Influence of Laser Fluence in ArF-Excimer Laser Crystallisation of a-SiGe:H Films

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Sezione INN-FIS-SPET

SiGe thin films

Properties and Advantages

* Low thermal conductivity
* Adjustable band gap
* Easy to micromachine
* Compatible with IC silicon technology

Applications

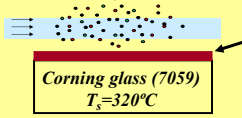
* Bolometers
* Solar cells
* Microelectronic devices

Laser assisted techniques

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

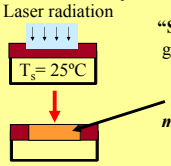
Photolysis of Si_2H_6 and GeH_4 in He

ArF-Laser radiation parallel to the substrate
(λ = 193 nm, E ≤ 0.7 W/cm²)



+ ArF-Laser assisted crystallisation

ArF-Laser radiation perpendicular to the substrate
(λ = 193 nm, ~20 ns, top-flat profile, H = 20-500 mJ/cm²)



"Step-by-step" process with gradually increasing fluence

Laser assisted techniques

Advantages

* Allow single chamber processing
* Low thermal budget techniques
* Ultra-rapid processes
* Widely used for TFT-production

Numerical Analysis

Modelling of

* Melting-solidification processes
* Segregation processes

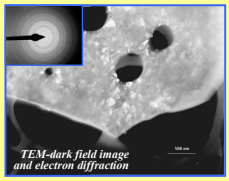
ArF-LCVD

* $Si_{0.7}Ge_{0.3}$ on glass with ~ 5 nm thick native oxide cap-layer *(XPS-depth profiling)*
* Hydrogen bonded to Si and Ge as well as in µ-voids *(H-Effusion, FTIR-spectroscopy)*
* Uniform 500 nm thick coating *(Profilometry)*
* Roughness of the film surfaces is RMS ~ 4 nm *(AFM)*

ArF-Laser assisted crystallisation without adequate dehydrogenation

(Starting the crystallisation process with laser fluences of H > 100 mJ/cm²)

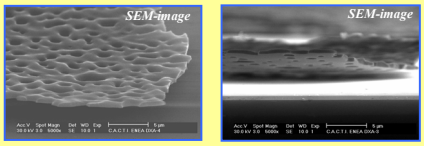
Crystallisation of fine grained material



BUT

* Explosive evaporation of Hydrogen
* Densification of the coating

Formation of holes and films peel off



Dehydrogenation through a controlled "step-by-step" process indispensable

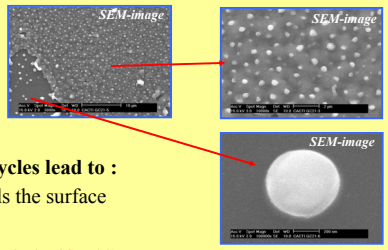
Crystallisation with excessive fluence or number of laser pulses

("step-by-step" process with too large total number of pulses and high final fluence)

(Sample irradiated with fluences up to 440 mJ/cm² using 17 steps)

Overheating provokes :

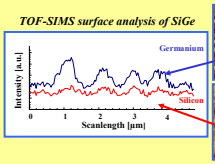
* Peeling of the film
* Formation of
  - islands on the coating
  - small spheres on the substrate

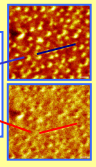


Large Nº of Melt/Solidification cycles lead to :

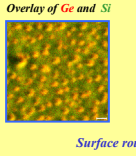
* Strong segregation of Ge towards the surface
* Formation of Ge rich islands

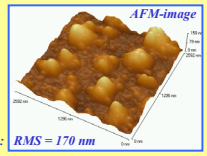
TOF-SIMS surface analysis of SiGe





Overlay of Ge and Si





Surface roughness: *RMS = 170 nm*

Careful adjustment of final energy and number of pulses indispensable

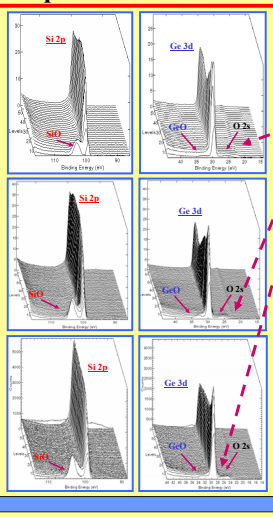
Composition and structure of the coatings at different stages of the "step-by-step" crystallisation process

Stage of the "step-by-step" process

H_{fin}= 100 mJ/cm²
3 steps, 10 shots each
(50, 75, 100 mJ/cm²)

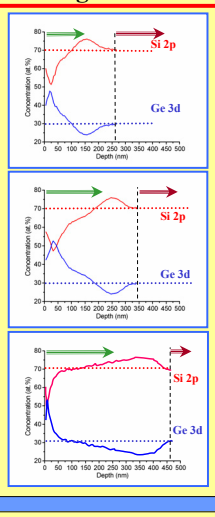
H_{fin}= 200 mJ/cm²
6 steps, 10 shots each
(50, 75, 100, 125, 160, 200 mJ/cm²)

H_{fin}= 280 mJ/cm²
12 steps, 1 shot each
(50, 75, 100, 105, 130, 150, 165, 185, 220, 250, 270, 280 mJ/cm²)



XPS depth profile analyses reveal in all samples

* Thin oxidised cap layer
* Upper layer with Ge gradient *(from the surface down to a certain depth)*
* Underlying layer *($Si_{0.7}Ge_{0.3}$ / glass)*



Thickness of "upper" layer (with Ge-gradient) + **"underlying" layer** ($Si_{0.7}Ge_{0.3}$)

~260 nm + ~ 240 nm

~340 nm + ~ 160 nm

~ 460 nm + ~ 40 nm

Additional results

Modelling through numerical analysis:
Thickness of the "upper"-layer corresponds to the depth of the molten pool.

FTIR-spectroscopy:
Hydrogen content diminishing with increasing Nº of steps suggests that the underlying layer is not completely dehydrogenised.

XRD analyses:
Presence of fine grained material with a coherence length of ~ 10 - 20 nm confirms the crystallisation of the coating.

AFM surface analysis:
Enhancement of roughness (RMS) with the Nº of steps suggests beginning of island formation:
As deposited : 4 nm;
After 3 steps : 6 nm ; After 12 steps : 40 nm

Conclusions

* **a-SiGe:H films has to be irradiated in a "step-by-step"- process with increasing fluence in each step, in order to avoid severe damage of the film caused by explosive H-Effusion**
* **For dehydrogenising and crystallising 500 nm thick films, several melt/crystallisation cycles have to be performed**
* **Segregation of Ge from the molten pool toward the surface can not be totally avoided**
* **Excessive fluences or Nº of pulses lead to strong segregation of Ge towards the surface and considerable damage of the coating surface**

Acknowledgements

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