Department of High Frequency Electronics

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PROGRAM and ABSTRACTS

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10.10-10.20 **Thermal Management of Mid-IR Sb-Based Surface Emitting Lasers**
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10.20-10.30 **Dark Current in Porous Silver Contacts of Silicon Solar Cells**
V. I. Laptev[1], H.M. Khlyap[2]
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10.30-10.40 **HgCdTe/Si Infrared Photovoltaic Detector for Room Temperature Operation**
F. F. Sizov, R. K. Savkina, A. B. Smirnov, V. A. Deriglazov
V. E. Lashkaryov Institute of Semiconductor Physics of NASU (Ukraine)

10.40-10.50 **HFET Stability and 1/f Noise**
H. Morkoç[1], C. Kayis[1], J. Leach[1], C. Zhu[1], P. H. Handel[2]
[1]Virginia Commonwealth University (USA)
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10.50-11.00 **Influence of Barrier Material on the Optical Performance of InGaN-Multiple Quantum Wells Emitting at 450 nm**
U. Zeimer[1], V. Hoffmann[1], U. Jahn[2], C. Netzel[1], J.-R. van Look[3], M. Weyers[1], M. Kneissl[3, 1]
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[3]TU Berlin (Germany)

~~11.00-11.30 Coffee Break~~ 10.50-11.20 coffee on the go!

11.30-13.20 Session E7 - Defects & Doping and Semiconductor Properties

11.30-11.50 **Invited: Electrical Reliability and Failure Mechanisms of GaN-Based HEMTs**
J. Joh and J. A. del Alamo
Massachusetts Institute of Technology (USA)

11.50-12.00 **Evaluation of Cz-Si-Ge Microstructure After High Temperature-Pressure Treatment**
A. Misiuk[1], N. V. Abrosimov[2], J. Bak-Misiuk[3], W.Wierzchowski[4], K.Wieteska[5], C. A. Londos[6], J. Kucytowski[7]
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[5]Institute of Atomic Energy, Otwock-Swierk (Poland)
[6]University of Athens (Greece)
[7]University of Silesia, Katowice (Poland)

12.00-12.10 **Degradation Analysis of High Power Laser Diodes**
A. Martín-Martín[1], M. P. Iñiguez[1], J. Jiménez[1], M. Oudart[2], J. Nagle[3]
[1]Universidad de Valladolid (Spain)
[2]Alcatel-Thales 3-5lab (France)
[3]Thales Research and Technology (France)

12.10-12.20 **Trapping Effects in Al_2O_3/AlGaN/GaN MOS Structures with Gate Oxide Prepared by Different Deposition Techniques**
D. Gregušová[1,2], Ch. Mizue[2], Y. Hori[2], R. Stoklas[1], J. Novák[1], T. Hashizume[2], and P. Kordoš[1,3]
[1]Slovak Academy of Sciences, Bratislava (Slovakia)
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12.20-12.30 **LTPL and TEM Investigations of 6H-Type Stacking Faults in Low-Doped 4H-SiC Epitaxial Layers**
T. Robert[1], M. Marinova[2], S. Juillaguet[1], A. Henry[3], E. K. Polychroniadis[2], J. Camassel[1]
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EVALUATION OF Cz-Si-Ge MICROSTRUCTURE AFTER HIGH TEMPERATURE-PRESSURE TREATMENT

A.Misiuk[1,*], *N.V.Abrosimov*[2], *J.Bak-Misiuk*[3], *W.Wierzchowski*[4], *K.Wieteska*[5], *C.A.Londos*[6], *J.Kucytowski*[7]

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Annealing of Czochralski grown Si-Ge single crystals at high temperature (HT) under enhanced hydrostatic pressure (HP) affects their structure. Microstructure and homogeneity of Cz-Si-Ge samples with $c_{Ge} \leq 8$ at.% were evaluated by X-ray (Bond method and reciprocal space mapping), infrared, synchrotron and related measurements, after annealing for up to 10 h at up to 1400 K under HP ≤ 1.1 GPa. HT-HP processing results in stimulated clustering of oxygen interstitials and assists in improvement of initial non-homogeneity of Ge distribution.

1. INTRODUCTION

Silicon-germanium single crystals (Si-Ge) are of wide interest, especially for application in optoelectronics. In the case of Czochralski grown (CZ) single crystalline Si-Ge, containing a few at.% of Ge, it not distributed uniformly so different nano- and micro-defects are formed within the Si-Ge bulk [1]. As stated recently [2], such defects can be substantially affected by annealing the Si-Ge samples at high temperature (HT), especially under enhanced hydrostatic pressure (HP) [3].

The effect of HT-HP on single crystalline Si-Ge with relatively high content of oxygen interstitials is now investigated.

2. EXPERIMENTAL

The p-type (hole concentration $\approx 1.3 \times 10^{15}$ cm^{-3}) single crystalline (111) oriented Si-Ge samples containing 1.8–8 at.% of Ge, with interstitial oxygen (O_i) concentration, c_o=(0.8-1.2)x10^{18} cm^{-3}, were cut from Czochralski grown Si-Ge rods.

Next the Si-Ge samples of about 8x6x(0.5-2)mm^3 dimension were annealed in Ar atmosphere, typically for 5 h, at up to 1400 K under 10^5 Pa (atmospheric pressure) or HP=1.1-1.2 GPa.

The as-grown and HT-HP processed Si-Ge samples were investigated by X-ray (Bond method and reciprocal space mapping), synchrotron (at HASYLAB DESY), infrared, and related methods.

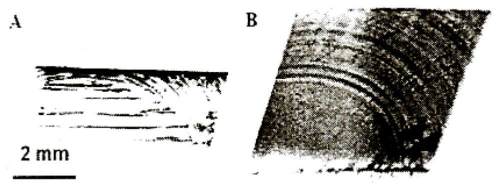

Fig. 1. White beam section (A) and projection (B) topographs of as-grown Si-Ge.

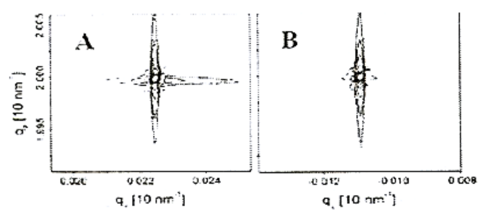

Fig. 2. XRRSM's of Si-Ge: A - processed for 5 h at 1270 K under 1.2 GPa and B – processed for 10 h at 1000 K under 10^5 Pa and, subsequently, for 5 h at 1270 K under 1.2 GPa (c_o = 6.5x10^{17} cm^{-3}).

3.RESULTS AND DISCUSSION

In what follows typical results concerning the Si-Ge samples with c_{Ge} =1.8 at.% are presented.

Dislocations, slip bands and striations, evidencing non-uniform distribution of Ge and its segregation, were revealed in the as-grown Si-Ge samples, also by synchrotron topography (Fig. 1).

Processing of Si-Ge for 5 h at 1270/1400 K results in volume HP-dependent precipitation of oxygen interstitials.

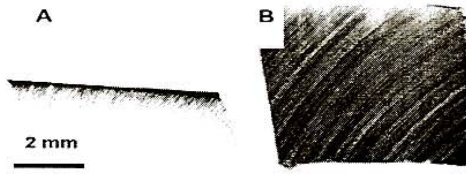

Fig. 3. White beam projection sectional (A) and projection (B) topographs of Si-Ge processed for 5 h at 1400 K under 1.1 GPa ($c_o = 5.3 \times 10^{17}$ cm^{-3}).

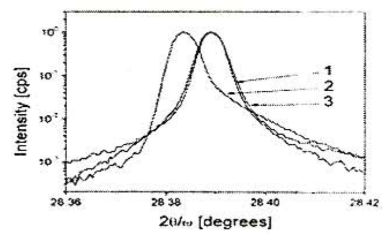

Fig. 4. 2Θ/ ω scans (111 reflection, triple axis configuration of X-Ray diffractometer) of Si-Ge: (1) as-grown, (2) processed for 5 h at 1400 K under 10^5 Pa ($\Delta c_o = 3.2 \times 10^{17}$ cm^{-3}) and (3) processed under 1.1 GPa ($\Delta c_o = 6.7 \times 10^{17}$ cm^{-3}).

After the treatment of Si-Ge at 1270 K under 10^5 Pa and 1.2 GPa, a decrease of c_o was, respectively, 3.5×10^{17} cm^{-3} and 7.5×10^{17} cm^{-3}.

Such processing produces numerous nano-dimensional clusters (Fig. 2A).

The same treatment of the samples pre-annealed at 1000 K under 10^5 Pa resulted in less pronounced X-Ray diffuse scattering, probably evidencing decreased dimension of newly created oxygen precipitates or/and their lowered concentration (Fig. 2B).

Annealing of Si-Ge at 1270 K / 1400 K under 10^5 Pa exerts minor effect on its microstructure, contrary to the case of processing under HP (Figs 3, 4).

The samples processed at 1400 K under HP present similar striations and slip bands as these observed in the as-grown samples (compare Figs 3 and 1). Still the Si-Ge sample processed at 1400 K under HP is of a little improved homogeneity (Fig. 3A). As follows from XRRSM's (not presented), the intensity of scattered X-Rays tends to decrease for Si-Ge processed at 1400 K under HP also evidencing improved homogeneity (compare Fig. 2).

Processing of Si-Ge at HT (HP) affects nano-dimensional Ge-containing non-homogeneities produced at growth of the Si-Ge rods [1, 2]. These non-homogeneities dissolve partially in the matrix at processing. This is related to enhanced diffusivity of Ge atoms at HT- HP [4].

Processing of oxygen-rich Si-Ge affects also the c_o value because of O_i's precipitation producing nano-dimensional sub-stoichiometric SiO_{2-x} clusters as well as other defects, among them the extended ones [5]. The lattice parameter, a, of cubic as-grown Si-Ge sample, determined from the 2Θ/ω scans (Fig. 4) is lower than that calculated from the Vegard law (that last assumes the linear dependence of a on the Ge concentration) [5]. This confirms that part of Ge admixture is contained in Si-Ge in the form of Ge-enriched clusters.

Processing of Si-Ge at 1270 K, both under 10^5 Pa and 1.1 GPa, results in an increase of Δa ($\Delta a = a_{processed} - a_{as\text{-}grown}$) for about 0.00005 nm ($\Delta a$ determined at 293 K). Processing at 1400 K under 10^5 Pa resulted in even more increased a_{293K}, Δa = 0.0001 nm (compare Fig. 4). These observations can be considered as proving dissolution of Ge-enriched clusters in the Si-Ge matrix. On the other hand, the value of a of the Si-Ge sample processed at 1400 K under 1.1 GPa (such treatment results in especially high percentage of precipitated O_i's - see the Fig. 4 caption) remains unchanged ($\Delta a \approx 0$).

It is known that processing of oxygen-containing CZ-Si at HT-HP is associated with the decreased a value resulting from removal of O_i's from the lattice (the presence of O_i's results in the increased, c_o - dependent value of a).

So the treatment of Si-Ge at HT under 10^5 Pa / HP exerts complex effects on its nanostructure, related, among other factors, to:

- dissolution of nano-dimensional Ge-enriched clusters in the Si-Ge matrix, dependent on HT, HP and annealing time, and
- precipitation of interstitial oxygen with a creation of nano-dimensional clusters composed of sub-stoichiometric silicon dioxide.

4. CONCLUSIONS

In general, HT-HP processing of single crystalline oxygen-containing CZ-grown Si-Ge results in stimulated clustering of oxygen interstitials and seems to assist in partial healing of initially present non-homogeneity of Ge distribution.

In view of important role of single crystalline Si-Ge in modern microelectronics and optoelectronics, determination of the effect of high temperature-pressure on its structure deserves extended future research.

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