Title

LITHIUM-DIFFUSED n+ CONTACTS ON HIGH-PURITY GERMANIUM: HOW THIN CAN THEY BE MADE - HOW STABLE ARE THEY?

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Publication Date

1974-12-01

Presented at the IEEE Nuclear Science
Symposium, Washington, D. C.
December 11-13, 1974

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December 1974

Prepared for the U.S. Atomic Energy Commission
under Contract W-7405-ENG-48

LBL-3630
c.1

DISCLAIMER

LITHIUM-DIFFUSED n^+ CONTACTS ON HIGH-PURITY GERMANIUM: HOW THIN CAN THEY BE MADE—HOW STABLE ARE THEY?*

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SUMMARY

A Li-diffused n^+ surface layer is the best n^+ contact developed up to the present time. However, the effective dead layer resulting from the Li-diffusion prevents the optimum stacking of detectors for counter telescopes. Diffusion temperatures as low as 160°C have been successfully used to produce effective dead layers as thin as 10 μ. Unfortunately, these dead layers increase significantly when the detector is annealed following radiation damage.

DISCUSSION

With the forthcoming operation of new high-intensity intermediate energy accelerators (LAMPF, Indiana, Columbia, SIN and TRIUMF) it is important to develop particle spectrometers to utilize the capabilities of these machines. The availability of high-purity germanium opens up the possibility of constructing thick multi-detector telescopes which will be less expensive and cover a larger energy range at one time than present spectrometers.

* This work was supported by the U. S. Atomic Energy Commission

Since the detectors will have to be stacked to achieve sufficient total stopping power, they must have thin windows on both the entrance and exit faces.* The surface barrier electrode, typically formed by a palladium evaporation at LBL, results in a very thin window--on the order of 0.1 μ. A lithium-diffused n^+ surface layer is the best n^+ contact developed up to the present time. Unfortunately, this lithium-diffused layer is relatively thick when our typical diffusion schedule is followed. A five minute diffusion at about 280°C results in a window thickness of about 250 μ.

In hopes of obtaining sufficiently thin windows while still employing the reliable Li-diffused n^+ contact we experimented with progressively lower temperature diffusions. Diffusion temperatures as low as 160°C have been successfully used to produce effective dead layers as thin as 10 μ.**

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* Stacking detectors together has several significant benefits compared with one large detector of equivalent total thickness. A large fraction of high energy charged particles undergo nuclear reactions prior to reaching the end of their range. For example, calculations[1,2] estimate that the low energy tail from nuclear reactions will be about 9% for 100 MeV protons, and this has recently been verified in an experiment using a germanium spectrometer.[3] If signals are available from each detector most of the events corresponding to a nuclear reaction in the germanium can be rejected by using appropriate electronic circuitry. The second major benefit arises because the electron-hole pairs do not have to travel as far to reach the electrodes when detectors are stacked together. Consequently, the detectors are less susceptible to charge trapping--this will be especially important in applications where radiation damage is likely.

** Effective window thicknesses were determined by two techniques:

1) Alpha particle spectra from a ^{228}Th source were obtained when the particles were incident on the Pd contact, and then when the particles had to pass through the Li-diffused contact. From the relative displacement of the alpha particle peaks an effective window thickness was calculated.

2) The displacement and resolution of the peaks corresponding to conversion electrons from a ^{207}Bi source were measured.

Although even thinner windows are desirable, the windows that can be obtained with low temperature Li-diffusions are acceptable for many spectrometer applications.

Unfortunately, the use of germanium spectrometers around accelerators will often result in radiation damage that will necessitate annealing the detectors at temperatures at least as high as 100°C for periods of several days.[4] The lithium mobility at these annealing temperatures is sufficient to cause the effective dead layer to increase significantly. For example, in the process of successfully annealing germanium detectors that had been neutron damaged at LAMPF, the thin lithium surface layer increased to over 250 μ.[3] Such an increase largely negates the great asset of being able to anneal high-purity germanium detectors without removing them from the cryostat, and consequently lithium-diffused n^+ contacts are not viable for spectrometers that are likely to be radiation damaged.

Storage at room temperature also causes the lithium surface layer to increase in thickness significantly. After a year at room temperature thin lithium surface layers increase to over 250 μ. However, the electrical properties of the n^+ contact remain excellent.

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