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Crystallisation of 500nm thick a-SiGe:H films through ArF-Excimer Laser radiation

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

SiGe thin films

Properties and Advantages

* Low thermal conductivity
* Tailoring of electrical and thermodinamical properties
* Easy to micromachine
* Compatible with IC silicon technology

Applications

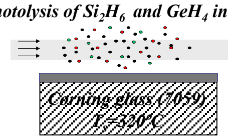
* Bolometers
* Solar cells
* Microelectronic devices

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)

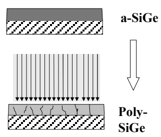


Growth of a-SiGe:H

+ ArF-Laser assisted crystallisation

"Step-by-step" process: Gradually increasing fluence

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



Dehydrogenation and modification to poly-SiGe

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

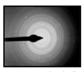
ArF-LCVD

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

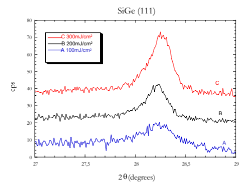
ArF-Laser assisted crystallisation

crystallisation process starting at fluences 80 mJ/cm²
Step by step process to avoid explosive evaporation of Hydrogen

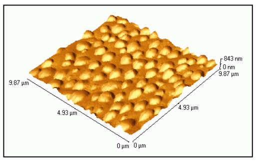
Crystallisation of fine grained material
Grain size ~30nm



TEM-dark field image and electron diffraction



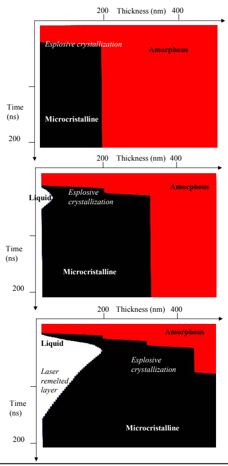
XRD analysis show film crystallinity increases with fluence



Roughening due to cumulative effect of shots
(17 steps till 440 mJ/cm²)

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)**



E ~ 100mJ/cm² film partially crystallized in fine grains by explosive crystallization (~200nm)

E ~ 200mJ/cm² film melts by explosive crystallization (~340nm). Surface remelts under laser fluence

E ~ 300 mJ/cm² film is totally melted by explosive crystallization. Remelts to a depth of about 160nm

* Surface melting threshold estimated to be ~ 60 - 80 mJ/cm²
* Substrate remains practically thermally unaffected for the fluences of interest
* Film grain size calculated from the simulation match those experimentally obtained in the range of fluences examined

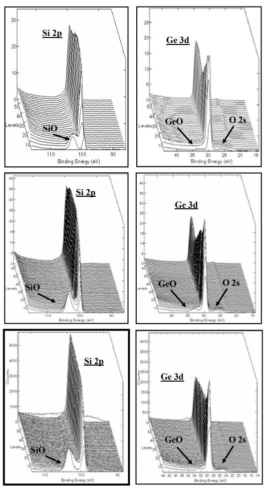
Composition and structure of the coatings at different stages of the "step-by-step" crystallisation process

Stage of the "step-by-step" process

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

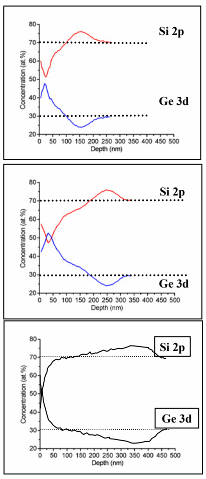
E_{in}= 200 mJ/cm²
6 steps, 10 shots each
(50, 75, 100, 125, 160, 200 mJ/cm²)

E_{fin}= 300 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 reveals 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** ($Si_{0.7}Ge_{0.3}$)

~230 nm + ~ 370 nm

~340 nm + ~ 160 nm

~ 450 nm + ~ 50 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.

AFM surface analysis:
Roughness (RMS) increases with the Nº of steps
As deposited : 4 nm;
After 3 steps : 6 nm ; After 12 steps : 40 nm

Conclusions

* **a-SiGe:H films has been 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 therefore not be totally avoided.**
* **Excessive fluences or Nº of pulses lead to strong segregation of Ge towards the surface**

Acknowledgements

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