after solidification of the materials. Sufficient experimental data are not yet available to draw definite conclusions about the nature of the state responsible for the τ_2 lifetime and increase three-photon rate nor about the mechanism of its destruction. However, our results suggest the importance of the order and structural state of the materials and perhaps such factors as the dielectric constant which is known to be temperature-dependent.

* Supported by the Office of Ordnance Research.

[1] R. E. Bell and R. L. Graham, Phys. Rev. **90**, 644 (1954).
[2] R. L. Graham and A. T. Stewart, Can. J. Phys. **32**, 678 (1954).

Effect of Elastic Strain upon Electrical Resistance when Cold-Work Induced Imperfections are Present

E. W. KAMMER
Naval Research Laboratory, Washington, D. C.
(Received May 3, 1955)

MOLENAAR and Aarts[1] have shown that the increase in electrical resistance produced in copper by cold work at liquid nitrogen temperature can be partially removed by annealing the specimen at room temperature. Experiments by Manintveld[2] indicate that the resistance contribution removable by this mild heat treatment is due to vacancies or aggregates of vacancies since the activation energies correspond closely with theoretically estimated values.[3] The experiment reported here is concerned with the effect of elastic strain upon the electrical resistance after the metal has been subjected to various amounts of cold-work. By means of simple tension, permanent elongation was produced in an annealed copper wire (diameter 0.001 inch) while submerged in liquid nitrogen. At certain increments of permanent elongation, an elastic strain cycle was performed during which the change in resistance per unit resistance, $\Delta R/R$, was measured as a function of elastic strain, $\Delta L/L$.

In Fig. 1 the quantity, G, defined by the ratio $(\Delta R/R)/(\Delta L/L)$, is plotted as a function of percent permanent elongation. Immediately preceding the measurement indicated by point A the wire was withdrawn from the liquid nitrogen and kept at room temperature for several hours. Without further cold work the specimen was again cooled and the ratio, G, represented by the point A, was determined. After a small increase in permanent elongation the wire was removed from the liquid nitrogen and the value of G was determined under room temperature conditions. This point is designated by B.

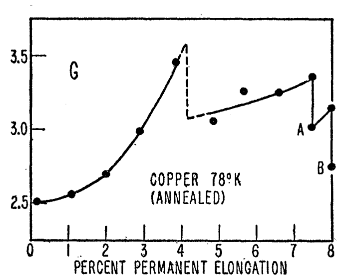

FIG. 1. The ratio, $G=(\Delta R/R)/(\Delta L/L)$, as a function of plastic elongation in copper at liquid nitrogen temperature. Each point represents the slope of an electrical resistance *versus* elastic strain relation measured at the indicated state of deformation.

The strain sensitivity factor, G, changes in much the same manner and degree as did the resistivity in the experiment of Molenaar and Aarts after the room temperature anneal. This behavior suggests that each type of imperfection makes its own contribution to the factor G. In this case vacancies generated by cold-work influence the relationship between elastic strain and resistivity to an easily measurable degree. The graph is also evidence that the factor G can experience large changes in magnitude during the deformation process, independently of the annealing treatment. Evidently there is a complicated interplay between the imperfection generation and escape or annihilation processes.

[1] J. Molenaar and W. H. Aarts, Nature, **166**, 690 (1950).
[2] J. A. Manintveld, Nature **169**, 623 (1952).
[3] T. Broom, Advances in Phys. **3**, 74 (1954).

Angular Correlation of Photons from Positron Annihilation in Solids

A. T. STEWART
Physics Division, Atomic Energy of Canada Limited, Chalk River, Ontario, Canada
(Received April 11, 1955)

MEASUREMENTS of the angular correlation of photons from positron annihilation have been continued[1] with better resolution, and two new effects have been observed.

The shape of the angular correlation curve varies considerably throughout a series of some dozen metals from Be to Pt. Figure 1 shows typical coincident counting rates, $I(z)$, as a function of z, the angle between the annihilation photons. These data, when corrected for instrument resolution,[2] have yielded the average momentum distribution, $N(k)dk$, of annihilating electron-positron pairs by using the fact that zdI/dz is proportional to $N(k)$.

For the light metals the momentum distribution of annihilating pairs resembles that found by other means[3] for the conduction electrons alone. For the heavier metals a component of higher momentum appears.[4] Figure 2 shows typical distributions for Zn and Mg. Results for a number of metals show that the higher momentum component increases with the fractional volume occupied by the ion cores, possibly indicating an increased number of annihilations with bound electrons or an excluded volume effect[5] in the annihilation with conduction electrons.

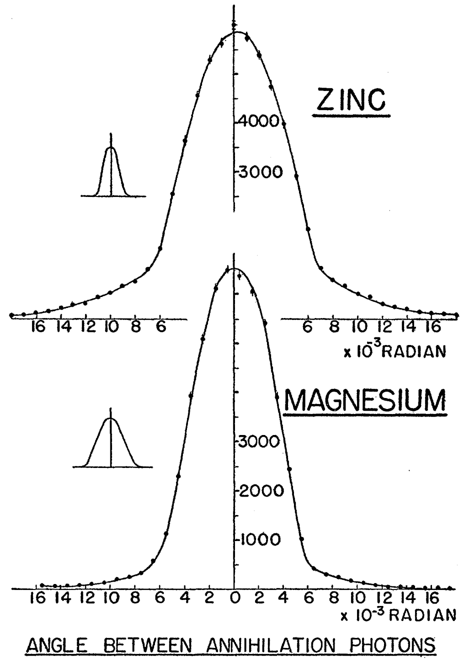

FIG. 1. Observed angular correlations of photons from positron annihilation in Zn and Mg. The instrument resolution is indicated.

In amorphous nonconductors, as Page *et al.*[6] have already shown, the angular correlation has a broad base and somewhat sharper peak than is observed for most metals. An example of this can be seen by comparing Fig. 1 and Fig. 3. In Teflon, the maximum coincident counting rate increases gradually with increase in temperature. In Fig. 3, the results for Teflon at two temperatures, 77°K and 525°K, are shown. If it is supposed that positrons in Teflon annihilate by two processes, corresponding to narrow and wide components of the observed curves, then it appears that as the temperature is raised the narrow component becomes narrower or its intensity increases at the expense of the other component. It is probable that these two annihilation processes may be related to the two modes of decay observed by Bell and Graham,[7] one of which also showed a temperature effect.

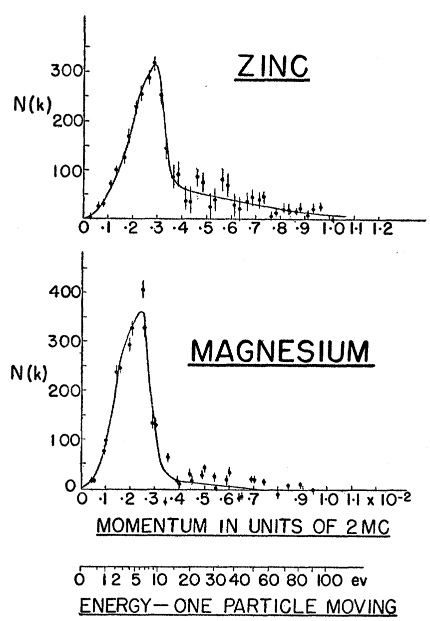

FIG. 2. Momentum distribution of annihilating pairs in Zn and Mg.

The observed lifetimes of positrons in solids, the three quantum annihilation rate experiments,[8] and the present measurements all suggest that the mechanism of positron annihilation in metals and crystalline solids is different from that in amorphous nonconducting materials.

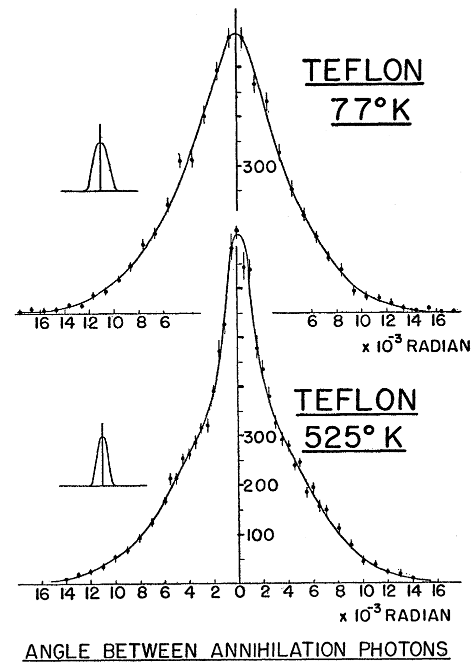

FIG. 3. Observed angular correlation of photons from positron annihilation in Teflon. The instrument resolution is indicated.

This work is being continued and a full account will be submitted for publication in the *Canadian Journal of Physics*.

[1] R. E. Green and A. T. Stewart, Phys. Rev. **98**, 486 (1955).
[2] C. Eckart, Phys. Rev. **51**, 735 (1937).
[3] For example, W. B. Skinner, Trans. Roy. Soc. (London) **A239**, 95 (1946).
[4] Through the courtesy of Professor S. DeBenedetti we have learned that similar results have been obtained in his laboratory.
[5] DeBenedetti, Cowan, Konneker, and Primakoff, Phys. Rev. **77**, 205 (1950).
[6] Page, Heinberg, Wallace, and Trout, Phys. Rev. **98**, 206 (1955) and L. A. Page (private communication).
[7] R. E. Bell and R. L. Graham, Phys. Rev. **90**, 644 (1953).
[8] R. L. Graham and A. T. Stewart, Can. J. Phys. **32**, 678 (1954); T. A. Pond, Phys. Rev. **93**, 478 (1954).