



EPCOS 2021
EUROPEAN PHASE-CHANGE AND OVONIC SYMPOSIUM
~ ONLINE CONFERENCE ~ 13 to 15 SEPTEMBER ~



Temperature Driven Structural Evolution of Ge-rich GeSbTe Alloys and Role of N-doping

Lucie Prazakova,

E. Nolot, E. Martinez, F. Fillot, D. Rouchon, N. Rochat, M. Bernard, C. Sabbione, D. Morel, N. Bernier,
A. Grenier, A.-M. Papon, M.-C. Cyrille, G. Navarro

CEA Leti, Grenoble, France



- Introduction and context: Ge-rich GeSbTe phase-change alloys
- Experimental part – investigated alloys
- Ge-rich GeSbTe and the impact of N doping
- Conclusions

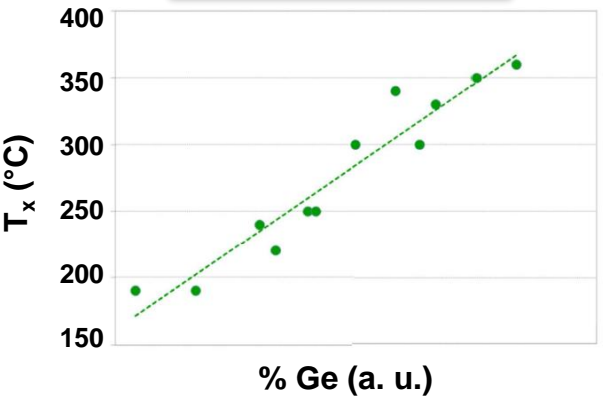
Context

Ge₂Sb₂Te₅ (GST)

Reference compound

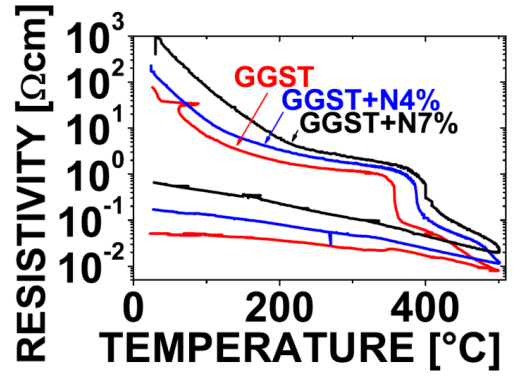
- ❑ T_x ~ 150 °C
- ❑ Poor amorphous phase stability
- ❑ Poor data retention of PCM device (in state 0)

Ge-rich GST

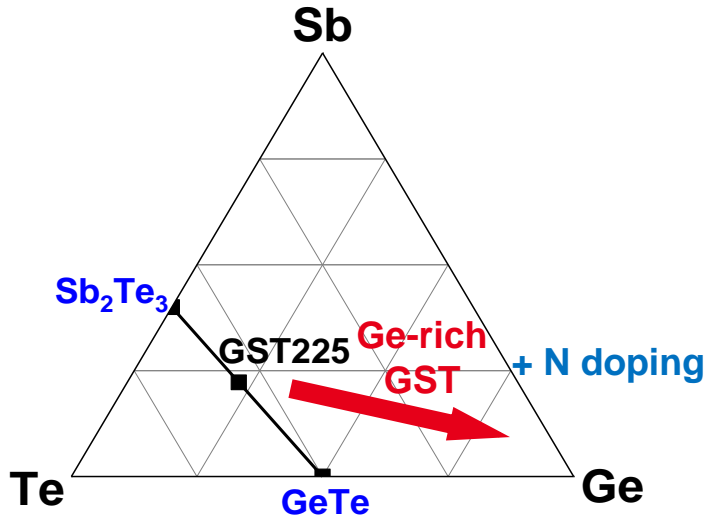


P. Zuliani et al., IEEE Trans. Electron Devices 60, 4020 (2013).

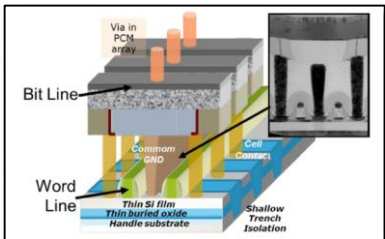
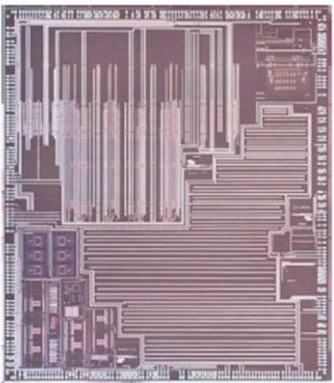
N-doped Ge-rich GST



G. Navarro et al., IEEE International Memory Workshop, pp. 1–4, 2016



Ge-rich GeSbTe PCM are compatible with Automotive requirements



Schematic drawing and TEM cross section of the ePCM cell and Micrograph of 6 MB ePCM based μC in 28 nm FDSOI HK metal gate technology.
Paolo Cappelletti et al 2020 J. Phys. D: Appl. Phys. 53 193002

Experimental Part

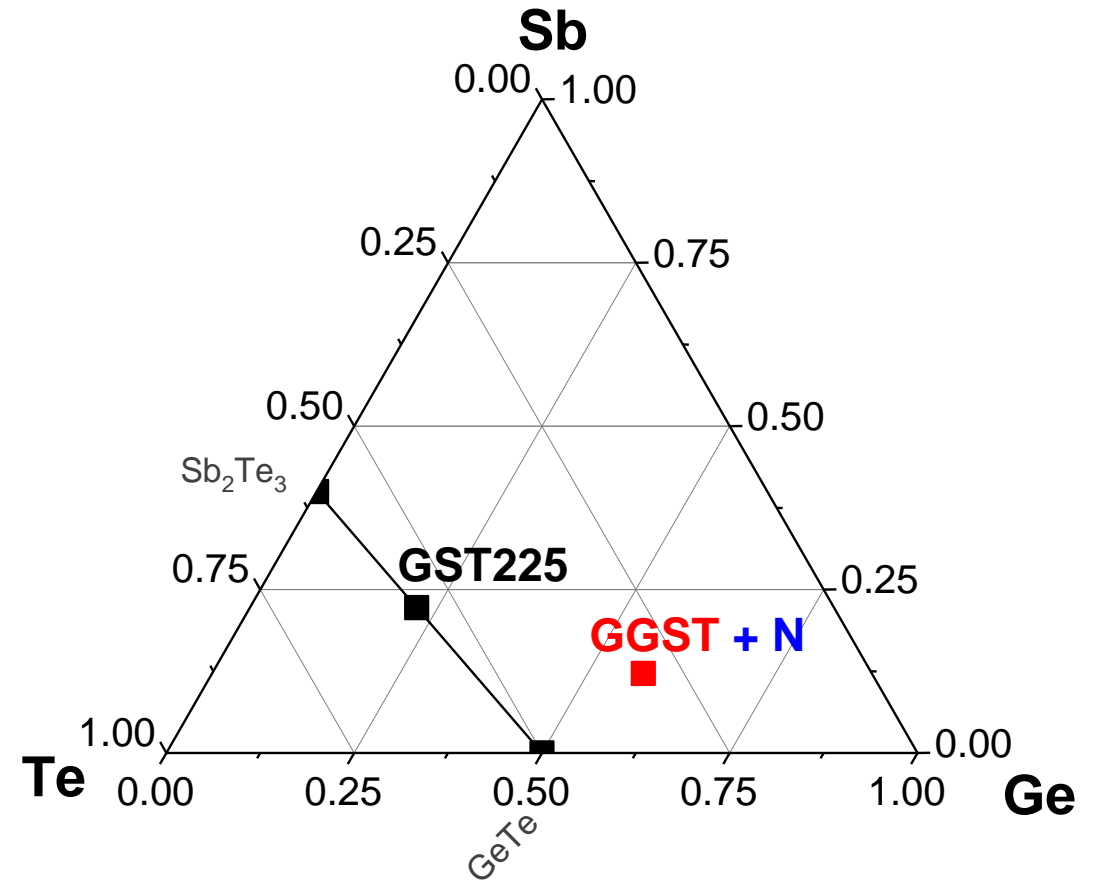
- Crystallization mechanism ?
- Role of N doping ?

Compounds:

- GST225
- Ge-rich GST225 (+ N)

Characterization techniques:

- Raman Spectroscopy
- FTIR Spectroscopy
- XRD
- TEM-EDX

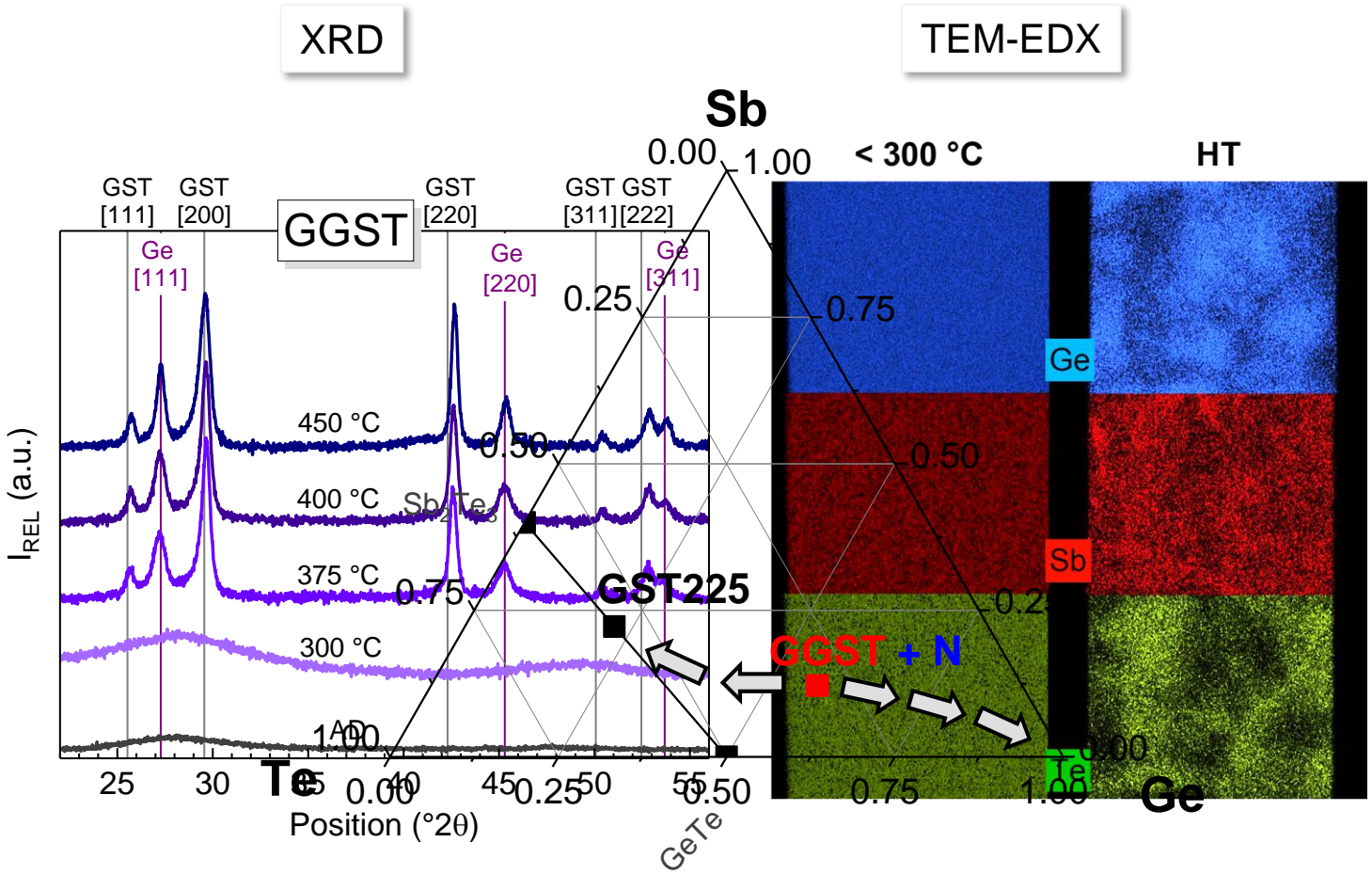


Ge-rich GST – System Segregation

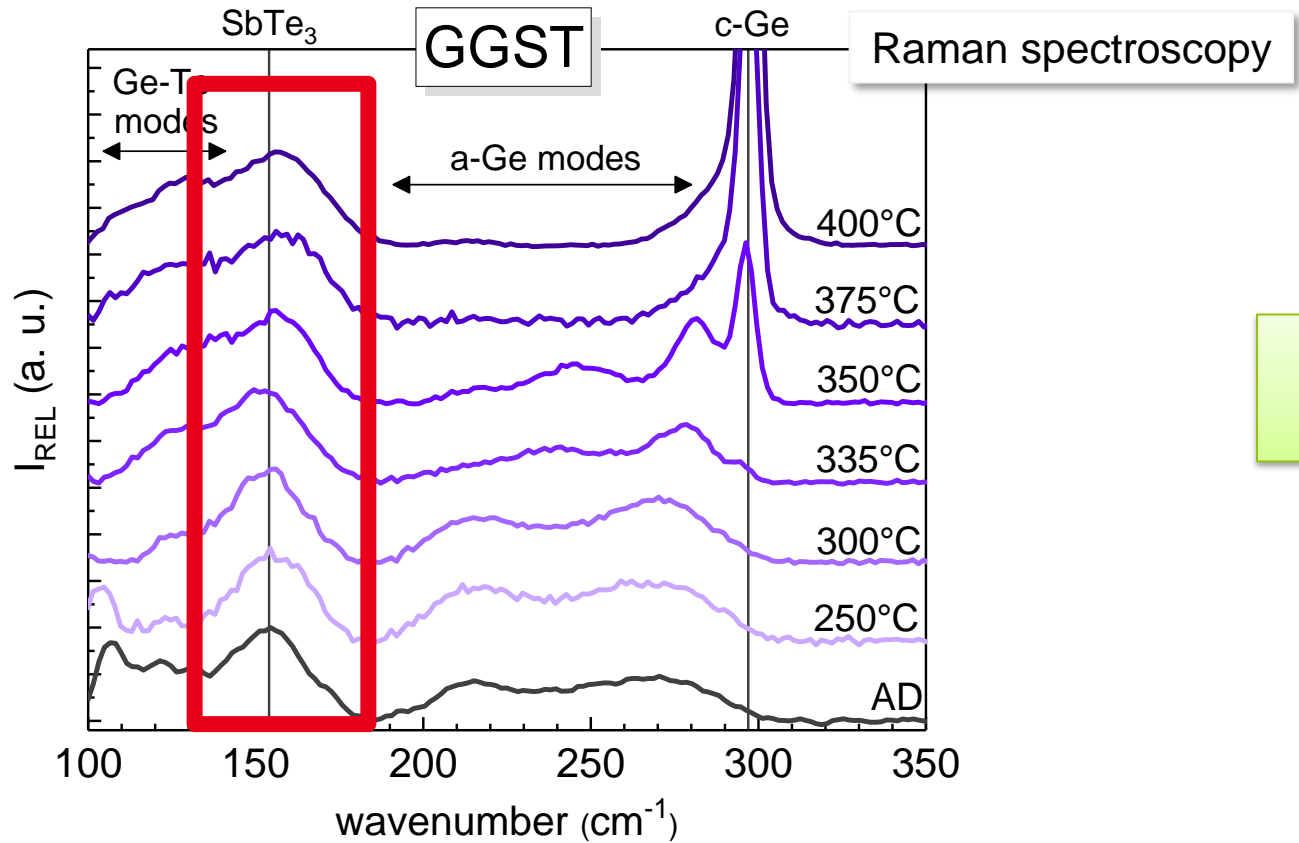
T < 300 °C

- perfect homogeneity of amorphous alloys
- Annealed (HT)
 - GST and Ge crystalline phases segregation (formation of **Ge-rich, Sb/Te-rich regions**)
- Ge crystallization below <400 °C possible in GeSbTe systems

GST and Ge phases segregation

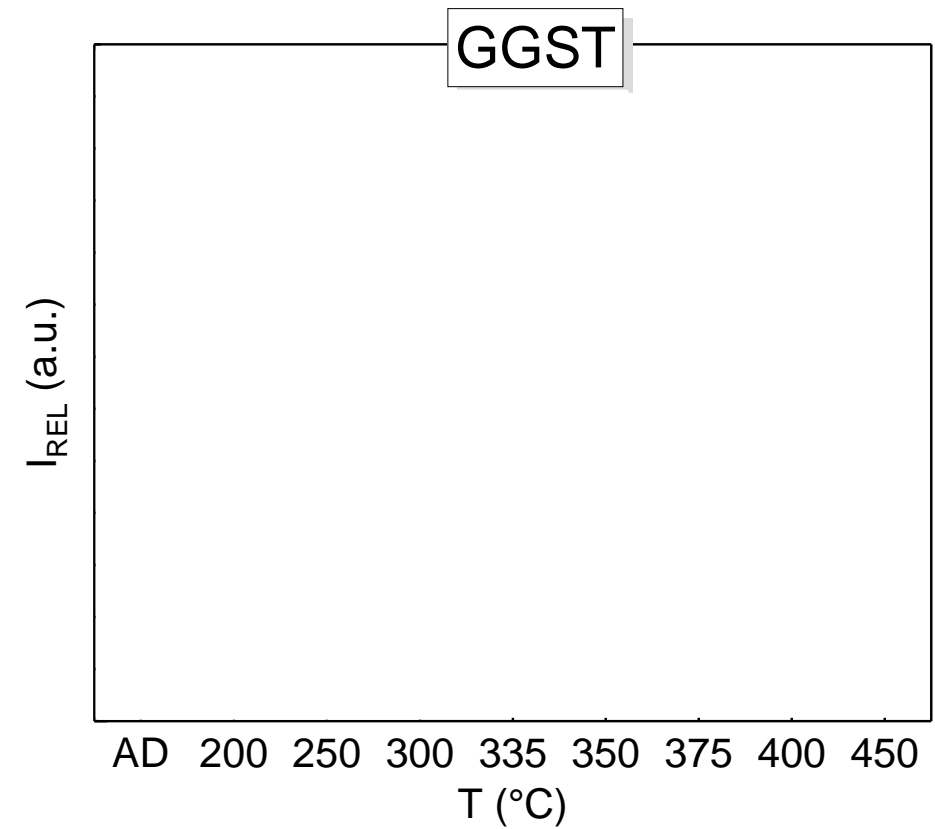
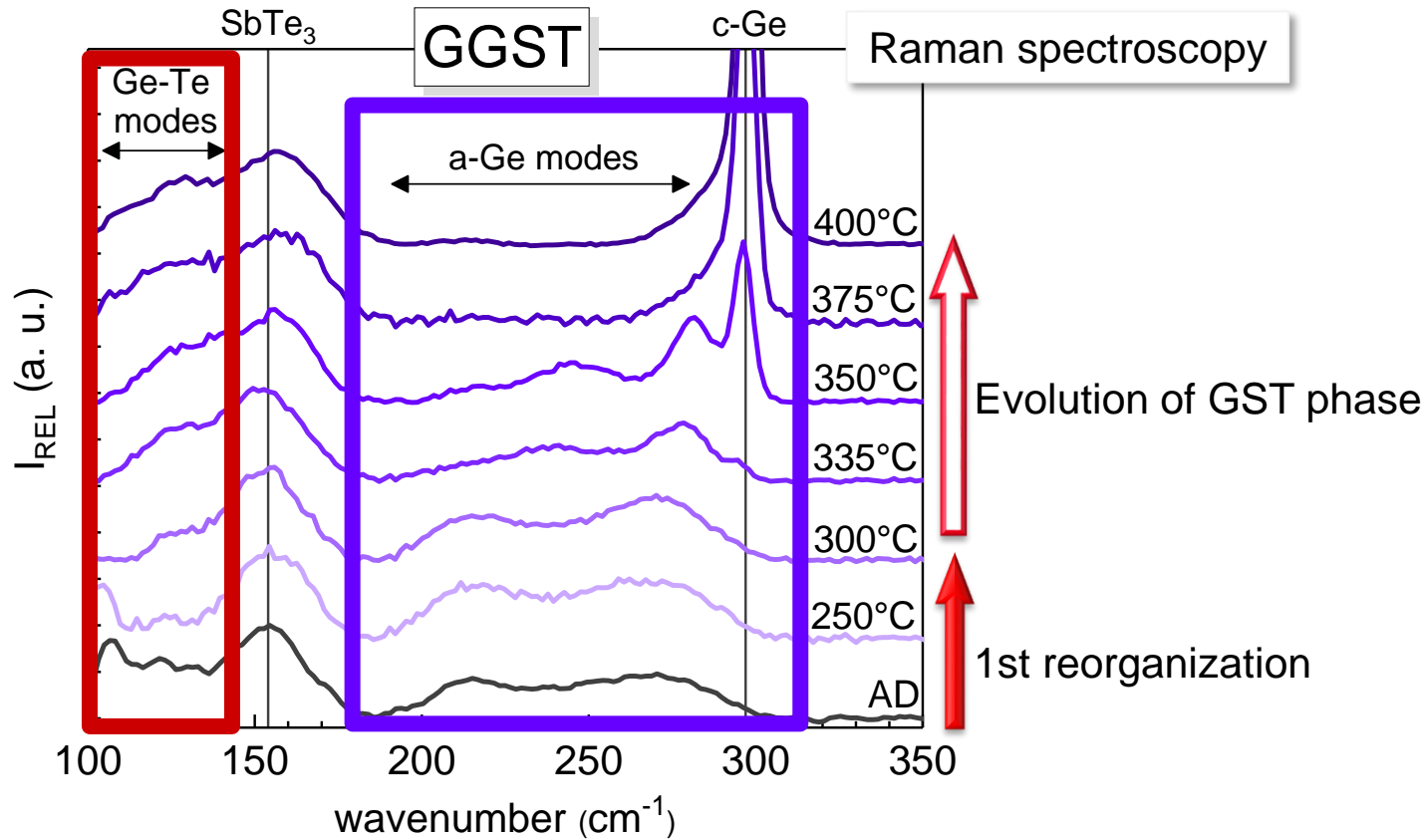


Ge-rich GST - Stability of Structural Features as a Function of Temperature



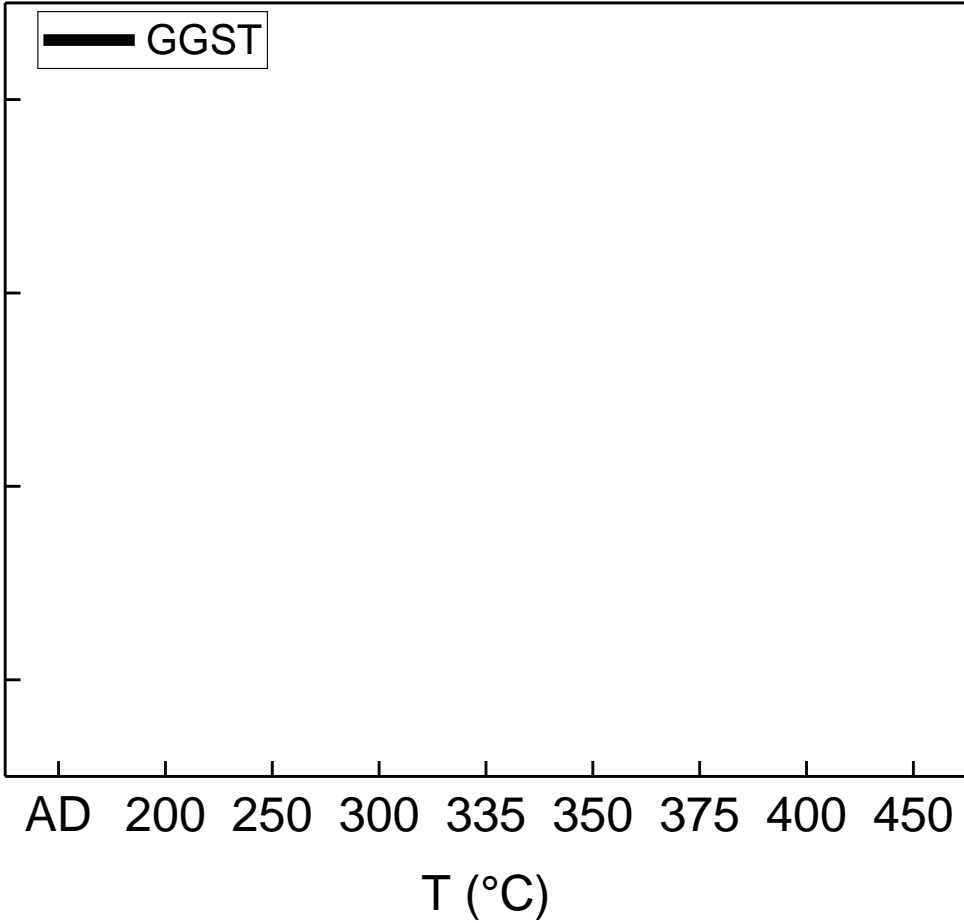
Stability of Sb-Te units in GST structure maintained up to high temperatures

Ge-rich GST - Evolution of Structural Features as a Function of Temperature

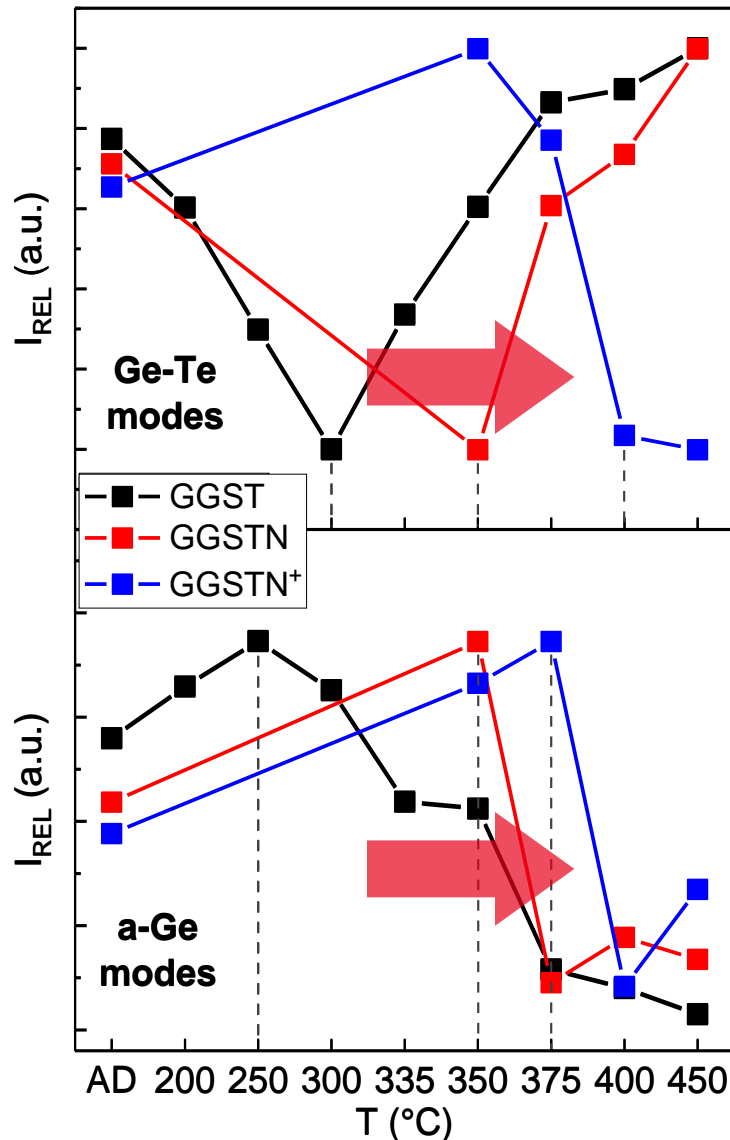


GST phase crystallization follows the Ge-Te rearrangement
Ge phase crystallization follows the GST structure reorganization and crystallization

Ge-rich GST – Steps of the Evolution Process



N-doped Ge-rich GST – Structural Evolution as a Function of Temperature



□ N-doped GGST in comparison with GGST

□ 2 different N content

GeTe modes:

□ Initial decrease of Ge-Te modes **delayed to higher T**

a-Ge modes:

□ Decrease of a-Ge modes **delayed to higher T**

□ Decrease more **abrupt** – faster dynamics due to higher temperatures

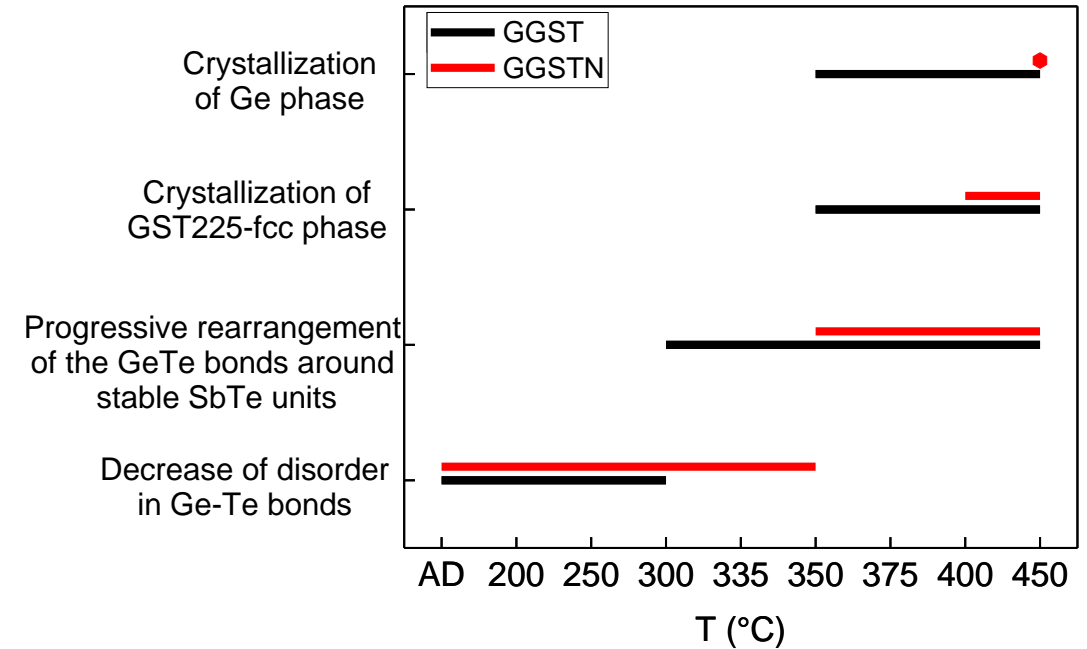
N-doping delays the structural reorganization of Ge-Te bonds (i.e. the 1st reorganization step) and Ge crystallization

Ge-rich GST alloys:

- ❑ **Stability of Sb-Te units** of GST phase up to high T
- ❑ Evolution process composed of **several steps**
- ❑ **Ge phase crystallization follows** the GST structure reorganization and crystallization
- ❑ GST and Ge phases **segregation** at high T

N-doping in Ge-rich GST alloys:

- ❑ Delays the **structural reorganization of Ge-Te bonds** and **Ge crystallization**
- ❑ **Faster dynamics** due to higher temperatures



- L. Prazakova et al., Temperature driven structural evolution of Ge-rich GeSbTe alloys and role of N-doping, *Journal of Applied Physics*. 128 (2020) 215102.
- L. Prazakova et al., The Effect of Ge Content on Structural Evolution of Ge-rich GeSbTe Alloys at Increasing Temperature - *publication under review*

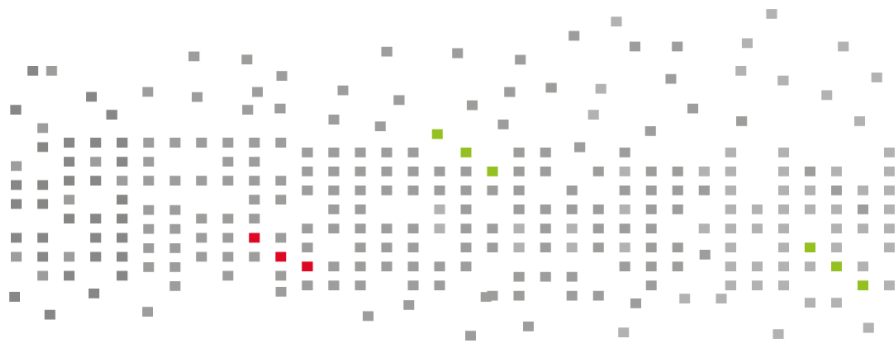


Temperature Driven Structural Evolution of Ge-rich GeSbTe Alloys and Role of N-doping

Lucie Prazakova

lucie.prazakova@cea.fr

Thank you for your attention !

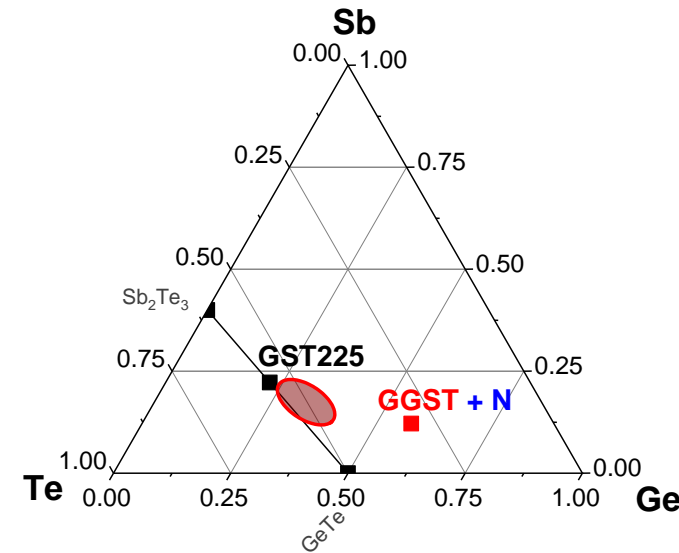
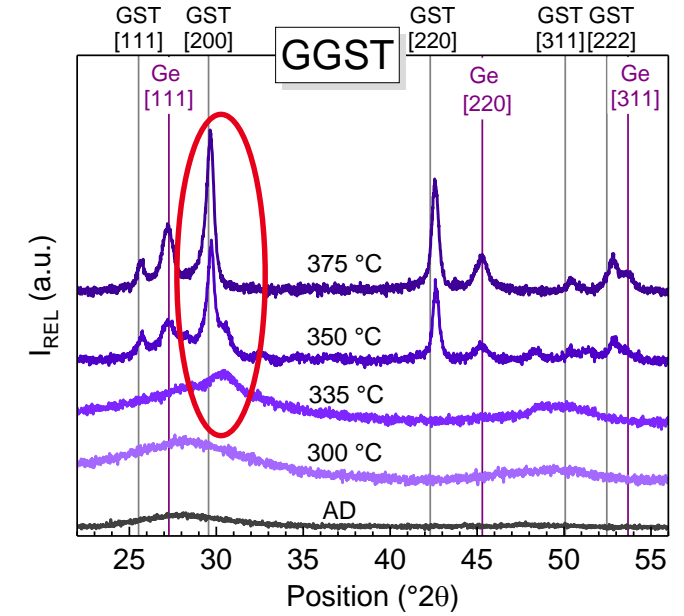
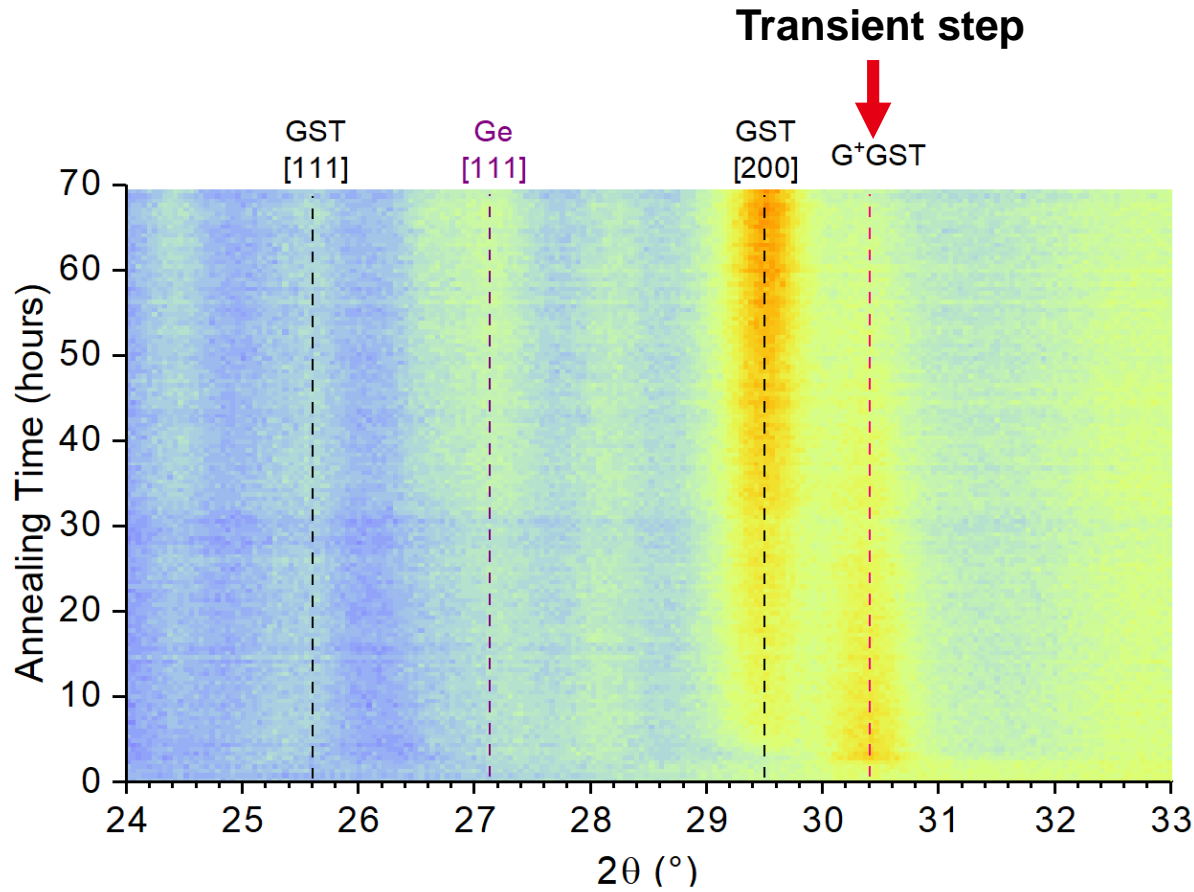


Leti, technology research institute
Commissariat à l'énergie atomique et aux énergies alternatives
Minatec Campus | 17 avenue des Martyrs | 38054 Grenoble Cedex | France
www.leti-cea.com



XRD Investigation of Transient Evolution Step

□ Isothermal XRD



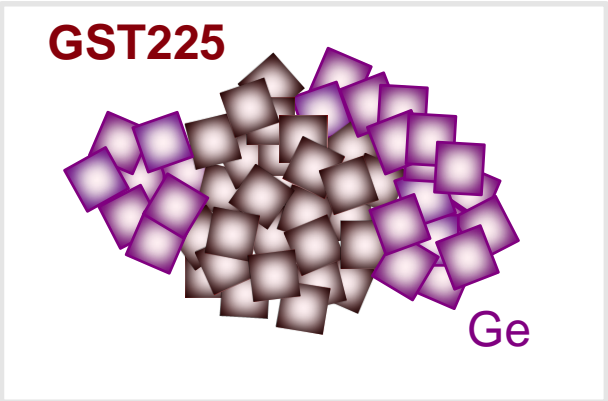
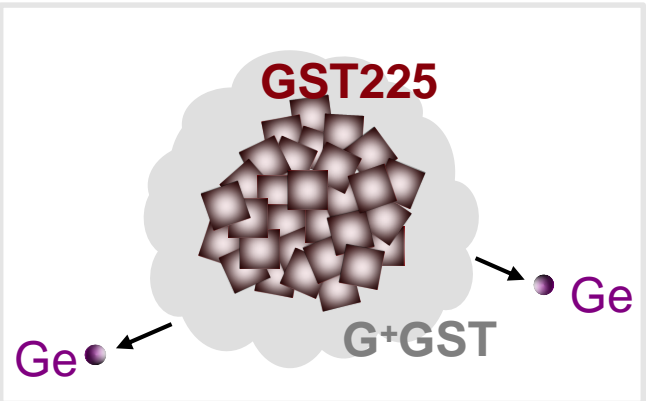
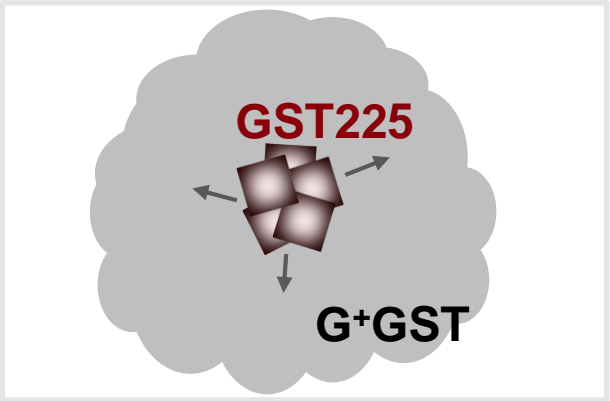
Appearance of GeSbTe metastable phase, enriched in Ge wrt GST225

Scheme of the G+GST Phase Evolution

Amorphous alloy

T (°C)

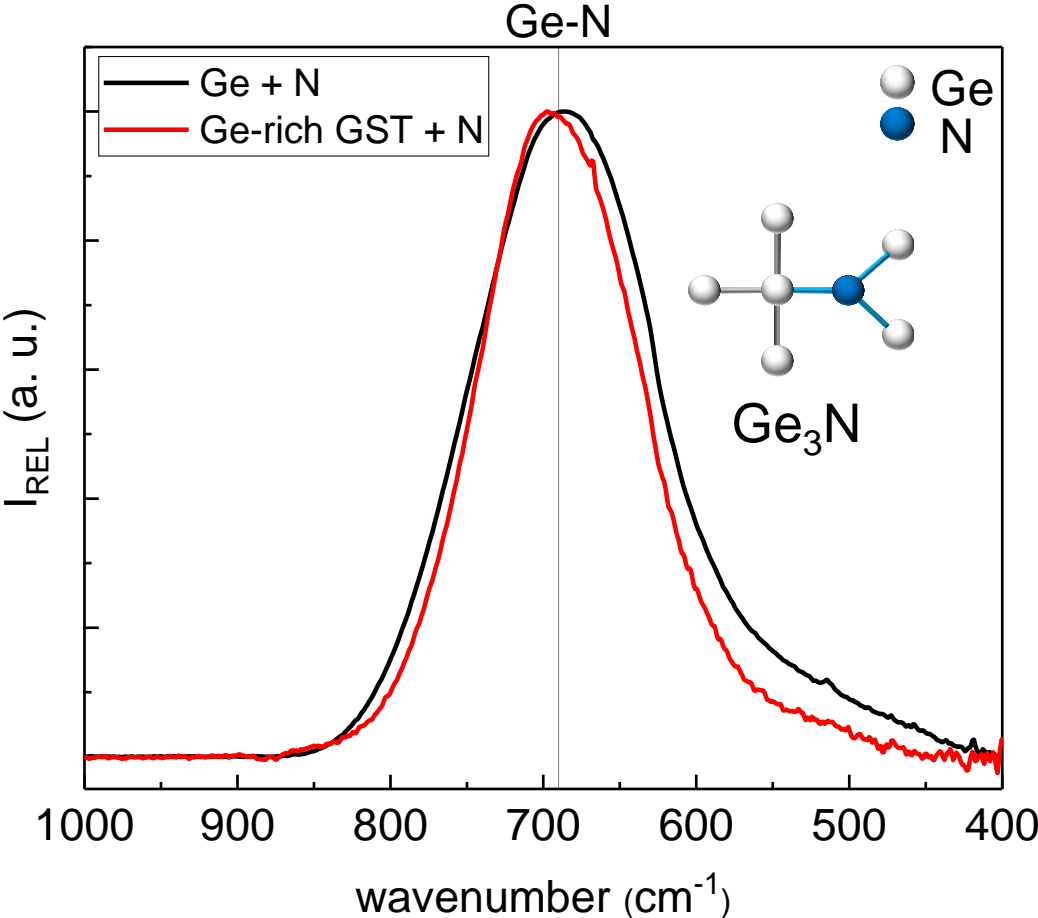
Segregated GST225 and Ge crystalline phases



Formation of Ge-N Bonds

- N-doped Ge alloy
- N-doped Ge-rich GST alloys

- Ge-N** observed by FTIR spectroscopy



I. Chambouleyron and A.R. Zanatta, Journal of Applied Physics vol. 84, no. 1, pp. 1-30, 1998