HORIZON 2020

Research Infrastructures

H2020-INFRAIA-2014-2015

INFRAIA-1-2014-2015 Integrating and opening existing national and regional research infrastructures of European interest

ENSAR2

European Nuclear Science and Application Research 2

Grant Agreement Number: 654002

# D10.3 - Advancement Report for the R&D on Segmented p-Type Coaxial Detectors

Version: 3.0
Author: D.Napoli, D.De Salvador, G.Maggioni, A.Gadea
Date: August 31st 2018

*PROJECT AND DELIVERABLE INFORMATION SHEET*

| | |
|---|---|
| ENSAR2 Project Ref. № | 654002 |
| Project Title | European Nuclear Science and Application Research 2 |
| Project Web Site | http://www.ensarfp7.eu/ |
| Deliverable ID | D10.3 |
| Deliverable Nature | Advancement Report |
| Deliverable Level* | PP |
| Contractual Date of Delivery | Month 30 |
| Actual Date of Delivery | Month 30 |
| EC Project Officer | Mina Koleva |

* The dissemination level are indicated as follows: PU – Public, PP – Restricted to other participants (including the Commission Services), RE – Restricted to a group specified by the consortium (including the Commission Services). CO – Confidential, only for members of the consortium (including the Commission Services).

*DOCUMENT CONTROL SHEET*

| | | |
|---|---|---|
| Document | Title: Advancement Report for the R&D on Segmented p-Type Coaxial Detectors | |
| | ID:10.3 | |
| | Version: 3.0 | |
| | Available at: http://www.ensarfp7.eu/ | |
| | Software Tool: Microsoft Office Word 2007 | |
| | File: | |
| Authorship | Written by: | D. Napoli, D. De Salvador, G. Maggioni, A. Gadea |
| | Contributors: | S. Bertoldo, W. Raniero, S. Riccetto, F. Sgarbossa, V. Boldrini, |
| | Reviewed by: | D. Ackermann |
| | Approved by: | K. Turzó |

*DOCUMENT STATUS SHEET*

| Version | Date | Status | Comments |
|---|---|---|---|
| 2.0 | August 19th 2018 | For internal review | |
| 3.0 | August 29th 2018 | For internal review | Corrections included |
| 3.0 | August 31st 2018 | Submitted on EC Participant Portal | |
| | | Final version | |

*DOCUMENT KEYWORDS*

| | |
|---|---|
| Keywords | Position sensitive Germanium detectors, detector technology, Laser Thermal Annealing. |

## Disclaimer

This deliverable has been prepared by Work Package 10 (PSeGe – - R&D on Position-Sensitive Germanium Detectors for Nuclear Structure and Applications) of the Project in accordance with the Consortium Agreement and the Grant Agreement n°654002. It solely reflects the opinion of the parties to such agreements on a collective basis in the context of the Project and to the extent foreseen in such agreements.

## Copyright notices

*TABLE OF CONTENTS*



*LIST OF FIGURES*



*REFERENCES AND APPLICABLE DOCUMENTS*

*LIST OF ACRONYMS AND ABBREVIATIONS*

| | |
|---|---|
| LTA | Laser Thermal Annealing |
| SIMS | Secondary-ion mass spectrometry |
| | |
| | |
| | |
| | |
| | |
| | |

*EXECUTIVE SUMMARY*

Created synergies with task 1 (see below) and between the Semiconductor Physics group of the University of Padova, Physics and Astronomy Department (DFA) who is associated to INFN-Laboratori Nazionali di Legnaro, and IFIC Valencia.
Under study the use of LTA and antimony as dopant to produce p-type HPGe detectors.
In parallel, simulation work on the understanding of the fields on the detector is being performed.

*INTRODUCTION*

The PSeGe JRA within ENSAR2 contributes to the R&D of detector technology for position-sensitive HPGe detector arrays. Key areas are detector production technology, the basic characteristics of the novel detectors, electronic instrumentation and software developments. In particular the tasks aim to the following goals.

Task 1: to investigate new technologies on passivation and segmentation,

Task 2: to perform R&D on novel Ge-detector geometries for ultimate position resolution and efficiency,

Task 3:to perform R&D on segmented p-type coaxial detectors,

Task 4: networking efforts on the demonstration of imaging applications and associated detector technologies. Several European institutions contribute with their specific expertise through workshops and personnel training visits.

The present Advancement Report will inform about the work performed in the first 30 months of the ENSAR2 PSeGe JRA on task 3.

## SECTION 1: ADVANCEMENT REPORT ON THE R&D ON SEGMENTED P-TYPE COAXIAL DETECTORS

During the first 30 months of the grant, the goal has been to define the task work-line, to fix a program that we have defined in collaboration with task 1 and to enrol a young technologist within the ENSAR2 framework in Spain.

The realization of segmented contacts in p-type coaxial detectors, stable and able to stand the standard annealing process in research applications, have been for years a technical challenge. A fundamental step to this aim is the substitution of thick Li diffused junctions with thinner and stable ones.

We have applied for the first time the well-known technology of Laser Thermal Annealing (LTA) to the fabrication of HPGe detectors. The main limit of any junction formation process into HPGE surface is the introduction of contaminant into the bulk during the process that limits the possibility of large volume depletion. LTA promotes the doping by a very short (typically 100 ns) annealing process that keeps the semiconductor bulk unheated and was never considered before for HPGe application. In Fig. 1 we report the carrier concentration in bulk HPGe as a function of temperature for samples we treated in different ways to induce surface junction (for details see reference [V. Boldrini et al. http://arxiv.org/abs/1807.00748]). As can be noted only after boron mplantation and LTA treatment the carrier level remains the same as in the case of untreated HPGe samples.

We developed a process using LTA and an antimony dopant source on HPGe detectors in deep collaboration with the Semiconductor Physics group of the University of Padova, Physics and Astronomy Department (DFA) who is associated to INFN-Laboratori Nazionali di Legnaro, Italy. High electrical activation and junction depth of only about 100 nm were measured. In Fig. 2a Sb concentration profile measured by means of SIMS at DFA

demonstrates the very thin confinement of the dopant after treatment. This fact is very promising for easy segmentation processes if compared with 0.5-1.0 mm thickness of Li contacts previously obtainable.

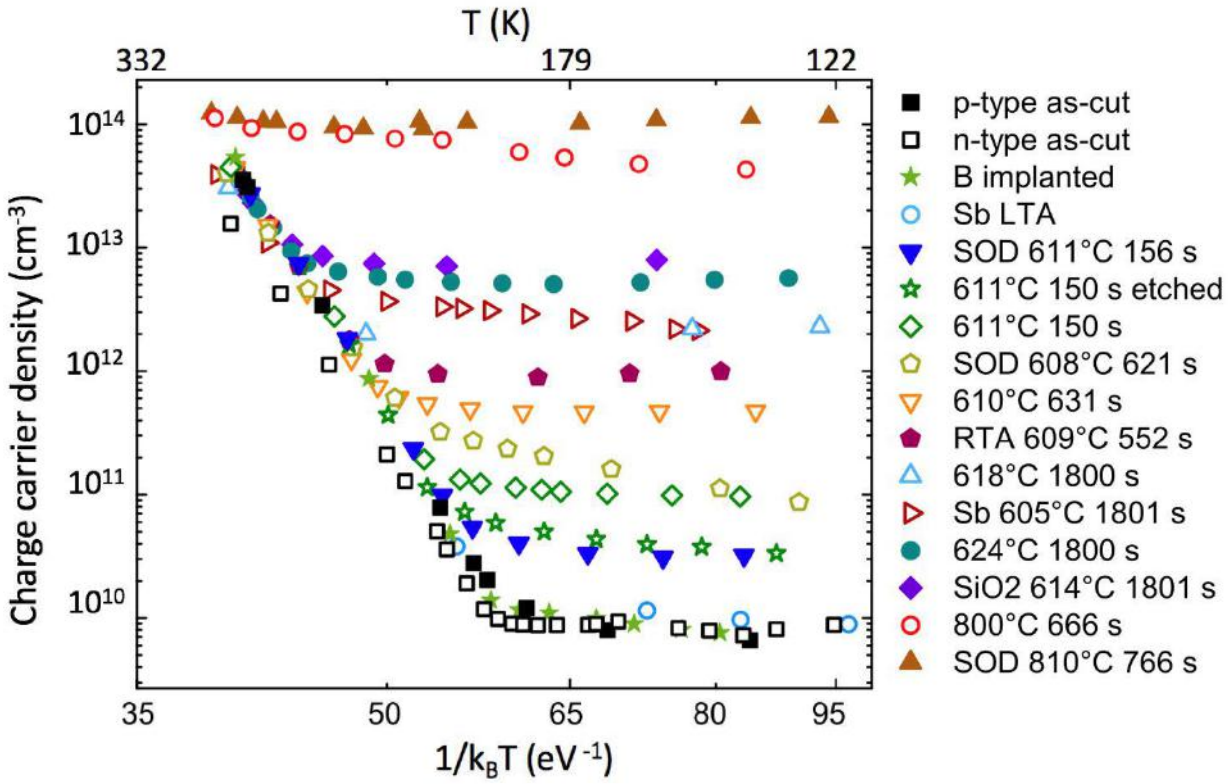


*Figure.1 Charge carrier density as a function of temperature in treated and untreated HPGe samples. Notice the low carrier level at low temperature (less than $10^{10}$ $cm^{-3}$) for untreated samples (squares), the B implanted sample (green stars) and the LTA treated sample (open blue circles). In all other cases bulk dopant contamination occurs.*

HPGE detectors with a first prototype of this contact have been tested in two different planar geometries (with and without guard ring) [G. Maggioni et al. "Pulsed laser diffusion of thin hole-barrier contacts in high purity germanium for gamma radiation detectors" EPJ-A 54:34 (2018) ]. Fig. 2b shows the test spectra obtained with the "no guard ring" version of the detector.
Even if they correspond to a first successful attempt to produce a detector prototype, the resolutions found during the test are satisfactory, encouraging further work in this direction.

Other geometries will be prepared for the next period as well as exploiting other materials dopant source. The last test will be the test of segmentation of two or more LTA contacts of a p-type detector.

In parallel, we have started a study of the optimal segmentation geometries through the use of computing simulation tools that can show the drift of charges inside the crystal in comparison with experimental measurements that will be done in next future.

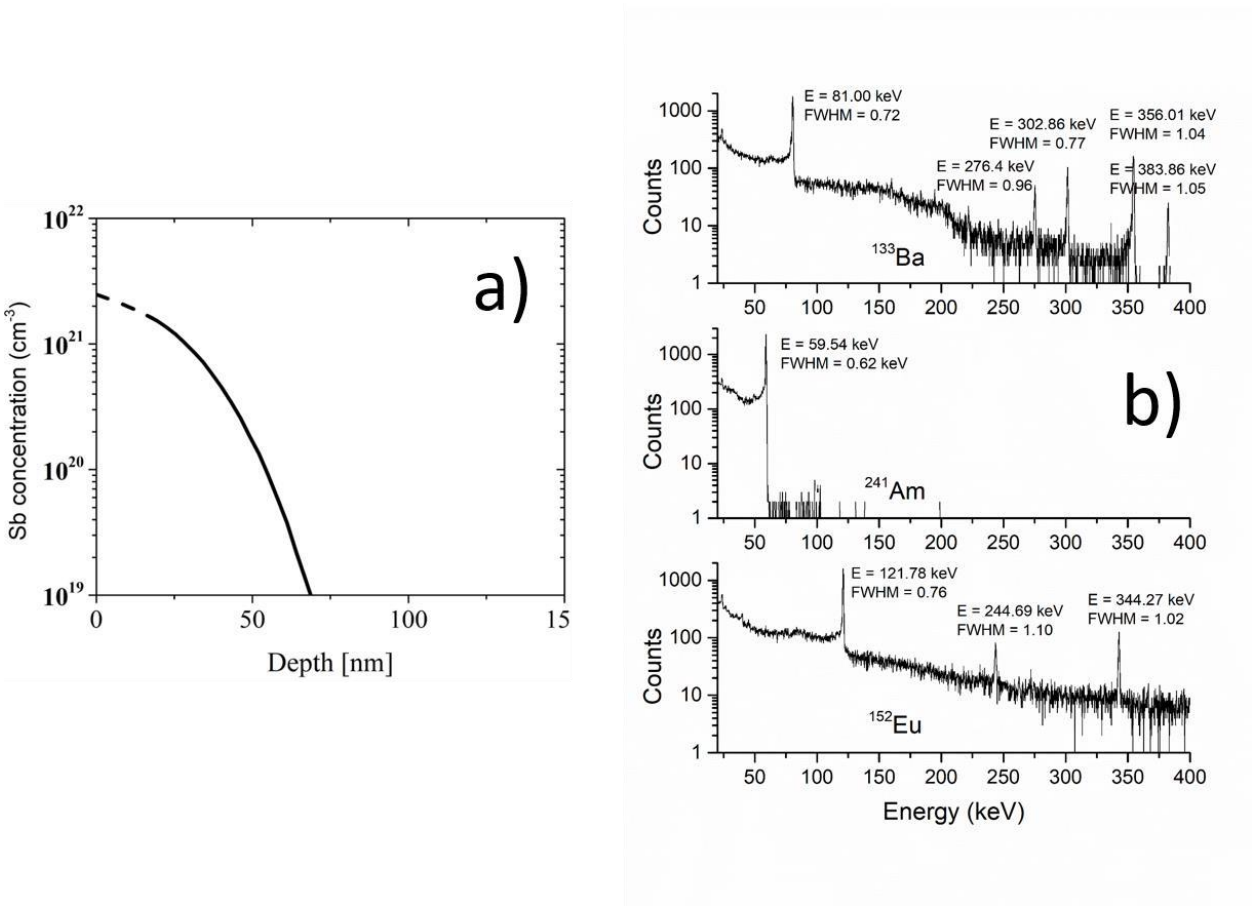


*Figure2 a) Concentration profile of the n (Sb) dopant measured by the SIMS technique. b) Test gamma spectra of the prototype of HPGe detector with different sources.*

## *CONCLUSION*

In this document we report on the advancement of task 3 of the work package 10, the PSeGE JRA, within ENSAR2.

Presently, there is no dopant material providing a stable segmented contact in p-type Ge-HP detectors. The use of Sb as dopant, performing the deposit of the material with sputtering techniques and activating the dopant with the (LTA) Laser thermal annealing technique, seems to be a promising technique to obtain such segmented contacts. The testing and characterization work is in progress.