Structural and electrical characterization of $Sb_2Te_3/Ge_xSb_2Te_5/Ge$ heterostructures

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Motivation

Ge-Sb-Te Phase Change Materials (PCM) are suitable for non-volatile memory applications[1] thanks to the high electrical resistance contrast between their amorphous and crystalline states. By combining Sb_2Te_3, Ge and $Ge_xSb_2Te_5$ layers, it is possible to grow PCM heterostructures which show a fast crystallization dynamics and a high transition temperature T_c (≥ 160 °C). Such a high thermal stability is of interest for the realization of devices for *IoT* automotive applications.

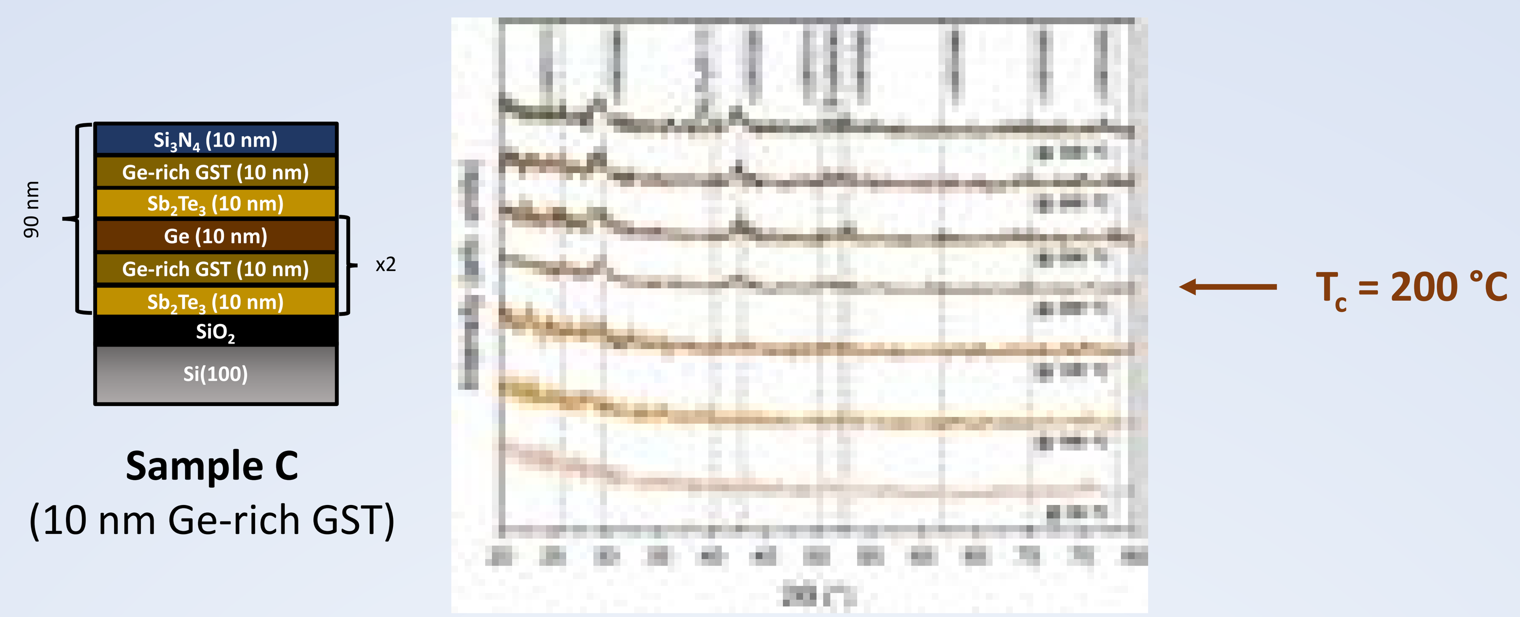
(1) A. Lotnyk, *Phase Change thin films for non-volatile memory applications*, **Nanoscale Advances**, 2019, 1, 3836

IoT (Internet of Things): devices and systems are connected and exchange data over the internet

SMART CARS (www.enisa.europa.eu)

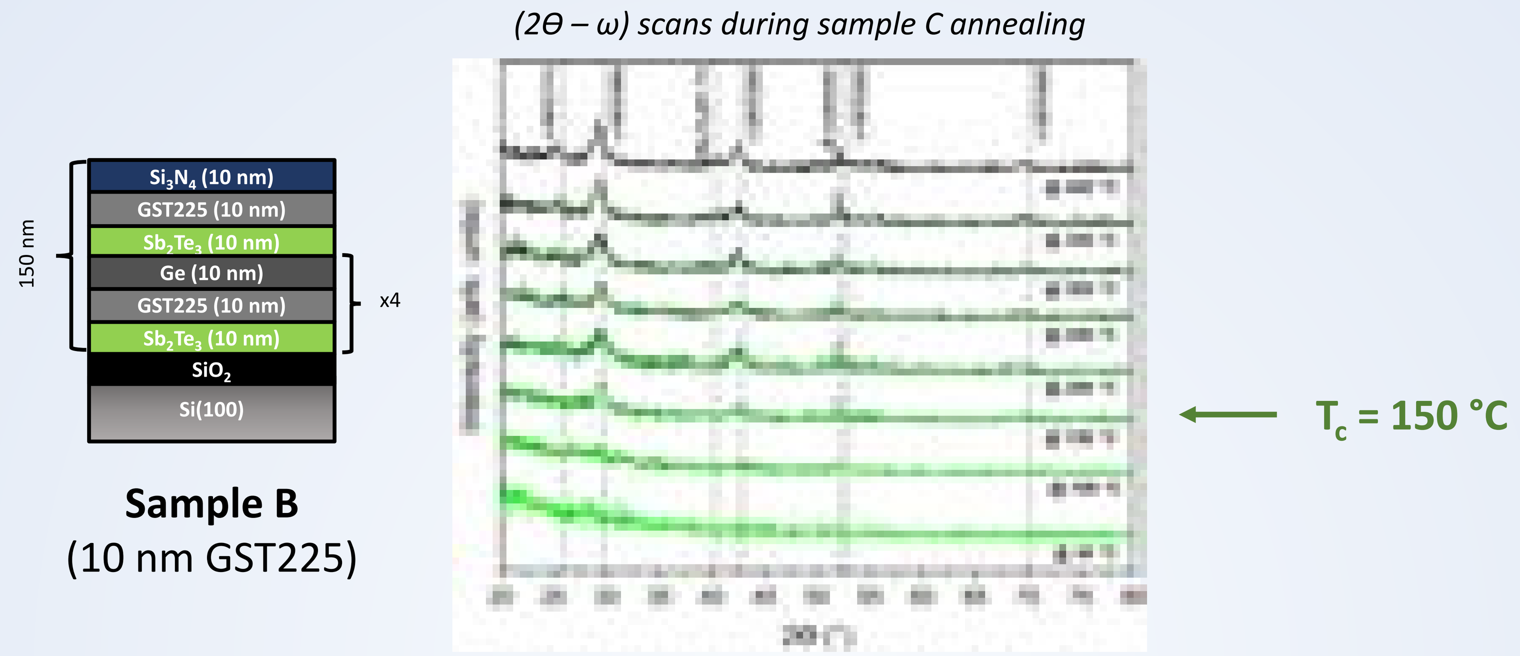
X-ray Grazing Incidence Diffraction

The XRD measurements were performed ex situ by a BRUKER D8 Discover diffractometer equipped with a Cu X-ray source (Cu-K_1 radiation λ = 1.54 Å, 40 kV and 40 mA) and a DHS1100 dome-type heating stage.



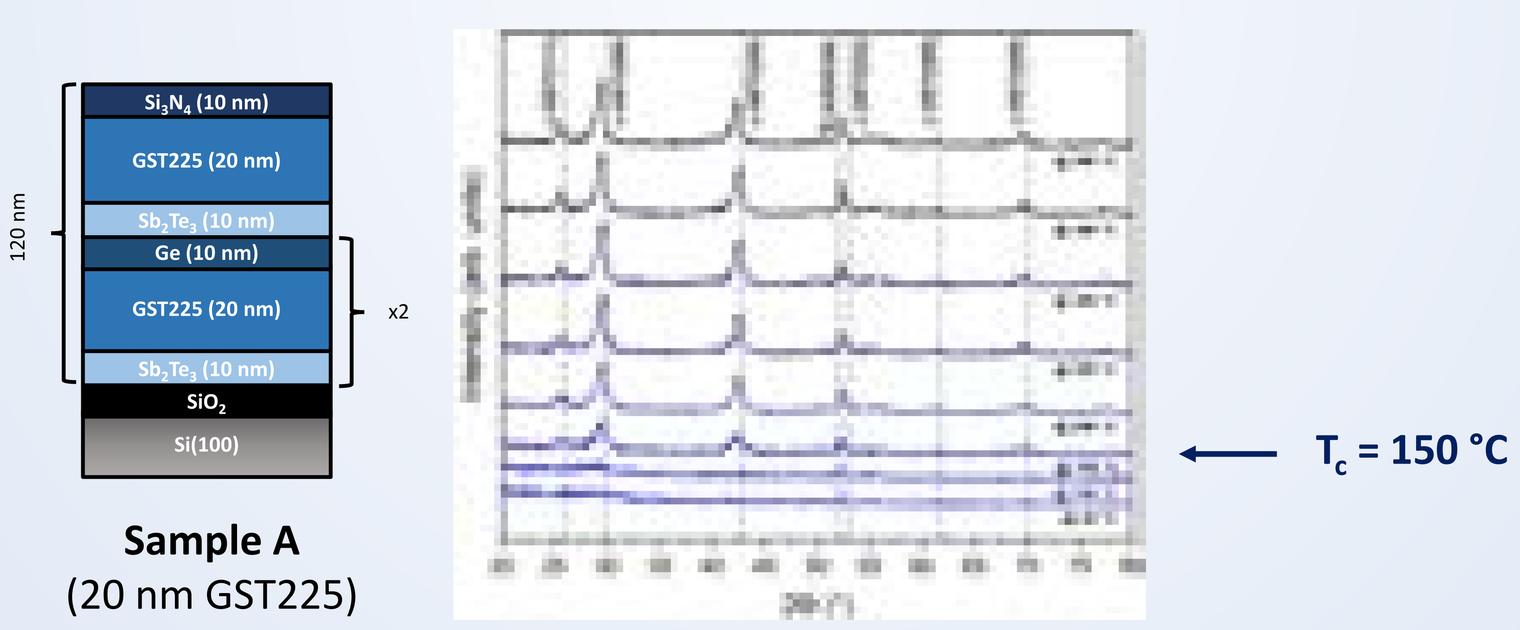
Sample C
(10 nm Ge-rich GST)

(2ϴ – ω) scans during sample C annealing



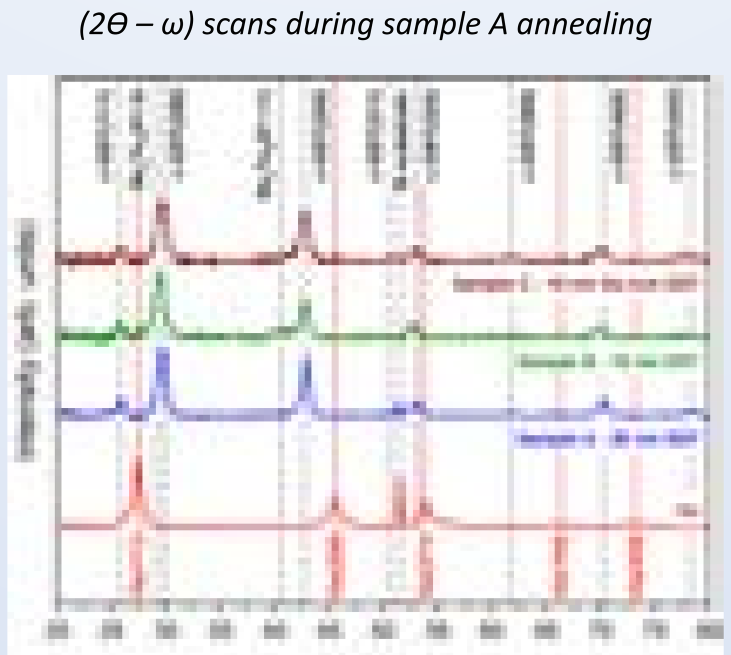
Sample B
(10 nm GST225)

(2ϴ – ω) scans during sample B annealing



Sample A
(20 nm GST225)

(2ϴ – ω) scans during sample A annealing



(2ϴ – ω) scans @ RT after annealing of samples A, B, C and Ge

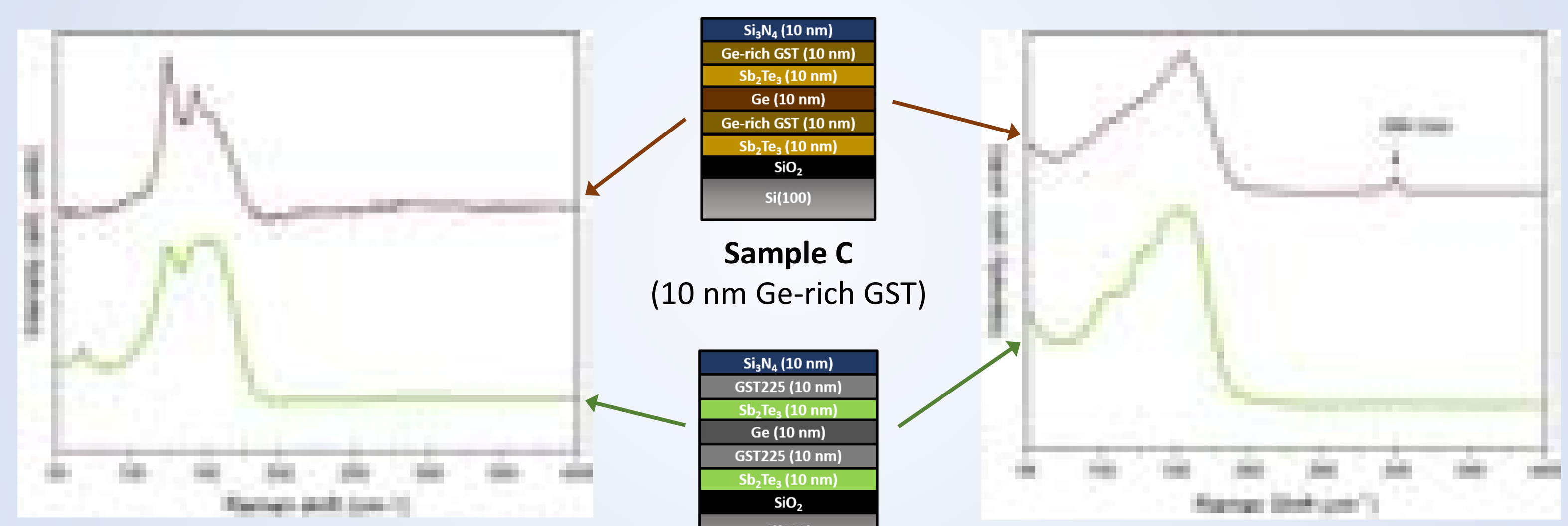
RESULTS
- Possible intermixing of GST225 and Sb_2Te_3
- Improved thermal stability with Ge-rich GST layer
- No evidence of Ge-segregation

Sample growth by RF-sputtering

The amorphous PCM heterostructures were deposited @ RT in a custom-made IONVAC sputtering system with four confocal targets ($Ge_2Sb_2Te_5$, Ge, Sb_2Te_3, Si_3N_4 – 99.9% pure, Robeko GmbH).

Raman spectroscopy

Raman spectra were acquired ex situ by means of a THERMOFISCHER DXR2xi Raman imaging microscope equipped with a 532 nm laser source and a 50X objective. The Raman data acquisition was performed @ RT in back-scattering geometry by using a 4 mW laser power at the sample surface.



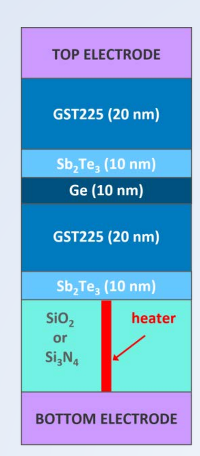
Raman spectra of amorphous (as-grown) samples B and C

Raman spectra of annealed samples B and C

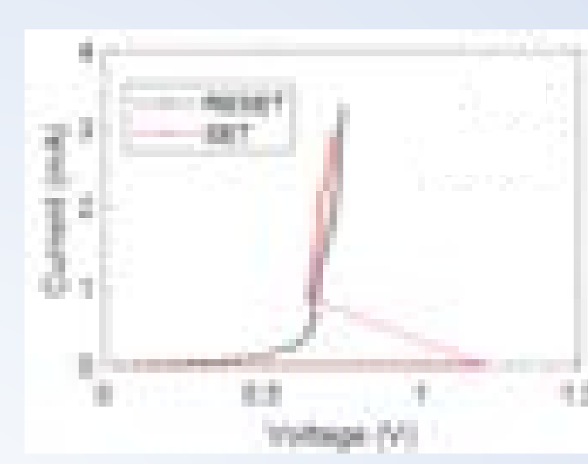
RESULTS
Minimal formation of Ge nanocrystals in the Ge-rich GST heterostructure

Electrical characterization

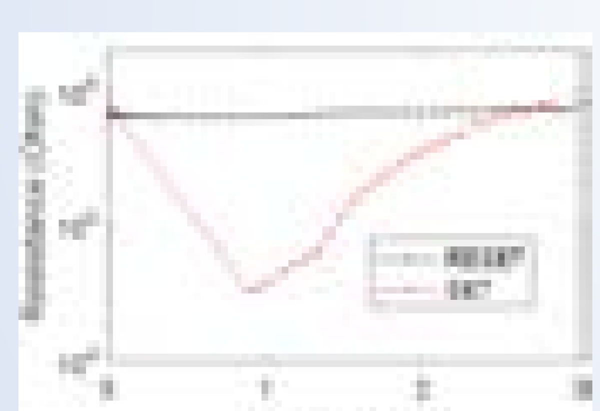
PCM-cells were realized with layer stacking of sample A (20 nm GST225) and electrically characterized.



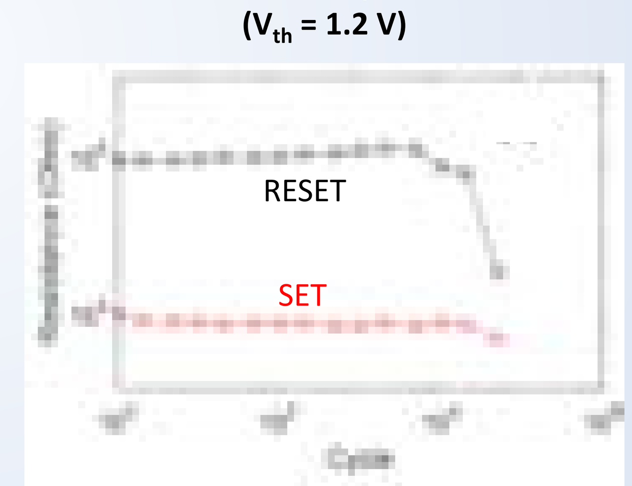
PCM-cell (heater diameter = 80 nm)



I = I(V) characteristic of the PCM cell
(V_{th} = 1.2 V)



R = R(I) characteristic of the PCM cell
(I_p = 2 – 2.5 mA)



Endurance test of the PCM cell
(Resistance contrast (R_{RESET}/R_{SET}) ~ 100, endurance = 4 X 10^4 cycles)

RESULTS
Good electrical resistance contrast (~100) and endurance (4 X 10^4 cycles)

Conclusions

The PCM heterostructure with 10 nm Ge-rich GST layer shows:
- high thermal stability (T_c~200°C) → high potential for automotive applications.
- minimal Ge-segregation → expected good device behavior during cycling.

The PCM-cell heterostructure with 20 nm GST225 layer shows good electrical resistance contrast (~100) and endurance (4 X 10^4 cycles).

This project has received funding from the European Union's Horizon 2020 research and innovation program, under grant agreement No. 824957 ("BeforeHand": Boosting Performance of Phase Change Devices by Hetero- and Nanostructure Material Design).