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Symposium H
Contribution H/PI.22

Laser assisted Integrated Processing of SiGeC Films on Silicon

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Heteroepitaxial SiGeC thin films

Properties and Advantages

* Adjustable lattice + band gap
* Reduce diffusion of dopants
* Easy to micro-machine
* Compatible with IC silicon technology

Applications

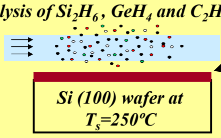
* Buffer layers in MODFET
* HBT and Near IR photodetectors
* New microelectronic devices

Laser assisted techniques

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

Photolysis of Si_2H_6, GeH_4 and C_2H_4 in He

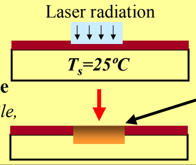
ArF-Laser radiation parallel to the substrate
(λ = 193 nm, E ≈ 0.7 W/cm²)



+ ArF-Laser assisted Pulsed Laser Epitaxy (ArF-PLIE)

Laser radiation (uniform due to a commercial homogeniser)

ArF-Laser radiation perpendicular to the substrate
(λ = 193 nm, ~20 ns, top-flat profile, H > 400 mJ/cm²)



Laser assisted techniques

Advantages

* Allow single chamber processing
* Low thermal budget techniques
* Ultra-rapid processes
* Established in TFT-production

Numerical Analysis

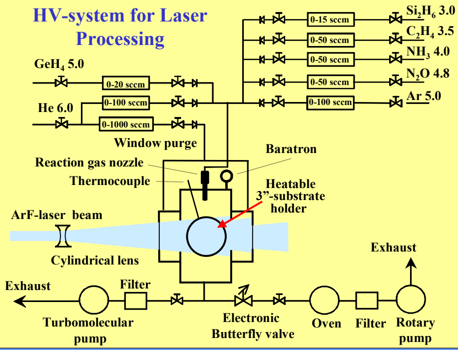
Modelling of

* Melting-solidification processes
* Segregation processes
* Temperature profiles

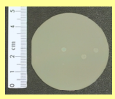
ArF-LCVD

* Uniform 40 nm thick coatings on 3" Si-wafers *(Profilometry, AFM, SEM)*
* a-$Si_{0.63}Ge_{0.30}C_{0.07}$:H with ~ 5 nm thick native oxide cap-layer *(XPS-depth profiling)*
* Hydrogen in µ-voids as well as bonded to Si, Ge and C *(FTIR-spectroscopy)*
* No crystalline components detectable *(XRD, TEM, Electron diffraction)*
* Roughness of the film surfaces is RMS < 4 nm *(AFM)*

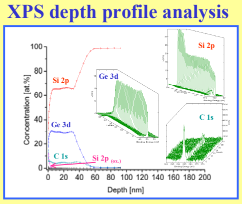
HV-system for Laser Processing



3" Si (100) wafer coated uniformly and in selected regions



XPS depth profile analysis



Numerical simulation of the Temperature gradients

1-D heat flow equation resolved using the finite difference scheme

$$C\rho\frac{\partial T(x,t)}{\partial t}=\frac{\partial}{\partial x}\left(k\frac{\partial T(x,t)}{\partial x}\right)+S(x,t)$$

(C = specific heat, ρ = density, k = thermal conductivity, T = temperature, S(x,t) = heat generation)

$$S(x,t)=P_d(t)\,\alpha(1-R)\exp(-\alpha x)$$

(α = optical absorption, R = surface reflectivity, $P_d(t)$ = time evolution of the laser beam power density)

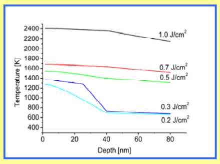
Shortcomings

* Thermal evolution of the optical and thermal properties of SiGeC are not well known
* Concentration of the surface species changes after multiple laser shots
* Surface roughness affects the film reflectivity and laser absorption

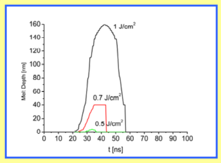
40 nm a-$Si_{0.63}Ge_{0.30}C_{0.07}$:H on Si (100)

* *Explosive crystallisation starts at H > 300 mJ/cm²*
* *Melting of the substrate starts at H > 700 mJ/cm²*
* *Melting of the alloy starts at H > 500 mJ/cm²*

Fluence dependence of



Temperature gradient

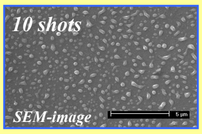


Melt depth

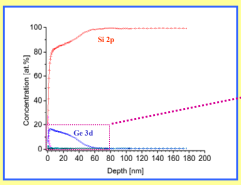
Composition and structure of the alloy after irradiating with different fluences

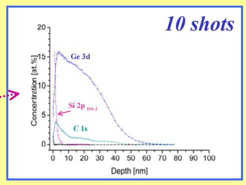
Energy density insufficient for PLIE (H ≈ 200 mJ/cm²)

Optical microscope images



XPS Depth profiles





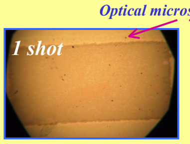
* Segregation of Ge to the surface forming Ge islands
* Carbon loss (Desorption due to oxidation after segregation)
* Alloy thickness has not increased (Wafer has not been molten)

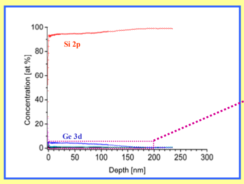
Energy density sufficient for PLIE

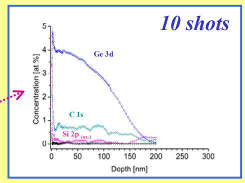
H ≈ 450 mJ/cm²

XPS Depth profiles

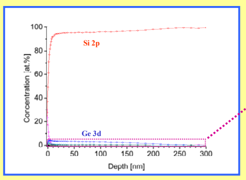
Optical microscope images

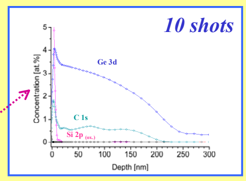






H ≈ 820 mJ/cm²





* At 450 mJ/cm² roughness increases, probably lowering the threshold for melting the Si (100)
* Alloy thickness increases with laser fluence (Wafer has been molten)

Conclusions

* **ArF excimer laser assisted CVD (ArF-LCVD) enables the growth of uniform a-SiGeC:H films with tailored composition.**
* **Irradiation of the films with fluences below the PLIE threshold provokes island formation due to Ge segregation, thus an increase of roughness.**
* **Loss of C is detected and attributed to desorption, probably due to oxidation of the C on the alloy surface caused by processing in air .**
* **After reaching the PLIE threshold an increase of the alloy depth is observed, indicating that the Si(100) substrate has partially been molten .**
* **Numerical simulation predicts higher PLIE thresholds than experimentally observed.**

***Suggested reason*: The decrease of the reflectivity due to the roughness enhancement might lower the threshold for the PLIE process.**

Acknowledgements

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