New developments in n-type junction for Ge detectors

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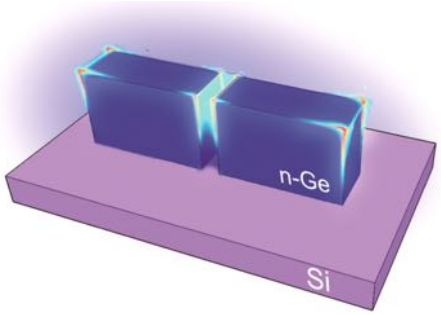
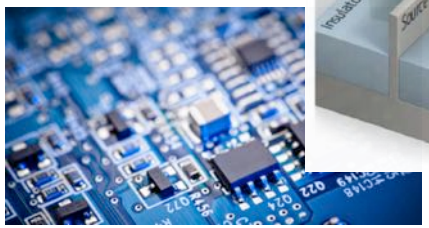
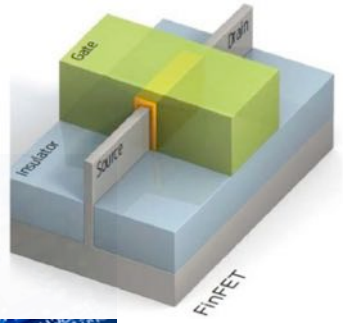
Ge-based devices



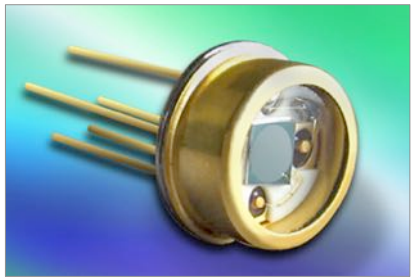
Plasmonic molecular sensors

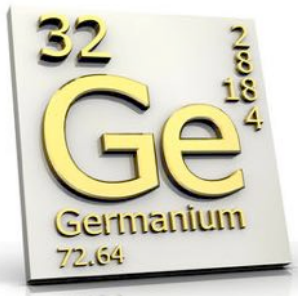
Nanolectronics

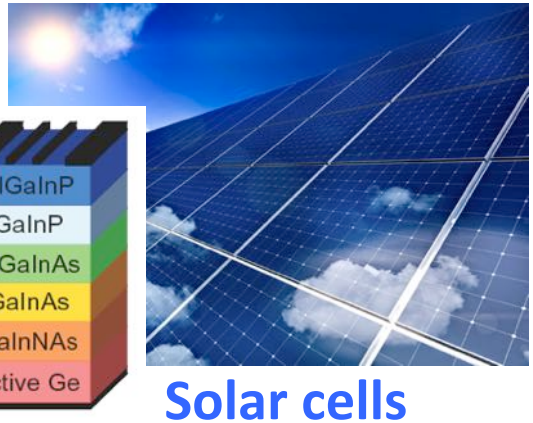




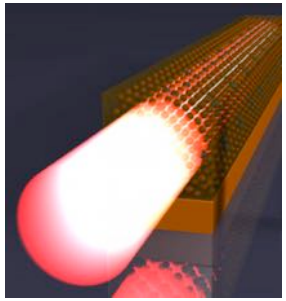
Photodetectors





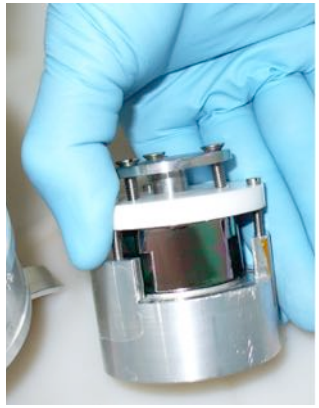


Solar cells



Lasers

γ-Ray detectors



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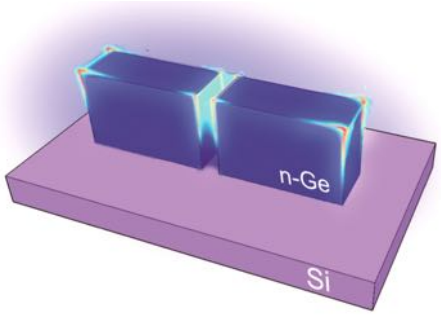

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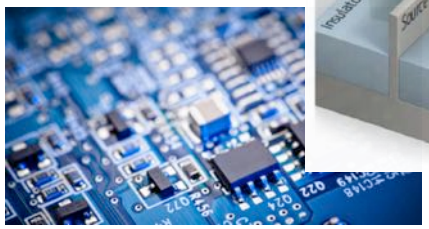

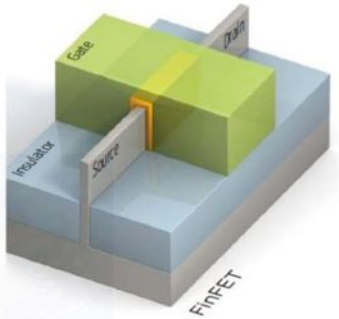

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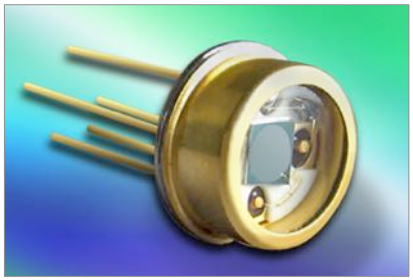

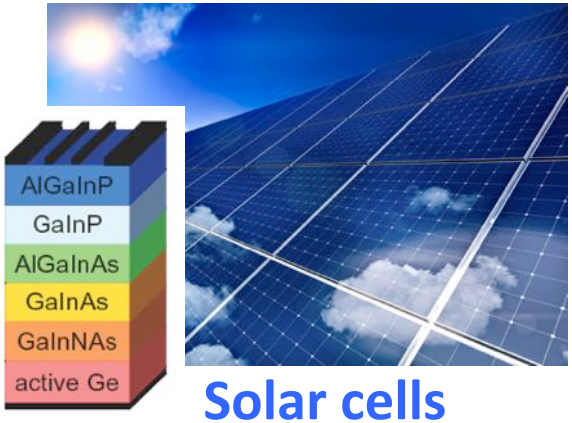

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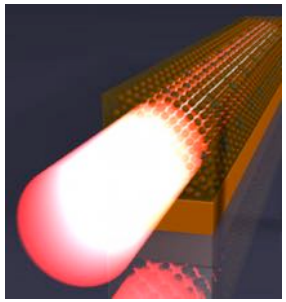

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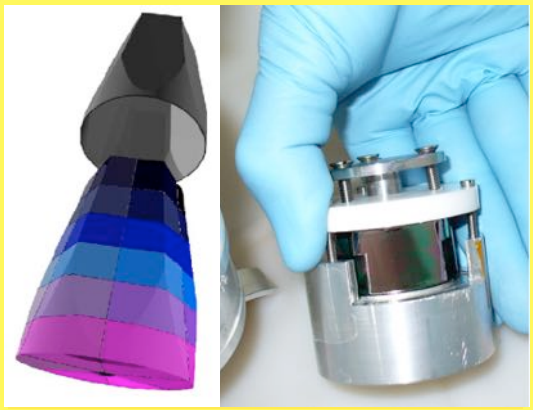

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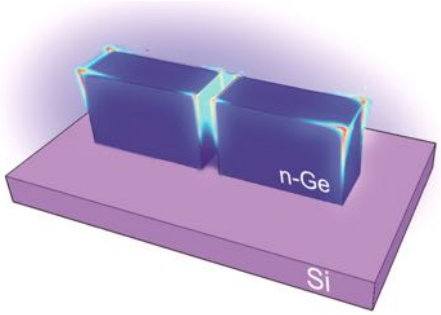

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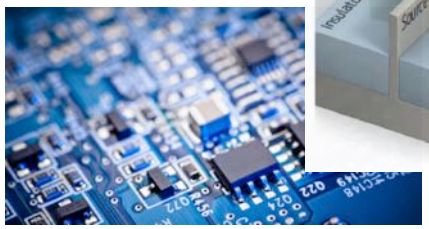

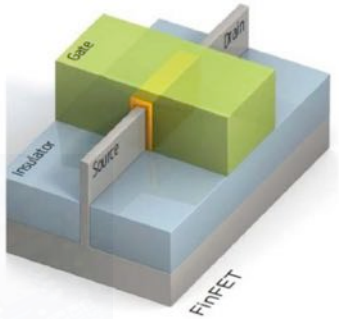

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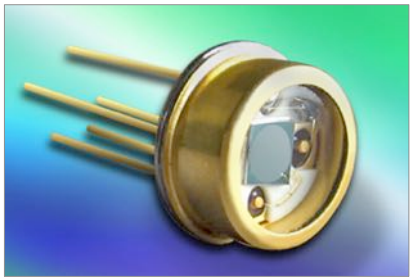

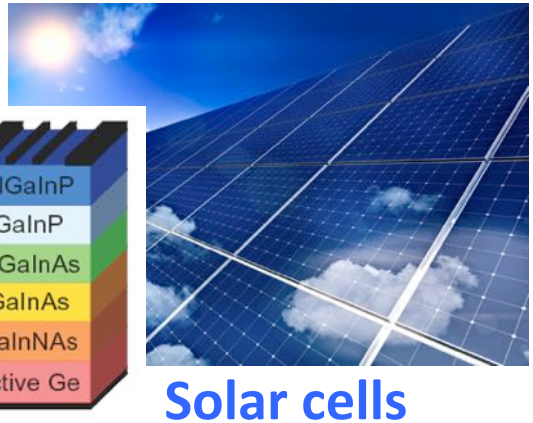

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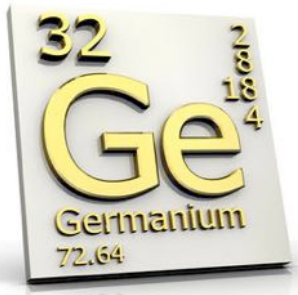
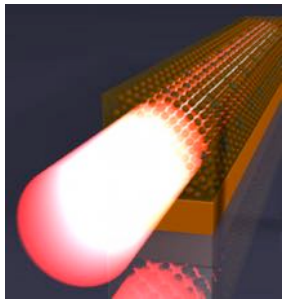
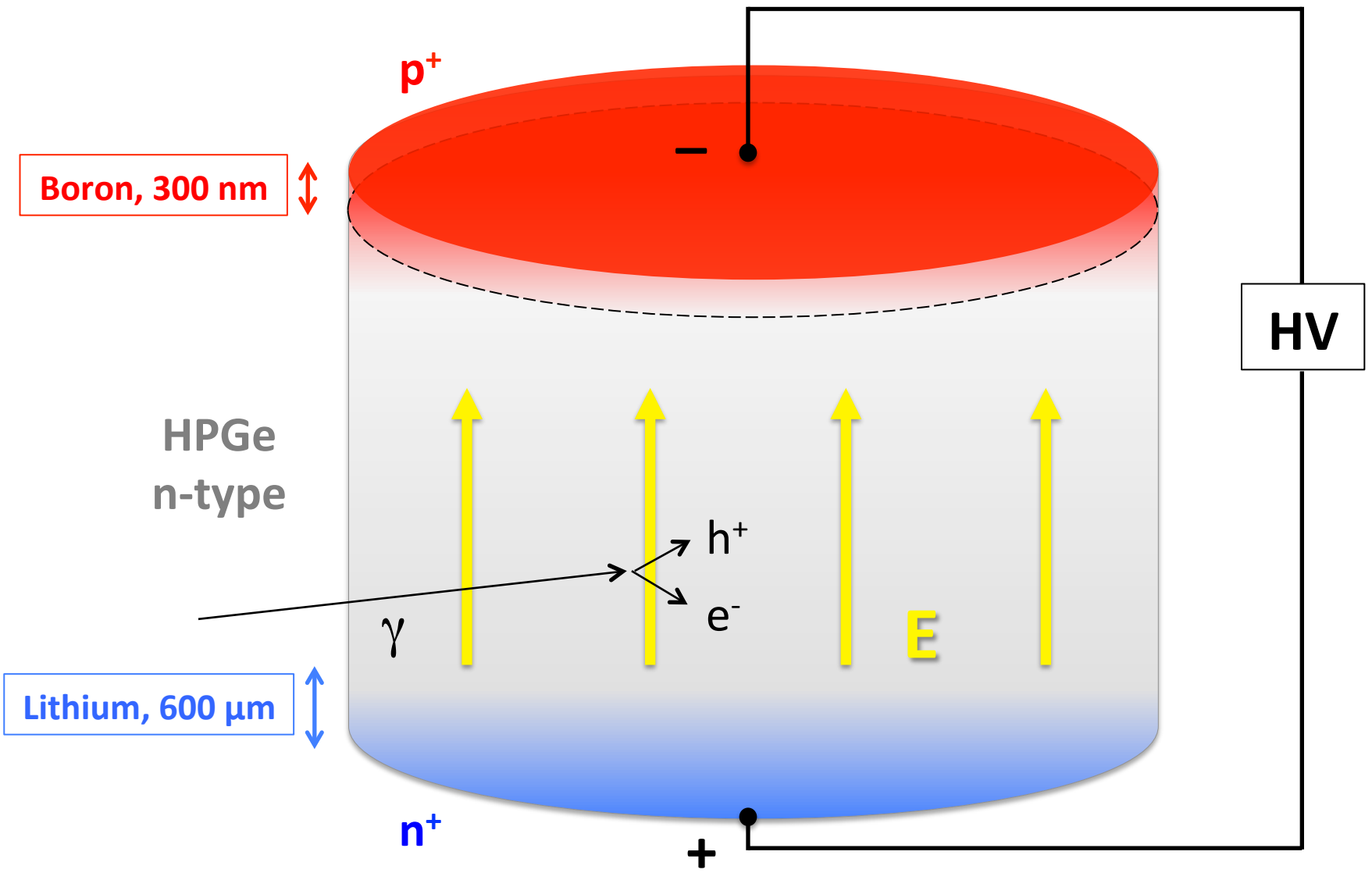




Lasers

γ-Ray detectors

High Purity Germanium flat detector



Problems with current n^+ layer

Thermal diffusion of lithium is not a satisfying technique for n^+ layer formation, due to Li high diffusivity in Ge at low temperature:

$$D\ (350\ °C)_{Ge} = 2.3 \times 10^{-7}\ cm^2 s^{-1}$$

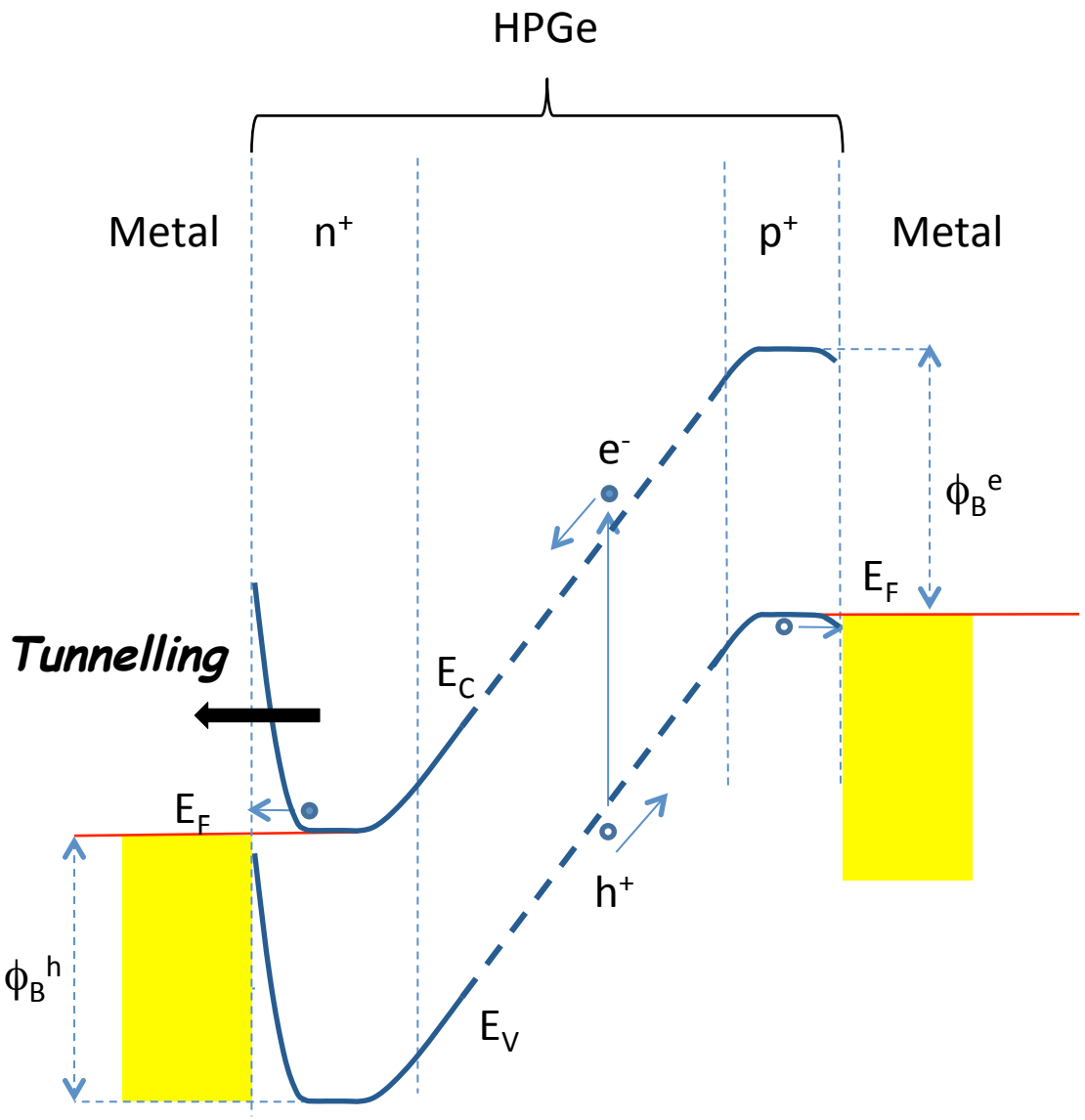
- Too thick (600 μm) ⟶ DEAD LAYER!

- Li migration also at room temperature prevents:
  - high T damage-recovery annealing
  - durable and fine segmentation on n^+ contact

Find a different technique for n^+ layer formation

Requirements for a new n^+ contact

- High doping concentration to enable electron tunneling ≈ 10^{19} cm^{-3}
- Barrier height for hole blocking $\Phi_B{}^h \geq 0.7$ eV
- Thickness ≥ 100 nm to compensate HPGe depleted charge



Spin-On-Doping from P-containing sol-gel

Substrate cleaning and preparation

Sol-gel deposition and spin coating

Curing of the film on a hot-plate

Annealing in furnace for dopant diffusion

Removal of the glassy film

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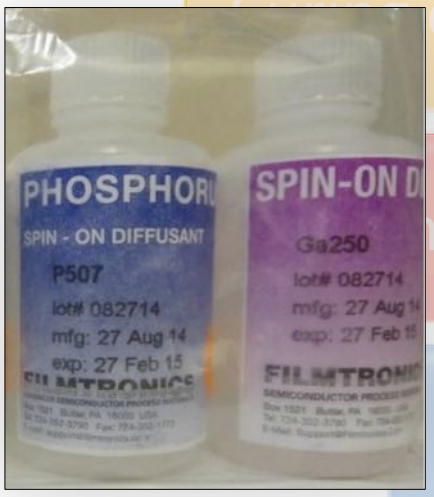

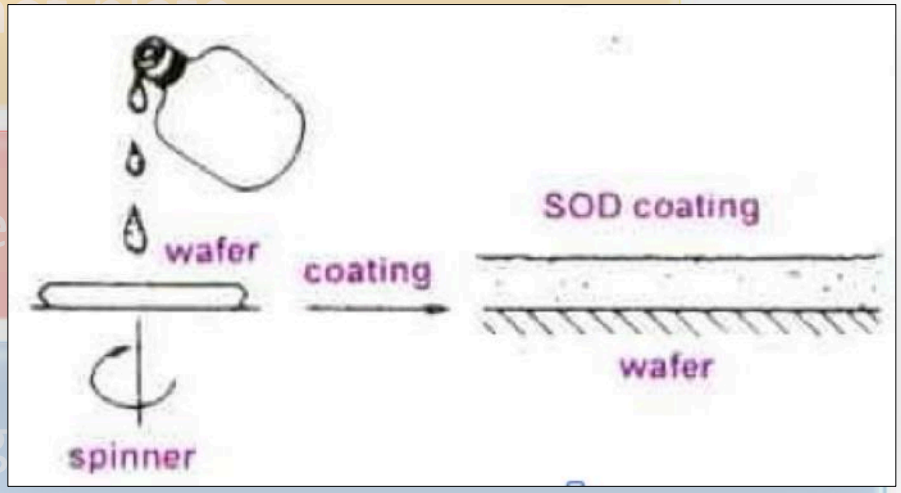

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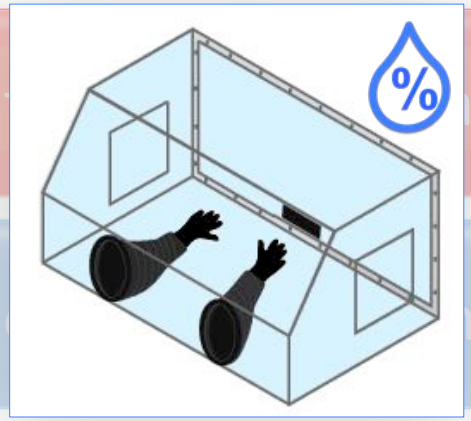

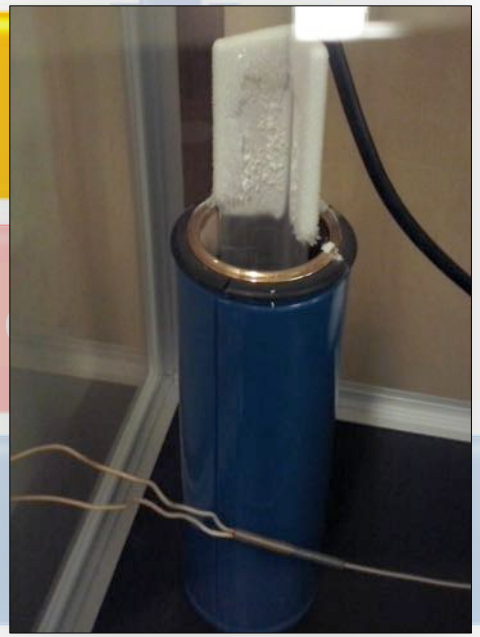

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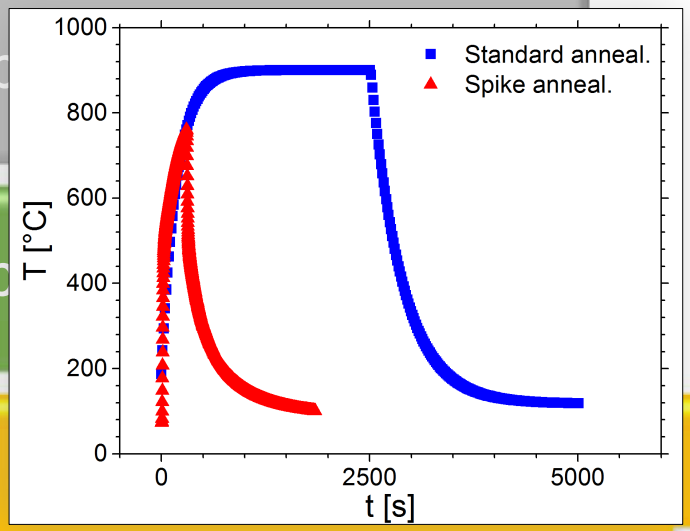

Annealing in furnace for dopant diffusion

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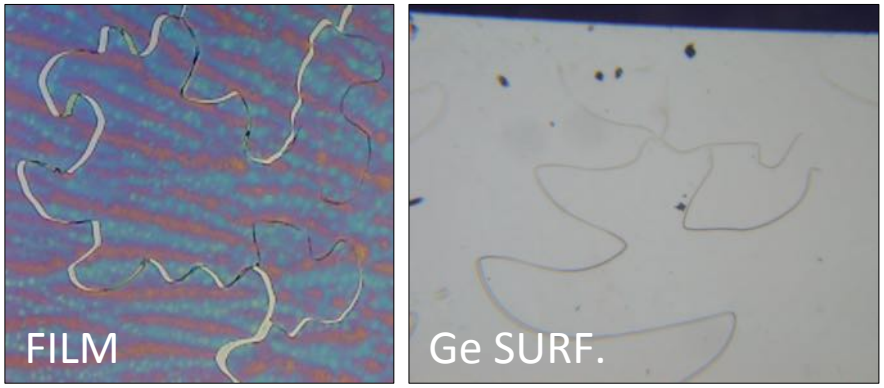
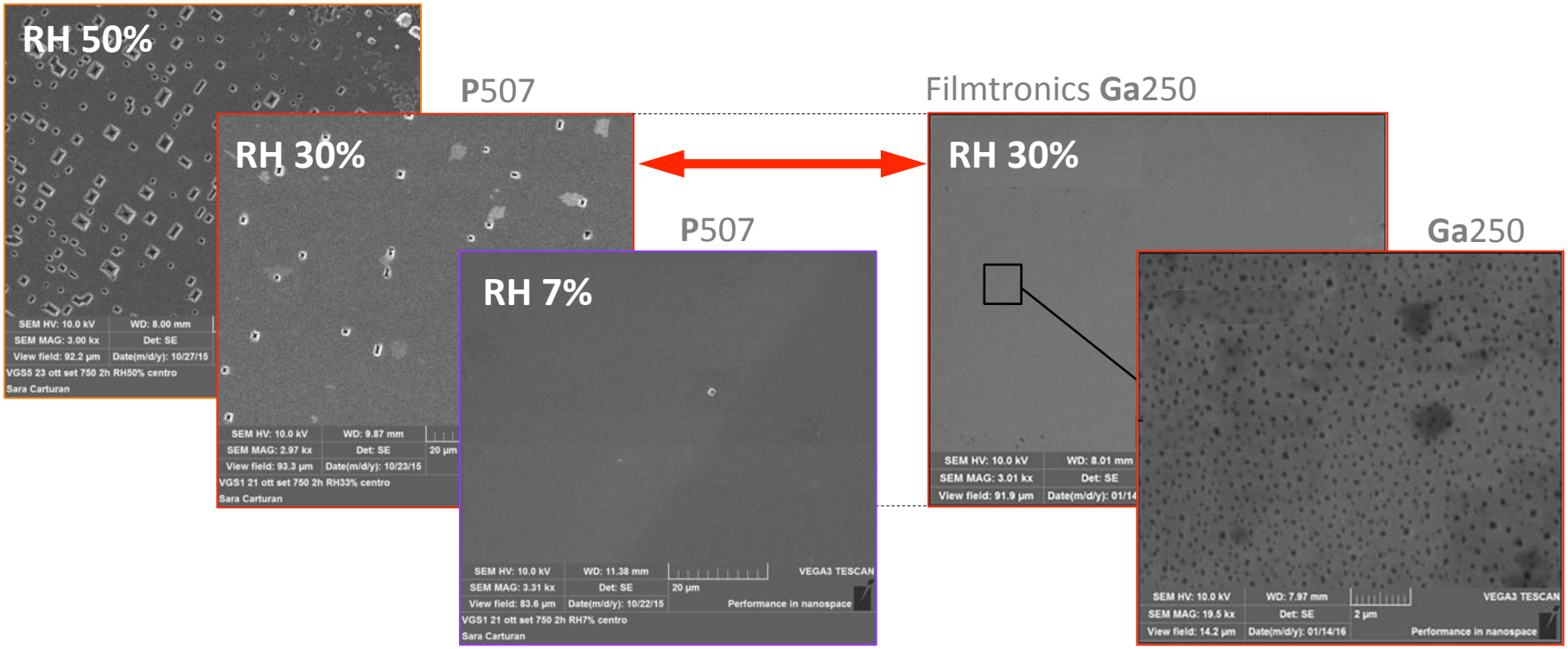
Relative humidity effect – Surface corrosion

If the SOD film absorbed water:

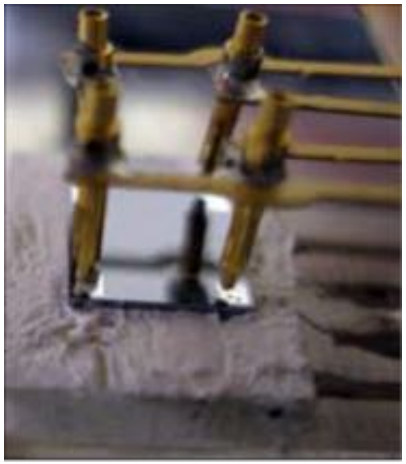
- Cracks in Ge surface (RH>30%)
- $Ge(s) + H_2O(g) \leftrightarrow GeO(g) + H_2(g)$

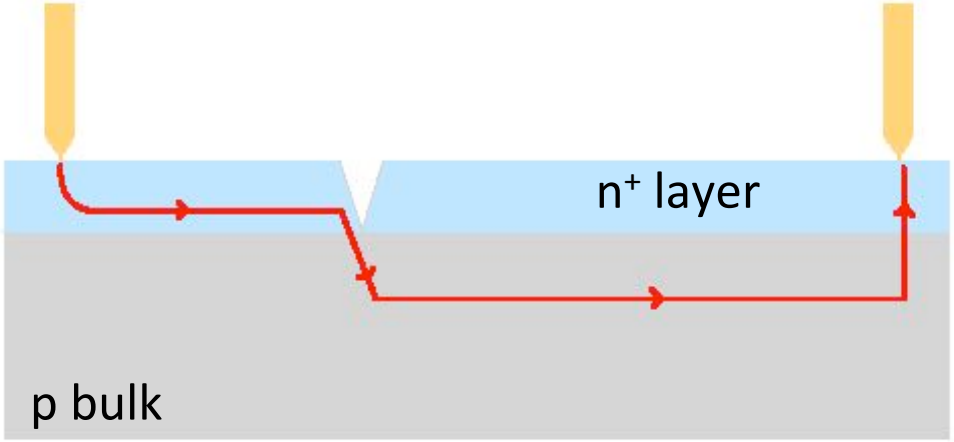


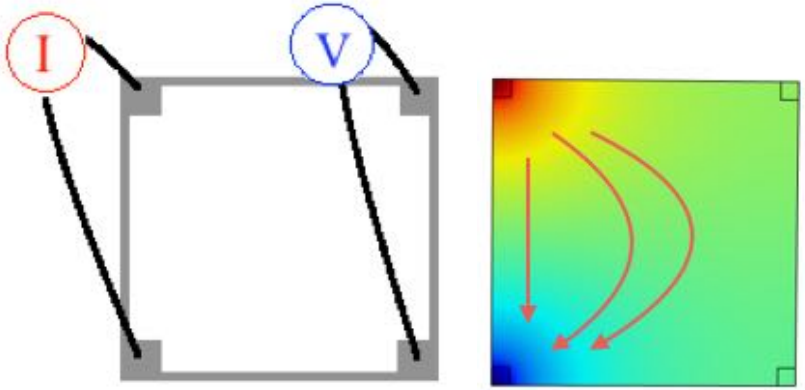
Filmtronics **P**507



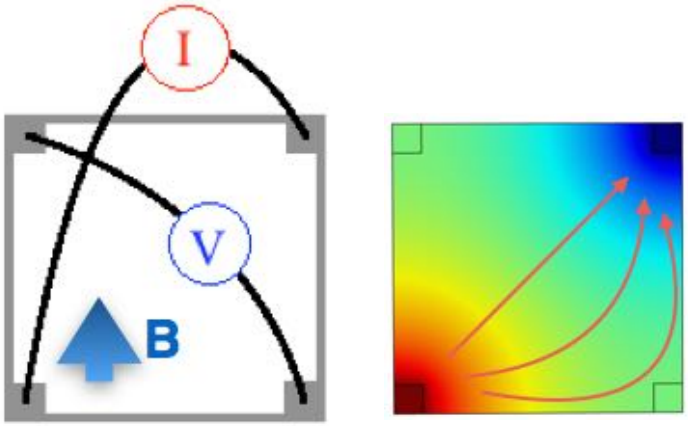
Four point probe electrical measurements







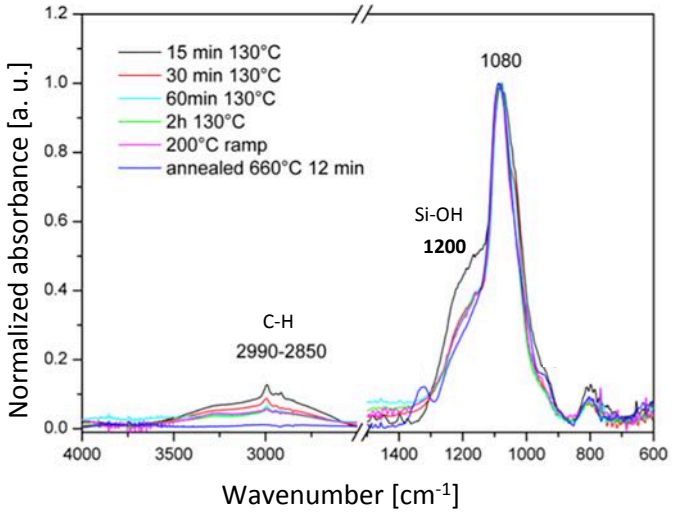
VDP configuration → R_{sheet}



Hall configuration → dose

Curing t and T effects (tests on microel. Ge)

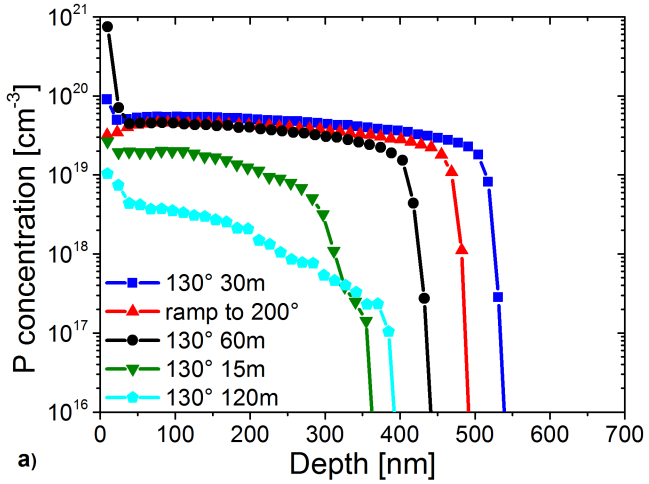
FTIR spectra on P507 films



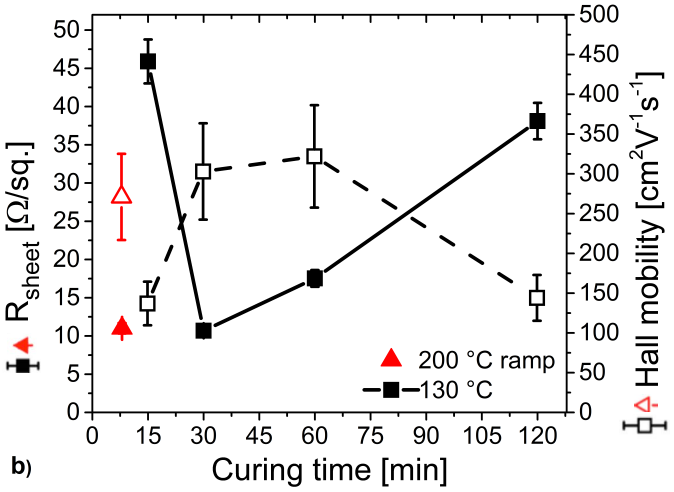
Rutherford Backscattering Spectrometry (RBS)

Curing time	% Si	% O	% P	% Ge
15 min	20 ± 1	68 ± 2	7 ± 2	4.7 ± 0.5
30 min	21 ± 1	64 ± 2	11 ± 2	4.3 ± 0.5
120 min	18 ± 1	68 ± 2	6 ± 2	5.0 ± 0.5

SIMS profiles of diffused P

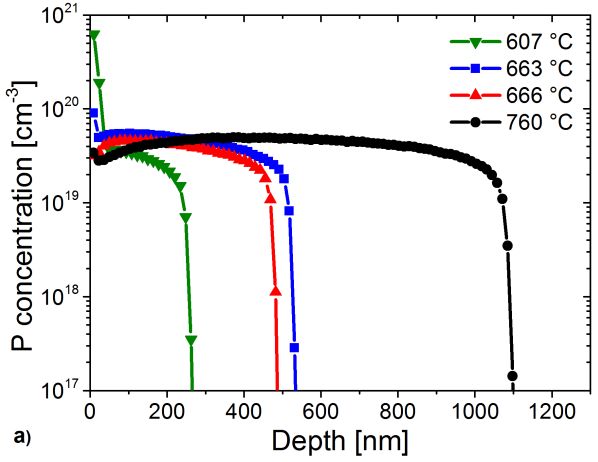


Sheet resistance and mobility



Tuning the junction and test on HPGe

SIMS profiles of diffused P



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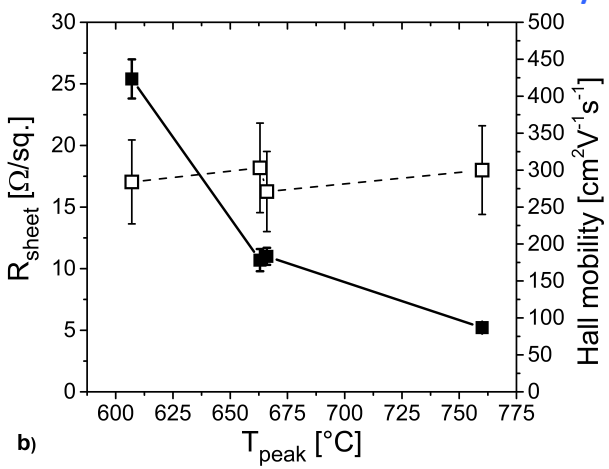
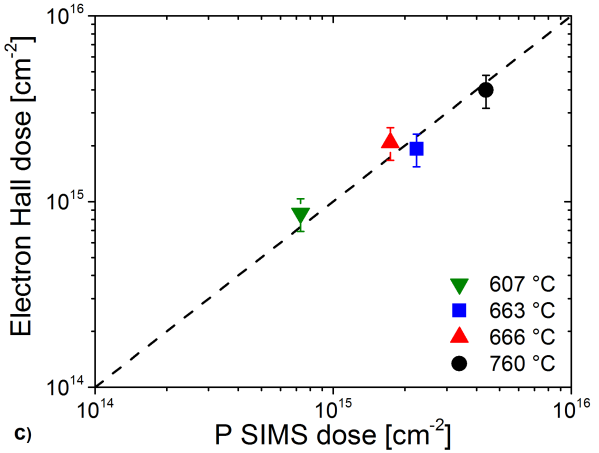


e$^-$ Hall dose vs. SIMS dose



[V. Boldrini, Applied Surface Science (2016) in press]

The technique, optimized for µ-electronic Ge, has been applied to p-type HPGe, with the following annealing treatment:

- spike annealing up to 610 °C in 12 minutes

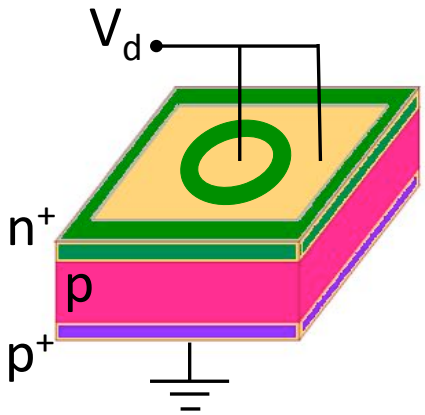
HPGe	
R_{sheet} [Ω/sq.]	40
dose [cm^{-2}]	-2.8x10^{14}
µ [cm^2/Vs]	572

Conclusions

- Spin-On-Doping can be effectively applied to Ge.
- Due to the reactivity of Ge surface when exposed to heat or humid environment, the optimization of a process protocol was necessary and has been achieved.
- Homogeneous phosphorus-doped layers, characterized by high concentration ([3-6]x10^{19} cm^{-3} → Φ_B^h = [0.69-0.72 eV]) and tunable thickness [100 nm-1 µm] have been produced in Ge.
- The technique turns out to be applicable also to HPGe and a first doped layer, electrically active, has been obtained.

Outlooks

- Further tests on HPGe (probing other spike annealings and performing SIMS measurements).
- Fabrication of flat diodes on HPGe wafers of n- and p-type, by substituting Li with P.
- Test the operation of these diodes at LN2 (77 °K) and try them as detectors.
- Work on the segmentation of the phosphorus contact.



Thanks for your attention!

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