Laser Crystallisation of Poly-SiGe for Microbolometers

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ENTE PER LE NUOVE TECNOLOGIE L'ENERGIA E L'AMBIENTE
Sezione INN-FIS-SPET

SiGe based Microbolometers

* Low thermal conductivity leading to
  → High device performance
* Easy to micromachine
* Compatible with IC silicon technology

Laser assisted techniques

* Single chamber processing possible
* Low thermal budget
* Ultrarapid processes
* Widely used for TFT-production

Laser assisted techniques

ArF-Laser induced Chemical Vapour Deposition (ArF-LCVD)

ArF-Laser radiation (193 nm, 5W, 50Hz)

Photolysis of Si_2H_6 and GeH_4 in He

Growth of a-SiGe:H

Corning glass (7059)
T_s=320ºC

+ Laser assisted Crystallisation

Laser radiation

T_s=24ºC - 450ºC

Modification to poly-SiGe

Option (a)
(pulsed)
ArF-Laser radiation
(193 nm, ~ 20 ns, topflat, fluence: 20-500 mJ/cm²)

Option (b)
(continuous)
Frequency doubled cw-Nd:YAG-Laser radiation
(532 nm, laser power 2 W, scanning velocity: 6 cm/s)

Modelling of Laser assisted Crystallisation through Numerical Analysis

for describing

* Melting-solidification processes
* Heat flow and nucleation phenomena
* Segregation processes

and adjusting or predicting

* Experimental parameters
* Grain sizes

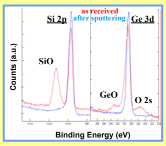
ArF-LCVD

500 nm thick $Si_{(1-x)}Ge_x$ films with native oxide cap-layer (g.r. of SiGe: 0.3 nm/s)

* Composition via XPS:

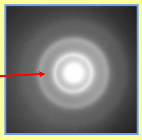
Si_2H_6 GeH_4
1 sccm + 0.8 sccm: $Si_{0.70}Ge_{0.30}$
1 sccm + 2 sccm: $Si_{0.57}Ge_{0.43}$

Both with ~ 5 nm oxidised cap-layer

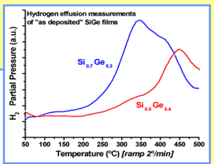


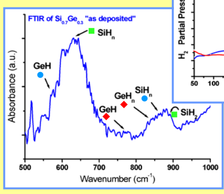
* No crystalline material through Raman, XRD or Electron diffraction detectable

(SiGe micro-EDS confirmed)



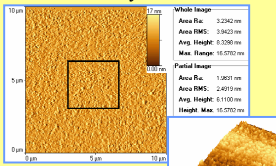
* H-Effusion and FTIR spectra reveal that dehydrogenation occurs below 550ºC

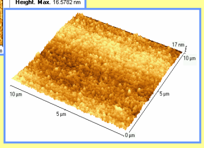




Elimination of H :
* *at T < 250ºC*
* *at 250ºC < T < 370ºC*
* *at 370ºC < T < 550ºC*

* Roughness of the film surfaces determined by AFM : RMS ~ 4 nm

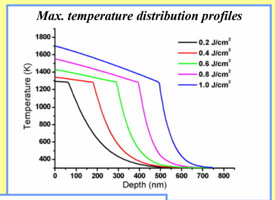




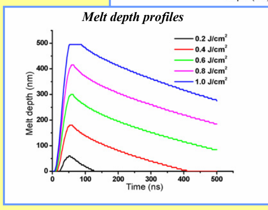
Modelling of ArF-laser assisted Crystallisation

* **Numerical simulation of the crystallisation for 500 nm thick SiGe films on glass irradiated by an ArF Excimer laser (20 ns pulses)**

  * Surface melting threshold estimated to be ~ 60 - 80 mJ/cm²
  * Higher fluences melt thicker layer and induce steeper temperature gradient
    (heating up of underlying a-SiGe)
  * Substrate remains practically thermally unaffected for the fluences of interest



  * Melting time depends on laser fluence
    ↓
    Probability of Ge-segregation increases with higher fluences



ArF-Laser assisted Crystallisation

"Step by step" (~ 30 mJ/cm² steps) irradiation at 25ºC

1º Low fluences (< 80 mJ/cm²)

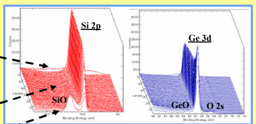
* Dehydrogenation *(Weakening of the broad SiH and GeH bands in FTIR)*

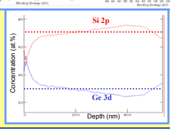
2º Increasing fluences (80 - 440 mJ/cm²)

* Residual H *(Sharp but very weak SiH and GeH peaks in FTIR spectra)*
* Crystallisation (small coherence length of 10 - 25 nm) *(Raman and XRD)*
* Slight segregation of Ge to the surface and surface roughening *(XPS and AFM)*
* Strain in crystallites with increasing fluence *(XRD)*

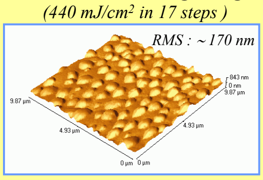
At 280 mJ/cm² final fluence :

* Underlying layer (~ 50 nm $Si_{0.7}Ge_{0.3}$ / glass)
* Upper layer (~ 450 nm)
* Oxidised cap layer
* Slight surface segregation of Ge





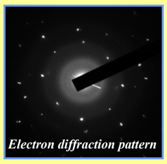
Excessive cumulative fluence leads to roughening
(440 mJ/cm² in 17 steps)



Nd:YAG-Laser assisted Crystallisation

Irradiation at 400ºC for ~ 2 ms leads to :

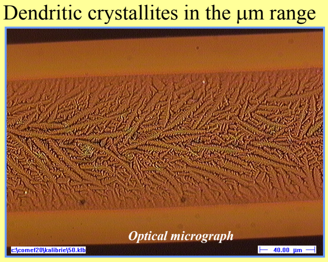
* Complete crystallisation

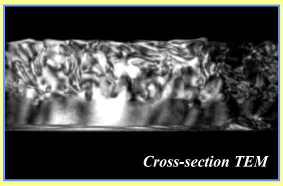

Electron diffraction pattern

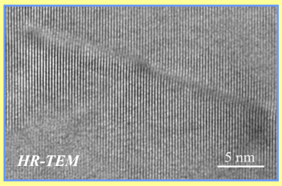
Segregation:

* Ge-content depends on position
* Single crystalline areas of several µm
* Lattice constant varies within each crystallite

* Dendritic crystallites in the µm range


Optical micrograph


Cross-section TEM


HR-TEM

Conclusions

LCVD: Production of uniform smooth amorphous SiGe alloys with tailored composition has been demonstrated.

"Step by step" ArF-laser crystallisation:

- **Low fluences:** Dehydrogenation of surface layer avoids explosive H-effusion.
- **Increasing fluences:** Melt/Crystallisation process of H-poor upper layers leads to explosive crystallisation of fine grained SiGe (10-25 nm). dehydrogenation of the underlying layers and slight surface Ge-segregation. Excessive cumulative fluence leads to surface roughening,

Cw-frequency doubled Nd:YAG-laser crystallisation:

Complete crystallisation of large crystallites with considerable segregation of Ge.

Numerical Analysis: Temperature gradients and melting duration consistent with "step by step" dehydrogenation and crystallisation.

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