

## Fabrication of Planar Ge(Li) Detector\*

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A planar Ge(Li) detector of active area 4.5 cm<sup>2</sup>, drifting depth 4 mm was completed and its fabricating procedure was described in detail. The energy resolution of the detector was measured to be 3.3 keV with the ORTEC 120-3F preamplifier, ORTEC 410 linear amplifier and detector bias of 500 volts. Its characteristic curves of the current-bias and the capacitance-bias were also measured.

### I. INTRODUCTION

THE lithium drift process has been widely used to make depletion layer diodes in the detectors. For gamma ray spectroscopy diodes of germanium, it has a considerable advantage over those of silicon since the photoelectric absorption cross section varies approximately as  $z^5$ <sup>(1-3)</sup>

Owing to the particle's detector, Si(Li) detector has been completed at here last year<sup>(4)</sup>, we had got enough the experiences to complete the Ge(Li) detector, and the planar Ge(Li) detector was therefore considered.

### II. PROCEDURES

**1. Cutting:** A p-type germanium single crystal of 43 mm in diameter, 60 mm in thickness, doped with gallium was bought from Hobken-Belgium, and its resistivity ( $\rho$ ), carrier lifetime ( $\tau$ ) and dislocation density are respectively 20.5-25.5 ohm-cm, 550  $\mu$ s and 3000-1800/cm<sup>2</sup>. Two slices of the crystal, the thickness are 2 mm and 5 mm, were respectively cut by a diamond saw for determining the diffused depth of the lithium and constructing the detector.

**2. Lapping:** The surfaces of the slices were lapped by use of the 600 mesh Al<sub>2</sub>O<sub>3</sub> powder and a flat glass plate in order to remove the saw marks. Lapping was continued until the two surfaces of the slices were very smoothly and in parallel. Then put the slices into a ultra sonic cleaner to wash about five minutes with respectively the trichloroethylene (C<sub>2</sub>HCl<sub>3</sub>), methyl alcohol (CH<sub>3</sub>OH) and de-ionized water.

**3. Etching:** The cleaned slices of the crystal were handled with teflon coated tweezers and immersed in the solution of HNO<sub>3</sub>:HF=3:1 to etch about 2 minutes then quenched by methyl alcohol and etched again with the solution of HNO<sub>3</sub>:HF=5:1 until the mirror-like surfaces were appeared. Finally the slices were rinsed with C<sub>2</sub>HCl<sub>3</sub> for the preparing of the diffusion.

**4. Diffusion:** In order to keep the slice from lithium contamination, a carbon mask shown

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(1) J. L. Blankenship, IRE Trans. on Nuclear Science NS-9, 181 (1962).

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in Fig. 1 was designed. The lithium metal was washed briefly in hexan to remove the oil coating and then put in the tantalm boat. Then placed the 5 mm slice of the crystal in the mask which a thermocouple and a heater were inserted into it as shown in Fig. 1. The things in the evaporator was now ready for diffusion, when the vacuum of the evaporator was pumped down to  $\sim 10^{-6}$  torr, the heater was put on and the temperature of the slice was raised to  $430^{\circ}\text{C}$  in a period of 30 minutes and then the lithium in the boat was evaporated for 1 minute. The diffusion was taken another 5 minutes after evaporating the lithium, the time of the diffusion was estimated from the data of another slice, 2mm thick slice, which was carried out the diffusion before present experiment. The depth of the diffusion is about 1 mm which was tested by copper plating method.<sup>(5)</sup>

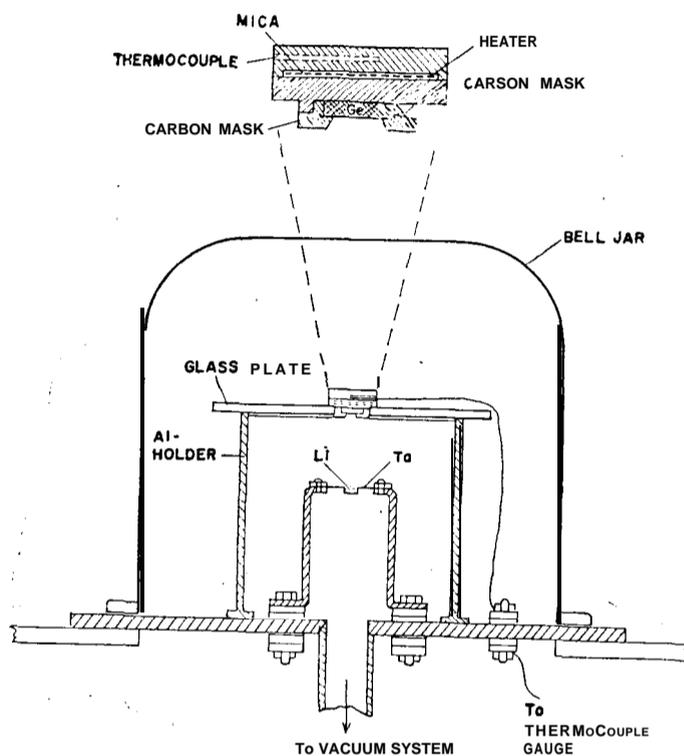


Fig. 1. Apparatus for Li-evaporation and diffusion.

**5. Drifting:** The lithium-diffused crystal, or diode, was etched again with the solution of  $\text{HNO}_3:\text{HF} = 5:1$  for 1-2 minutes and then placed in the drifting assembly as shown in Fig. 2. The contact between the crystal and the brass holder was painted with Ga-In alloy to insure good electrical and thermal conduction. The drifting was carried out under a reverse bias between 250-350 volts for the period of 7~8 days, in the meantime, the leakage current was increased from 9 mA to 30 mA owing to the widening of the drifting region and increasing in thermal generating current and the drifting temperature was kept in  $25^{\circ}\text{C}\sim 28^{\circ}\text{C}$ . The drifting depth was obtained to be 4-5 mm.

**6. Clean-up:** In order to improve the breakdown voltage<sup>(6)</sup> and reduce the capacitance,<sup>(7)</sup> diode has to go through a clean-up drift at lower temperature and high electric field. The clean-up process was performed in the drifting apparatus which was surrounded by dry ice ( $\sim -30^{\circ}\text{C}$ ) and supplied a reverse bias of 100 to 480 volts for about 42 hours shown as Fig. 3.

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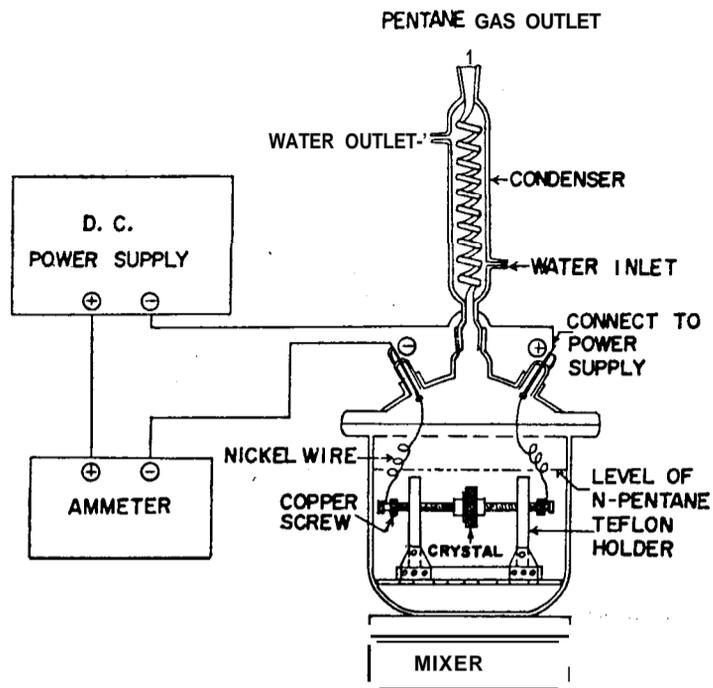


Fig. 2. The whole system of Li drifting apparatus.

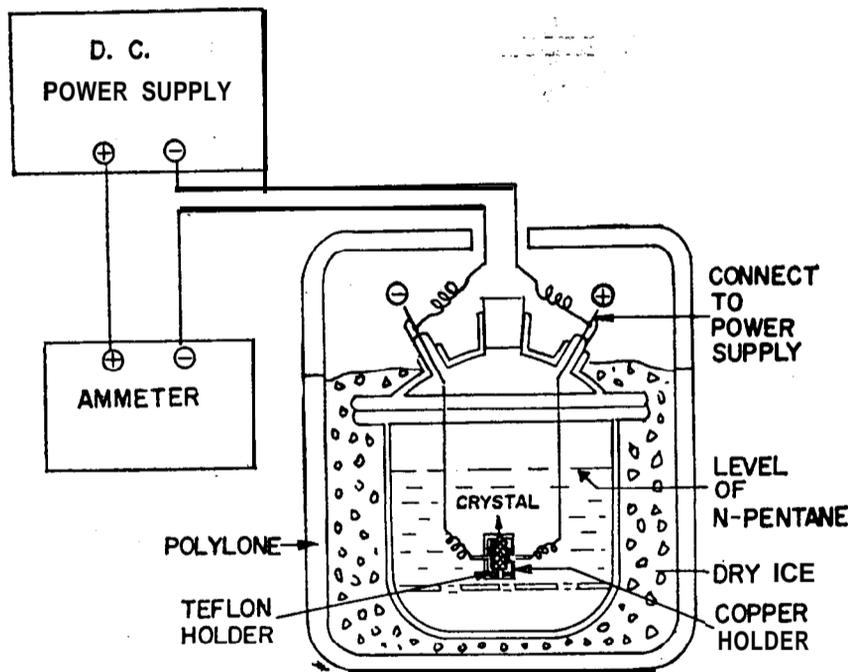


Fig. 3. Schematic of a clean-up unit.

7. **Mounting:** In order to reduce the leakage current and the noise, the Ge(Li) detector must be performed at liquid nitrogen temperature (LNT) and kept in a vacuum  $\sim 10^{-6}$  torr. All the mounting procedure must be carried as quickly as possible, so that the Ge(Li) detector may be kept from moisture and air pollution. Fig. 4 is a diagram of the structure of the cryostat.

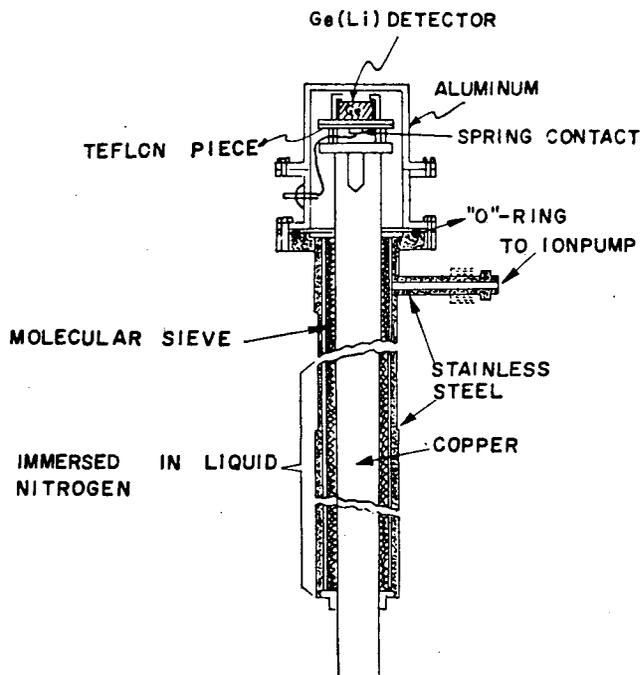


Fig. 4. Schematic of a cryostat.

### III. RESULTS AND DISCUSSIONS

For understanding the results of the completed Ge(Li) detector, the characteristic curves of the current-bias and the capacitance-bias were measured. Those are shown in Fig. 5. From the figure

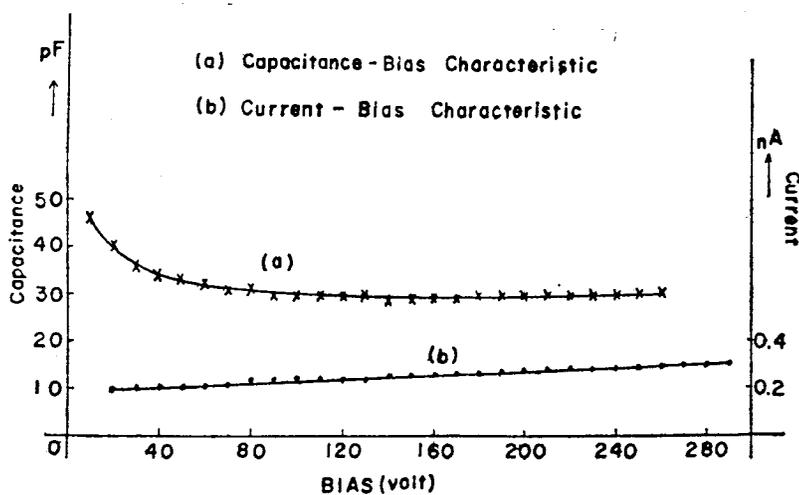


Fig. 5. The characteristic curves of the current-bias and the capacitance-bias of the fabricated Ge (Li) detector

we can understand that the leakage current increases very slowly as the detector bias increases and the current is less than one nano-ampere when the applying voltage of the detector bias is 300 volts. For the capacitance, it is almost keeping constant when the detector bias increases beyond 120 volts. These good characteristics imply that the surface's treatment and the fabricating steps described above are acceptable and reliable. For understanding the energy resolution of this detector, the 1.33 MeV and 1.17 MeV gamma rays of  $^{60}\text{Co}$  were tested by this detector with ORTEC 120-3F preamplifier and ORTEC 410 linear amplifier. The voltages of the detector bias were kept at 300 volts and 500 volts, and the energy resolutions were measured to be 3.7 keV and 3.3 keV respectively. The Fig. 6 is the spectrum of the gamma rays of  $^{60}\text{Co}$  for the detector bias of 500 volts.

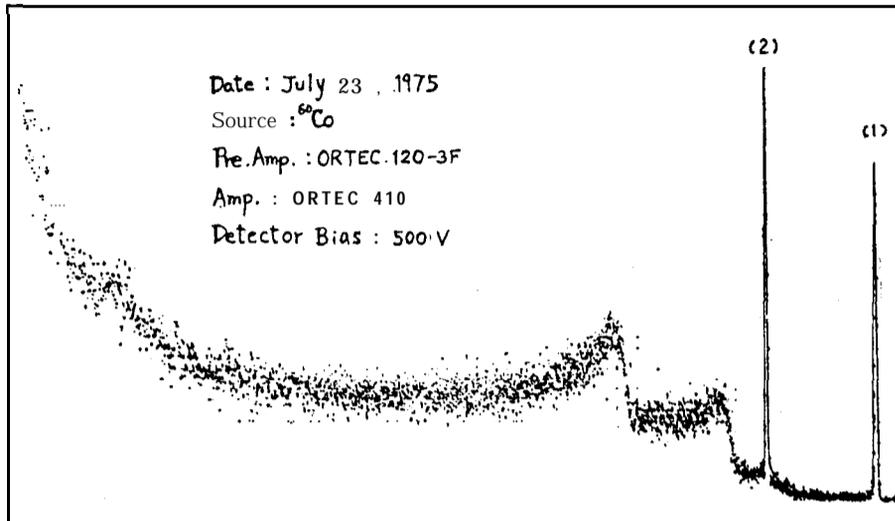


Fig. 6. A gamma ray spectrum of  $^{60}\text{Co}$  for the detector bias of 500 volts.

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