Mass separated Focused Ion Beams using Alloy Liquid Metal Ion Sources

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EFUG2000, October, 2nd, 2000, Dresden, Germany

Outline

Introduction

Alloy LMIS
Preparation
Characterisation

FIB System IMSA-100

Applications
$CoSi_2$ microstructures
Ge^{++}, Co^{++} beams - damage & annealing
Sputtering investigations
Micro-optical applications
Ion-acoustic Microscopy

SUMMARY

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Alloy LMIS

Preparation:

Needed ion species → choose a suited alloy
- sufficient concentration (phase diagram)
- low melting temperature (eutectic alloy)
- low vapour pressure at T_{melt}
- no chemically related effects

Preparation of the needle - hair pin or capillary type
- spot welding of thr source base
- electro-chemical etching of the W-tip (r_{tip} ~ 5 µm)
- mechanical treatment Ta-tip
- wetting by dipping in a cruicible in HV

Test and analysis:

- I-V-characteristics
- long-term stability
- temperature behaviour
- mass spectra
- energy distribution and ballistic deficit (energy spread)
- axial angular intensity

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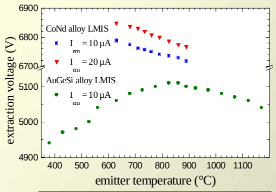
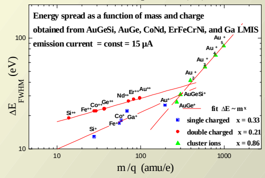
Results





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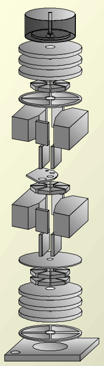
FIB system IMSA - 100



alloy LMIS

objective lens
stigmator 1
measuring aperture
E x B 1
beam blanking 1
variable aperture
stigmator 2
E x B 2

beam blanking 2
blanking aperture
deflection system
projective lens
MCP detector
xy stage

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Parameter IMSA-100 FZ Rossendorf:

Energy:	20 - 50 keV (single charged)
Ions:	B, Si, Cr, Fe, Co, Ni, Ga, Ge, Nd, Er, Au, ...
Current:	0.01 - 30 nA (max. 10 A/cm² at 100 nm spot)
Spot size:	100 - 2000 nm
Sample:	6"- wafer, 7"- masks
Stage:	Laser-interferometer controlled, x-y-area: 160 x 160 mm² accuracy: 50 nm
Options:	Heating targets up to 700 °C Cooling, ➂T = 60 grd Sample contacting, rotating Acoustic sensor ASCII, AutoCAD data input

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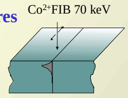
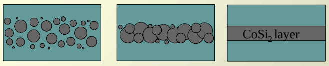
Applications

$CoSi_2$ microstructures

Co^{2+}FIB 70 keV

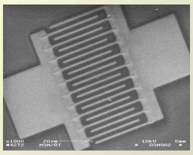
Writing FIB
Co - implantation
into a heated target





growth
nucleation
coalescence
Ostwald ripening
buried layer

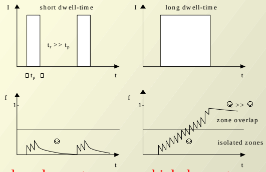
annealing 600°C, 60 min and 1000°c, 30 min in N_2 ⟶



SEM image of a MSM-Photodetector teststructure on silicon with $CoSi_2$ electrodes

Ge^{++} and Co^{++} implatation as s function of T

Investigation of damage accumulation and dynamic annealing during FIB irradiation

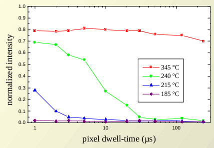


low dose rate	high dose rate
averaged	within the FIB
isolated amorphous zones can anneal	overlap of amorphous zones can not anneal
Si crystalline	**Si amorphous**
t_d = 1 µs, I = 0.7 nA	t_d = 250 µs, I = 0.7 nA
J = 1.4 x10^{14} ions/cm²s	J = 3x10^{18} ions/cm²s
j = 44 µA/cm²	j = 1 A/cm²

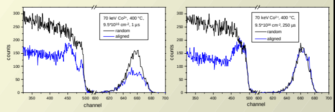
f - normalized damage fraction, 0 = crystalline; 1 = amorphous
☺ - temperature depending annealing time constant

Results:

70 keV Ge ++ , dose: 1.3 x 10^{15} ions / cm²



Normalized intensity of the Raman line of c-Siof 520 cm^{-1} as a function of the pixel dwell-time for different temperatures.

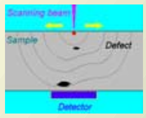


RBS-C analysis after 70 keV Co^{++} implantation for short (left) and long (right) dwell-times.

The relaxation-time lies in the µs - range.

Ion - acoustic Microscopy

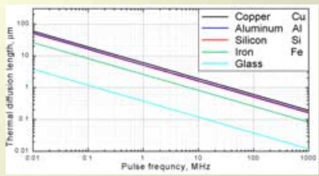
Principle:
modulated particle beam generates thermoelastic waves



Resolution:

$$d^2 = d_{th}^{\ 2} + d_s^{\ 2} + d_V^{\ 2}$$

Thermal diffusion length $d_{th} = \sqrt{\dfrac{\kappa}{\pi C \rho f}}$



Results

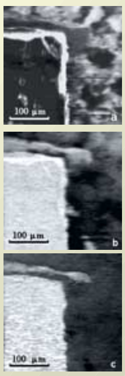
Secondary electron (a), acoustic amplitude (b) and acoustic phase (c) images of a corner of a silicon chip glued on a brass plate.

Pictures size is 100x100 pixels.

Acoustic images resolution is about 15 µm.
SE image resolution is 3 µm.

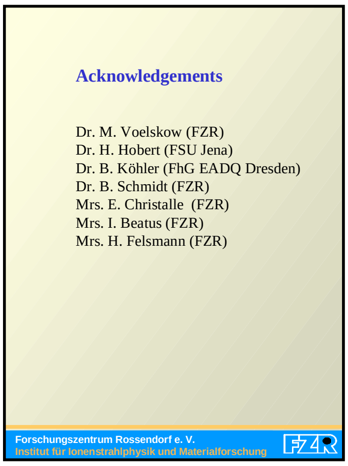
Exposition time of the acoustic images was 40 minutes.

Au+ ion beam.
E = 35 keV I = 2.6nA



Summary

1. **The use of mass separated FIB from alloy LMIS offers many new applications in micro-structuring .**
2. **The obtainable spot size is determined by the energy spread (I_{em}, q, m, T) and on the influence of the E x B filter.**
3. **The variability of the dose rate can be used for basic damage investigations in a range which is not possible with other techniques.**
4. **The writing implantation with FIB is very useful in maskless structuring of prototypes within the R&D process.**


Acknowledgements
Dr. M. Voelskow (FZR)
Dr. H. Hobert (FSU Jena)
Dr. B. Köhler (FhG EADQ Dresden)
Dr. B. Schmidt (FZR)
Mrs. E. Christalle (FZR)
Mrs. I. Beatus (FZR)
Mrs. H. Felsmann (FZR)
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