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During the past year, results from our research have contributed to an understanding of radiation damage of metals because of our detailed studies of the recovery spectrum of stage I for aluminum. For polycrystalline aluminum samples, the independent substages within stage I have been found to depend upon atomic recoil energy. This dependence is quite similar to the energy dependence of stage I of copper.¹ Report no. ORO-3098-2 explains this common behavior for two metals in terms of how the fcc lattice structure can influence the production of point defects. For single crystals of aluminum, we have found² that the intrinsic substage I_b can be enhanced or partially suppressed when electron irradiation occurs along specific directions of the crystal. Annealing data which shows this behavior was determined by a comparison between the recovery data of polycrystalline and single crystal samples after irradiations with electrons of 2.3 Mev. Crystals oriented along both the $\langle 100 \rangle$ and $\langle 111 \rangle$ with respect to the beam have been irradiated for the same single crystal specimens. Although the results of this work are conclusive, there was a discrepancy in the initial shape of the annealing curves for the polycrystalline samples. This non-reproducibility could be caused by (1) an excess sample temperature during irradiation, or (2) preferential grain orientation within the polycrystalline samples. Therefore, these experiments

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are to be repeated before quantitative information can be determined.

An initial investigation of radiation doping³ for polycrystalline aluminum has been performed. Results show (1) that radiation doping enhances the stage I recovery and (2) that a saturation effect of the enhancement does occur. Such conclusions are in agreement with published information⁴ that deals with copper samples.

During each irradiation, values of damage rate have been determined in terms of resistivity change per unit flux. Values of damage rate, which refer to a given energy of electron irradiation, show a fluctuation of approximately $\pm 10\%$. More precise values are certainly desired. One cause for the scatter in the damage rate value may be associated with the variation of the electron distribution over the irradiation area. Therefore, we have rebuilt the electronic sweep-circuit which deflects the bombarding electrons over the position where samples are located. A preliminary test of this modification indicates that the electron beam is distributed more uniformly over the entire sample area. Final evaluation of this system will be judged by the reproducibility of results which deal with extended times of irradiation.

The energy of the irradiating electrons is determined by the high potential of the Van de Graaff accelerator. This high potential is monitored by means of a Generating

Voltmeter which is a linear type of instrument that produces an AC output signal. Measurements of the magnitude of this AC signal are done by using a relatively insensitive microammeter and by means of a recently installed digital voltmeter (Hewlett-Packard model nos. 3440A and 3445A). After the Van de Graaff accelerator operates for approximately one hour, the microammeter measuring system indicates that the acceleration energy increases by 10 Kev but the digital voltmeter reading remains constant. It is believed that the discrepancy between these two independent measuring systems is caused by electronic components of the microammeter measuring circuit whose sensitivity varies with temperature. Such a fluctuation would normally cause operation at different irradiation energies. The precision of our work is certainly improved since we now know and can compensate for this variation.

The high voltage that is generated by the Van de Graaff accelerator was initially calibrated from values of column current and column resistance as measured by the manufacturer. Because the precision of this measurement was not known, we have accomplished an independent calibration to determine the energy of the accelerated

electrons. The calibration procedure⁵ used the known energy values of the internal conversion electrons from a Ba¹³³ source. One determines the energy response of a surface barrier detector and its associated pulse height analyzer. By knowing the energy dependence of this electronic measuring system, measurements can be made of the energy of the electrons that are accelerated by the Van de Graaff. The measured electrons form an energy distribution. The shape of this energy distribution is such that a maximum number of electrons have an energy of approximately 90% of the maximum electron energy, and the half-width of this distribution is approximately 18 Kev. Both primary and secondary electrons are responsible for the measured distribution. From a study of these distribution curves at different energies and from the known linearity of the voltmeter measuring system, we conclude that the average energy for the primary electrons can be estimated to ± 4 Kev.

To obtain suitable samples of single crystals of aluminum, aluminum foils of 7.5 mil are used for growing large size grains by a variation of the strain-anneal technique. This method of growth has a fifty percent chance of producing grain sizes that are between 1 and 2 inches in length. It has been found that grain growth possesses a preferential orientation which lies along a band that joins the (110) and (112). At present, our

inventory includes 45 large grain samples of aluminum foils. Because it is desired to irradiate different single crystal samples along various directions, we now choose the particular kind of sample which is most suitable for an experiment.

Large grains from the aluminum samples are used for the preparation of very thin single crystal specimens. The method of preparation has been established by trial and error. Basically, after deciding upon a particular sample which has the desired crystallographic orientation, the sample is reduced in thickness from 7.5 to 2 mils. An acid saw is used for cutting individual strips of approximately 30 mils in width. The desired narrow strips of sample material are then mounted to a rectangular frame which reduces the chances of deforming the thin foils. Electrical leads are soldered to the samples and all solder joints are coated with an epoxy; thus the soldered connections are not harmed when the final chemical etch is used to reduce the thickness of the sample to less than one mil. X-ray examinations are used frequently during this process to determine that no undesirable strains exist in the sample and that the correct crystal direction is preserved.

Satisfactory specimens of high purity magnesium have been prepared. Operations which are used in this fabrication include rolling, etching, and annealing. In order to mount and to connect electrical leads to the magnesium, various connections are spot welded. Measurements of this polycrystalline material have shown that samples possess a ratio of room-temperature resistance to helium temperature resistance which is greater than 400. An improved annealing method, that is being used, should be helpful for increasing this resistivity ratio.

An experimental curve can be obtained from values of damage rate versus atomic recoil energy. A theoretical computation of this curve depends upon the mathematical function which is used to describe the probability of atomic displacement, $P(T)$.⁶ We are using different mathematical expressions for $P(T)$ to obtain results which are applicable to aluminum samples. Some portions of this problem have been calculated with an IBM 360 computer. (Model 40). As yet, this work is still in the early stages of development, but results will eventually be compared with experimental values from polycrystalline and single crystalline samples. Another portion of the radiation damage problem concerns the multiple scattering of the bombarding electrons while the electrons penetrate the

thin foil specimens. Calculations to date have basically used the Moliere multiple scattering theory.⁷ Results do explain how the I_b recovery stage of single crystal samples of aluminum is changed when the irradiation direction is varied. The determination of the extent of this agreement between theory and experiment is not complete and therefore remains as one of the objectives of this work.

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"Energy Dependence of Stage I Recovery in Electron - Irradiated Aluminum", H. M. Simpson and R. L. Chaplin, Bull. Am. Phys. Soc. 11, 838 (1966).

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"Recrystallization in High Purity Aluminum Foil - II", D. A. Venkatee, A. B. Pruitt, and R. L. Chaplin, read before South Carolina Academy of Science, April 29, 1967.

"Energy Dependence of the Stage I Recovery of Aluminum", R. L. Chaplin and H. M. Simpson, Report no. ORO-3098-2, Submitted for publication in the Phys. Rev.