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Fabrication and research of high purity germaniun detectors with abrupt and thin diffusion layer

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A different high purity germanium detector's fabrication method is described. A very thin diffusion film with an abrupt change of the type of conductivity are obtained. The fine diffusion layer thickness makes possibly their utilization in experimental systems in which all the data are elaborated directly on the computer.

Fabricación e investigación de detectores de germanio puro con una capa difundida fina y abrupta

Se describe un método de fabricación de detectores de germanio puro, en el cual se obtienen capas de difusión con un cambio brusco del tipo de conductividad, y un grosor muy fino lo cual hace posible su utilización en sistemas experimentales en los cuales todos los datos son elaborados directamente por computadora.

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Introduction

Advantage of detectors with abrupt and thin diffusion layer

Detectors with abrupt and thin diffusion layer are necessary because of they are often used in accelerate particle beams, in order to collect information from detector telescopes directly to the PC [1, 2, 3,4].

For experimental data elaboration is absolutely necessary to introduce in the software geometrical characteristics of each detector then we need to manufacture detectors that must have thin and abrupt p-n junction. This junction must penetrate inside the detector material at the same depth. They must have sharpest separation border (donor impurities dependence Vs diffusion depth has P Shape).

Technology we use for this type of detector fabrication allows to heat detector surface till higher temperature than the uniform heating, this way we can increase lithium solubility in Germanium (Figure 1). Lithium surface concentration also increases and better ohmic contact is obtained.

In the detector fabrication we use only surface heating. The main crystal is not warm up, hence Germanium crystal will be able to preserve his good crystal characteristics (life time of minority carriers, crystal uniformity, etc.).

The electric field strength inside the detectors will change uniformly (Figure 2) and the time characteristics will improve.

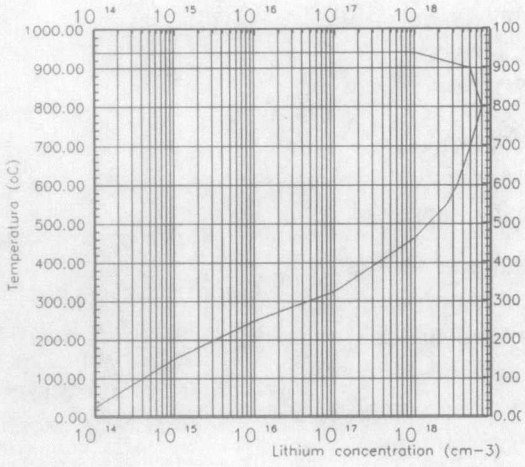

Figure 1. *Lithium solubility in Germanium.*

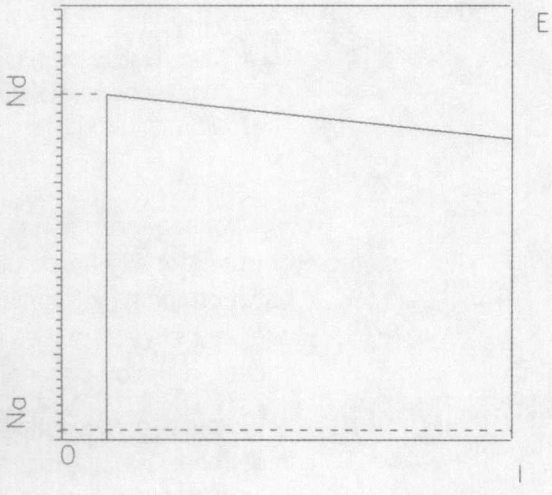

Figure 2. *Electric field strenght's variation through detector's thickness in light pulse's diffused high purity germanium detector.*

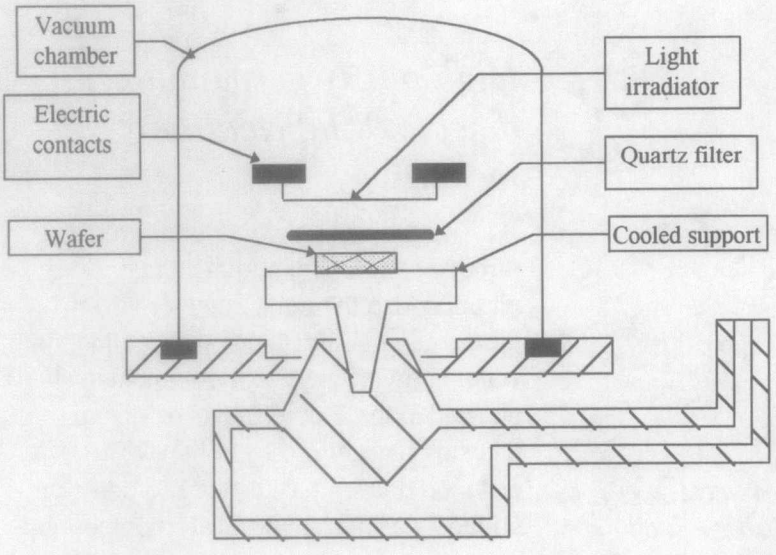

Figure 3. *Light pulse's diffusion equipment.*

Materials and methods

Fabrication technology of detectors with abrupt and thin diffusion layer by means of light pulses

To obtain abrupt diffusion layer is necessary to create temperature gradient in order that the diffusion coefficient rapidly decreases from the surface toward the crystal depth. For this purpose the best heater we found was tungsten or tantalum thin plate light irradiator. Tantalum irradiator's surface temperature could reach 2000∞ C (T_{fusion}= 3000∞ C) and we can heat crystal surface (size to 10 cm^2 and more, separated from irradiator at 5-10 mm) upper 700∞ C for 5 seconds.

Choosing pulse's duration and interval between them (while one side of the wafer surface is cooled) is heated only very thin surface layer and toward the crystal depth the temperature is abrupt decreased. In the Figure 3 is shown the equipment drawing for light pulse's diffusion.

The main heating power is dissipated irradiation and only a little part of power is dissipated by thermal conductivity through electric contacts. Irradiation is dissipated nearly 900 watts.

Total irradiation equation for "non absolutely black body" is [5]:

$P = S\varepsilon_t \sigma (T^4 - T_o^4)$, where:

S irradiated surface (cm^2);

ε total irradiation body coefficient (for non oxidized tungsten ε_{tungs}= 0,24,

for tantalum ε_{tantal}= 0,26);

σ Stephen Voltsman constant ($5{,}7.10^{-2}$ Wcm^{-2} $grad^{-4}$);

T irradiator's temperature °K;

T_o around temperature °K; which frequently is possible no consider If $T >> T_o$.

If we take into account only power dissipated by irradiation, then surface temperature is equal to 1900°C.

Due to thermal exchange between heater and wafer occur in a distance the equipment construction is greater simplified.

In the Figure 4 is shown surface wafer's temperature Vs light pulse's duration. Wafer's temperature variation Vs distance between irradiator and wafer with different pulse's duration is also shown in the same figure. Temperature's distribution through the wafer thickness in the "non cooled" wafer is shown in the Figure 5.

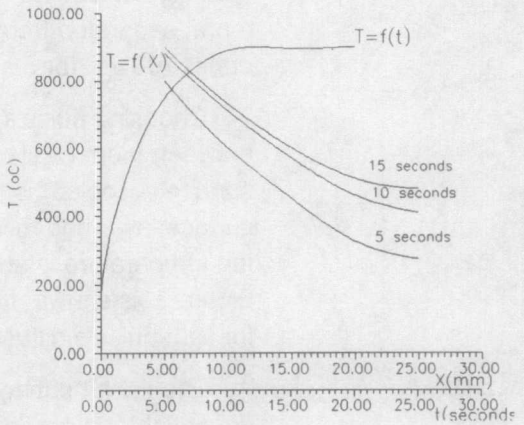

Figure 4. *T=f(t) Surface wafer's temperature*

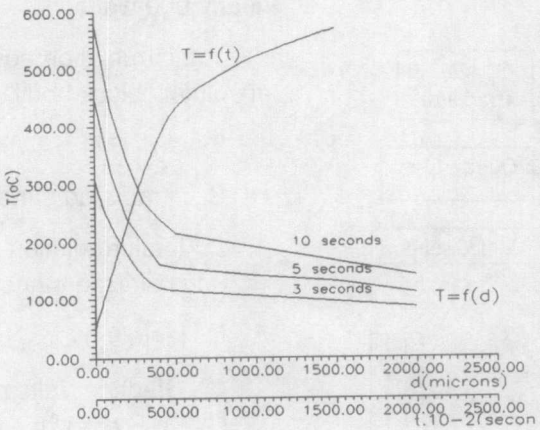

Figure 5. *T=f(d) Temperature's distribution Vs light pulse's duration. Through the wafer's thickness Vs T=f(X)Wafer's temperature variation heating time. Vs distance between irradiator and T=f(t) Surface wafer's temperature wafer with different pulse's duration. Vs light pulse's duration.*

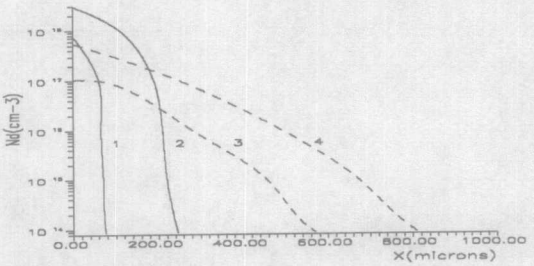

Figure 6. *Lithium distribution profile in germanium after diffusion.*

1. *Heating with 2 light pulses, duration 10 seconds, interval between them 5 min, distance between irradiator and wafer 5 mm.*
2. *Heating with 2 light pulses, duration 15 seconds, interval between them 1 min, distance between irradiator and wafer 3 mm.*

3,4. Calculated distribution profile of impurity concentration in germanium after lithium diffusion with uniform heating.

Consequently if we change the wafer's or irradiator's temperature, distance between them, light pulse's duration, interval between pulses we can obtain the chosen diffusion concentration profile.

Impurity concentration distribution's profile in germanium after lithium diffusion with uniform heating, and experimental lithium concentration's distribution with heating by light pulses is shown in the Figure 6.

High purity germanium detector's fabrication technology

The germanium wafer after grease removing, polishing and etching is introduced in the equipment for lithium evaporation. After lithium evaporation the wafer is rapidly sent to the equipment showed in the Figure 3, where lithium diffusion by light pulses is done. The distance between irradiator and detector surface was 10 mm, irradiator temperature 1900°C, light pulse's duration 1.5 seconds, interval between pulses 60 seconds,

number of pulses is equal to 10. In the same side where diffusion was make the guard ring is fabricated. The detector is again etched in the mixture of HNO_3: HF (relation 9:1).

The diffusion side is covered with acid resistant tape and another side (where will be p^+ contact) is polished. Finally the detector is etched in the mixture HNO_3: HF (relation 3:1). The posterior fabrication technology steps are the same than in the standard high purity germanium detector's technology.

Conclusions

Using light pulse's technology were fabricate planar germanium detector with 8 mm of diameter and sensitive region thickness 6.5 mm.

Germanium impurity concentration was $(N_a\text{-}N_d) = 1.10^{10}\ cm^{-3}$.

Technological diffusion regimens were the following: pulse's number = 10; pulse's duration = 1,5 seconds; interval between pulses = 60 seconds; distance between irradiator and detector 8 mm. Current-voltage (I-V) and capacity-voltage (C-V) characteristics rough leak to saturation, it follows that p-n junction is abrupt (Figure 7).

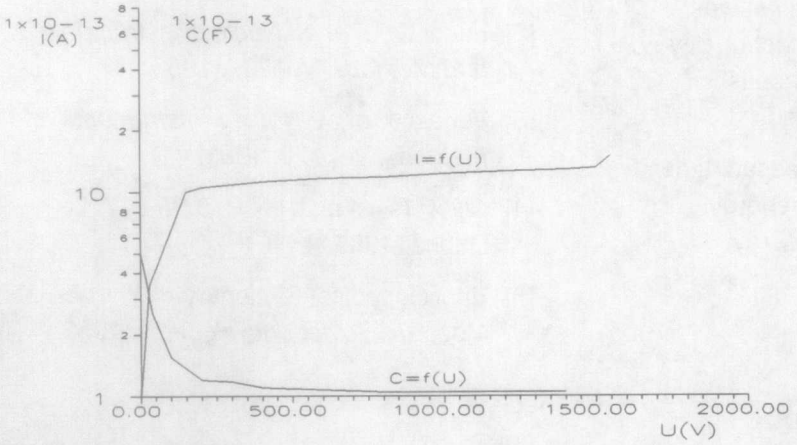

Figure 7. *Current-voltage (I-V) and Capacity-voltage (C-V) detector's characteristics*

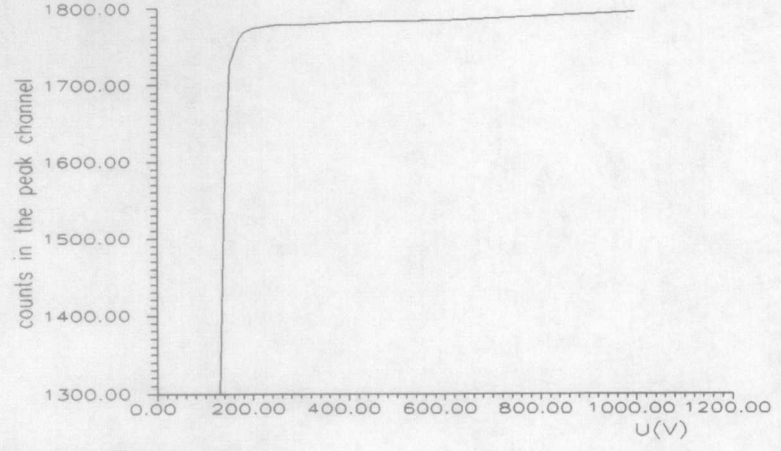

Figure 8. *Detector efficiency.*

These characteristics had been obtained in the best uniformly heating diffused detectors. Inasmuch as explained technology is new and requires successive improvement there are possibilities to obtain much better results in the future. Leakage current of these detectors must be improved.

The detector's rupture voltage was between 1400 V and 1600 V; it is significatively larger than rupture voltage for traditional diffusion fabricated detectors. Detector's efficiency is shown in the Figure 8. This characteristic also rough leaks to saturation.

In the Figure 9 are shown direct current-voltage detector's characteristics. The curve 1 belongs to traditional technology fabricated detector, contact resistance is 294 Ω and curve 2 belongs to light pulse's fabricated detector has contact resistance 77Ω. This fact indicates that the use of light pulse's heating increases lithium surface concentration and the ohmic contact is better.

Entrance window thickness of the detectors was 10 microns. With light pulse's technology were obtained equal values of window thickness for all researched detectors that were fabricated with the same technological regimens.

As result of this work was demonstrated that detectors had thin and abrupt diffusion

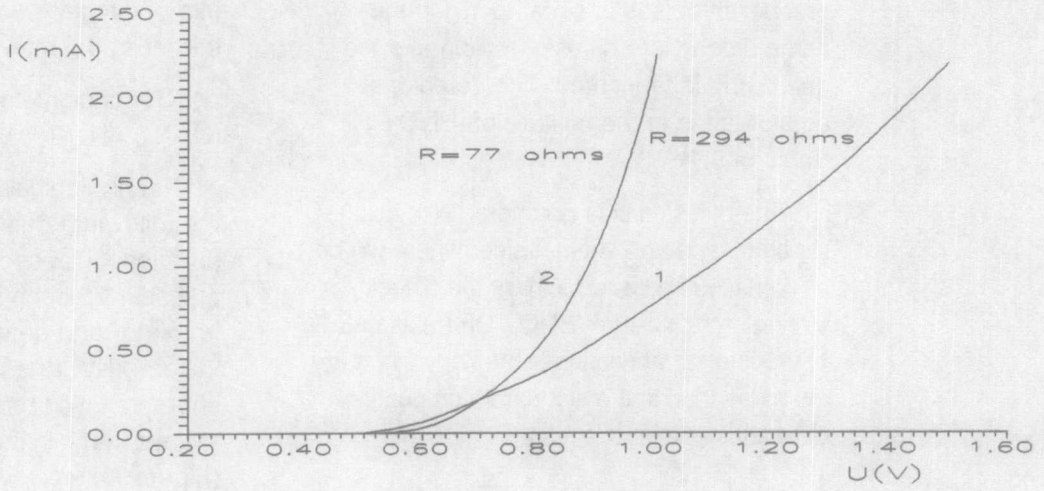

Figure 9. *Direct current-voltage detector's characteristics. 1. Lithium diffusion with uniform heating 2. Lithium diffusion with light pulse's heating.*

layers, they are easy reproducible, also diffusion layer's thickness is the same for all researched detectors.

Lithium surface concentration was increased and the ohmic contact quality is better. Due to contact resistance is decreased the noise is reduced.

Rupture voltage was increased, time resolution was improved and energy resolution was near to limit energy resolution.

References

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