disagreement. One observes from this calculation, however, that frequency-dependent deflections are readily obtained from elementary combinations of familiar field relations. It is suggested that an experimental determination of the variation of displacements over available wavelengths, should prove helpful in understanding the gravitational field and its interaction with photon fields.

[1] See Campbell and Trempler, Lick Observatory Bulletin **11**, 41 (1925); **13**, 130 (1928).
[2] Freundlich, v. Kluber, and Brunn, "Ergebnisse der Potsdamer Expedition zur Beobachtung der Sonnenfinsternis von 1929, Mai 9, in Takengon (Nordsumatra)." Z. Astrophys. **3**, 171 (1931).
[3] P. G. Bergmann, *Introduction to the Theory of Relativity* (Prentice-Hall, Inc., New York, 1942), p. 213 ff.
[4] See reference 3, p. 220.

The Effect of Neutron Irradiation on Metallic Diffusion

T. H. Blewitt and R. R. Coltman
Oak Ridge National Laboratory, Oak Ridge, Tennessee
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THE study of the interaction of high energy neutrons with solids has been studied theoretically by Seitz[1] and observed experimentally by several investigators.[2–4] These investigations indicate that a fast neutron knocks-on an atom, displacing it from its lattice position. This displaced atom has sufficient energy to displace further atoms and hence a localized region with a large number of Frenkel defects should result. If Frenkel defects play a predominate role in the atomic diffusion of metals, neutron bombardment should greatly increase the rate of microdiffusion. On the other hand, macrodiffusion, that is the atomic diffusion over large distances, will be unaffected since the mean path for recombination of the defects will be small. An appropriate material for the study of this phenomenon is disordered Cu_3Au alloy, where every atomic motion will tend towards ordering.

The following experiment was performed. A sample of Cu_3Au was disordered, sealed in vacuum, and the electrical resistance measured at 200°C where the relaxation time is of the order of 10^5 hours.[5] The sample was then placed in an ORNL graphite reactor at a location where the fast neutron flux was of the order of 1×10^{12} neutrons per cm² per sec, with the temperature being maintained at 200°C. The electrical resistance was subsequently measured as a function of time and the results are shown in Fig. 1. A constant neutron flux was assumed. It is particularly interesting to note that a lag of 12 hours was observed when the pile was shut down (see Fig. 2) indicating that the relaxation time for ordering had decreased to about 12 hours at 200°C.

From these results and the room temperature bombardment of ordered Cu_3Au, an estimate can be made of the mean path for recombination of the Frenkel defects. The experiments on ordered Cu_3Au indicate that about 10^4 atoms are affected per atom

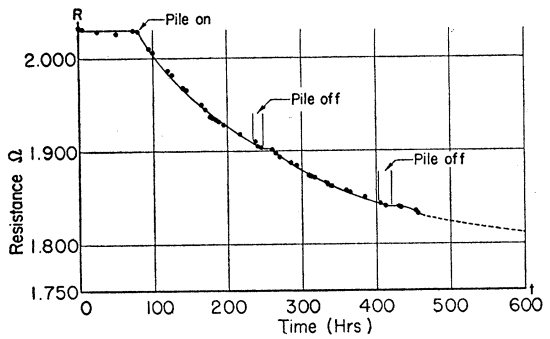

FIG. 1. Resistance of disordered Cu_3Au *vs* time. Temperature = 200°C. Fast neutron flux = 1×10^{12} n/cm²/sec.

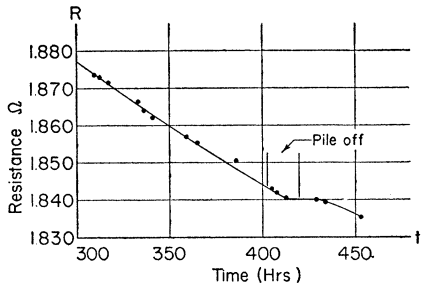

FIG. 2. Resistance of disordered Cu_3Au *vs* time. Temperature = 200°C. Fast neutron flux = 1×10^{12} n/cm²/sec.

knocked-on by a neutron.[2] From the data of Fig. 1 saturation should occur after about a month's exposure which is equivalent to 1×10^{18} neutrons per cm². Assuming the fast neutron scattering cross section to be 3 barns, the number of primary knock-ons is about 1×10^{17} per cm³. If 10^4 atoms or regions about 40A in diameter are affected per primary knock-on, saturation should occur in about 100 months. Since the saturation appears to be reached in one month, then 10^6 atoms, or regions about 100A in diameter, should be affected, indicating that defects have a small but an appreciable mean path before annihilation.

The foregoing deduction can be verified by an experimental measurement of the size of the ordered domains. Since the order is not a single valued function of the resistance, it is not possible to deduce the degree of order from these measurements. It seems logical, however, to assume that the antiphase ordered regions have an equilibrium degree of order. If this assumption is made the resistance will indicate an average domain size of about 65A. X-ray studies are planned to determine the size of the domains and verify the above calculations.

If, as the theoretical treatments indicate, Frenkel defects are formed by fast neutron bombardment, then the above data offers strong evidence that an increase in the number of Frenkel defects will substantially increase the diffusion rate in metals. Further evidence that Frenkel defects play a role in metallic diffusion arise from measurements which indicate that the activation energy for the annealing of neutron radiation effects in copper is in close agreement with the activation energy for self-diffusion in copper.[6] Further studies on the radiation of disordered Cu_3Au are in progress and will be reported later.

[1] F. Seitz, Disc. Faraday Soc. No. 5, 271 (1949).
[2] S. Siegel, Phys. Rev. **75**, 1823 (1949).
[3] D. S. Billington and S. Siegel, Metals Progress **847** (December, 1950).
[4] J. H. Crawford *et al.*, Phys. Rev. **83**, 312 (1951).
[5] F. Sykes and H. Evans, J. Inst. Metals **58**, 255 (1936).
[6] To be published.

Properties of Powdered $BaTiO_3$

V. E. Derr and M. D. Earle
Radiation Laboratory, Johns Hopkins University, Baltimore, Maryland
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RECENTLY much interest has been shown in the properties of ceramic barium titanate. In this laboratory an effect has been found to exist in the powdered form of $BaTiO_3$ which is present to only a negligible extent in the ceramic material. These experiments were conducted on capacitors whose plates were approximately 35 mm in diameter and 0.5 mm apart, and whose dielectric consisted of powdered $BaTiO_3$. The first experiments were conducted on capacitors in which the powder had been packed by hand pressure only. Later the experiments were repeated, using a hydraulic press to pack the powder to a much higher density than could be done by hand.

It was found that if these capacitors were initially charged (the charging source was a 45-volt battery) and then short circuited for