×10^{19} n/cm^2 at 480°C, there was significant recovery considerably below the irradiation temperature. Do you have an explanation for this result?

H. I. Jang and J. Moteff—The result is not well understood at present, but it could be explained in terms of a hypothetical transient defect configuration that might be present at the loop-to-void transition temperature. The threshold temperature for void formation in metals is often quoted as ~0.3 T_m, and the voids in molybdenum have been reported at irradiation temperatures as low as 440°C (3.5×10^{20} n/cm^2).[5] However, voids were not observed in the specimen of this study (5×10^{19} n/cm^2, 480°C), and Brimhall et al (see Ref *8* of paper) have reported vacancy loops as the only identifiable vacancy defects at temperatures ≤ 500°C for

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[2] Tewordt, L., *Physical Review*, Vol. 109, No. 1, 1958.
[3] Hanada, R., *Transactions*, Japan Institute of Metals, Vol. 12, 1971.
[4] Code 6390, Naval Research Laboratory, Washington, D. C. 20290.
[5] Elen, J. D., Hamburg, G., and Mastenbroek, A., *Journal of Nuclear Materials*, Vol. 39, 1971, p. 194.

similarily irradiated molybdenum specimens. Evans et al[6] reported the production of voids by postirradiation annealing of specimens irradiated at 60°C and suggested that the vacancies released from the vacancy loops transfer to the voids by a bulk diffusion process during annealing.

At the threshold temperature for void formation, it could be assumed that there is almost equal probability for the formation of both voids and vacancy loops. Under which condition the voids or the loops are formed is a matter of conjecture; it is generally believed that voids will not form unless void nucleation sites are available and they are stabilized by impurity atoms. If these conditions are not fulfilled, the vacancies (or void embryos) which otherwise would have formed voids will either migrate to stable defects sinks, namely, vacancy loops, or remain as a metastable transient configuration. Although the latter case has less probability of occurring, the result of this study would seem to support its occurrence. This configuration could be retained when the specimen is cooled to room temperature after irradiation, and subsequently anneal out upon reheating at relatively low temperatures.

[6] Evans, J. H., Mahajan, S., and Eyre, B. L., *Philosophical Magazine*, Vol. 26, 1972, p. 4 and Vol. 28, 1973, p. 6.