Patterned heteroepitaxial SiGe thin films through UV Excimer Laser radiation

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Silicon-Germanium (SiGe) alloys and hetero-structures combining ultra-thin Si, SiGe and Ge films are well established components for a great variety of microelectronic and biomedical devices as well as photovoltaic thin film solar cells. Their effectiveness as virtual buffer layers or as active layers in micro-electronic devices is well established and the benefits of using such structures as sacrificial layers for the production of Micro-Electro-Mechanical- Systems (MEMS) or Silicon On Nothing (SON) devices explored. For producing such hetero-structures, the control of the interfaces between layers and of both, their composition and their crystalline structure is of greatest importance due to the dramatic influence of these characteristics on the optoelectronic, thermo-dynamical and mechanical properties of the material. To guarantee such a control, a careful and exhaustive research, dedicated to improve the growth processes through conventional IC technologies, has therefore been done and a tailoring of crystal lattices and interfaces to atomic scale precision been achieved. Nowadays, in addition to these challenges, the aim of lowering costs by including bottom-up steps in the growth processes for reducing processing steps and the emergent interest in using temperature sensible substrates or multilayer structures for reducing costs and improving device properties is also drawing more and more attention. These last conditions restrict the applicability of various conventional IC processing technologies, thus encouraging the research on new alternative techniques that avoid high substrate temperatures, allow a very precise local control of the temperature profiles in the hetero-structures and also permit the development of bottom-up processes. This contribution will present the combination of two UV-Excimer laser assisted techniques for obtaining thin patterned amorphous Si/Ge-bilayers on Si(100) through stencil assisted ArF-Excimer Laser induced Chemical Vapour Deposition (LCVD) in parallel configuration. The regular patterns, achieved using these type of shadow masks, has then been irradiated under Pulsed Laser Induced Epitaxy (PLIE) conditions for transforming them into heteroepitaxial SiGe alloys with a Ge rich ultra-thin layer buried under a stressed Si-rich heteroepitaxial top layer. The aim of these experiments was to continue recent studies done with similar bi-layer structures that were not previously patterned. The result of those previous studies demonstrated the efficiency of the Laser assisted processes for producing the proposed hetero-epitaxial Si/SiGe-structures on Si(100) and their applicability as sacrificial layers for SON or MEMS production. Moreover, numerical simulation of the process confirmed that the applied PLIE conditions produce ultra-short melting and solidification cycles in the sub-microsecond time scale, that are expected to induced the epitaxial growth and a reduced inter-diffusion of the bi-layer elements, as observed in the experiments [1-3].

In a first step, single chamber ArF-Excimer Laser (193 nm at 25 ns, Lambda Physik LPX 220i) induced Chemical Vapour Deposition (ArF-LCVD) in parallel configuration has been used for growing, at 250 ºC, thin a-Si:H/a-GeH bi-layer structures. Total pressure/precursor gas flows during LCVD processes were for Si_2H_6 1.2 kPa // 0.3 cm^3/min and for GeH_4 5.3 kPa // 3 cm^3/min. Film thicknesses were approximately 50 and 25 nm for a-Si:H and a-Ge:H coatings, respectively. All processes have been done using 50 cm^3/min He as buffer gas and 1000 cm^3/min He as window purge. The bi-layers have been grown on a Si(100) wafer through SiN shadow masks (nanostencils) and, after removing the stencil, been irradiated in He atmosphere with 10 laser pulses with a fluence of 240 mJ/cm^2. The 193 nm laser radiation impinging normally to the substrate has been spatially homogenized using a fly-eye homogenizing system (Exitech Limited Beam homogenizer EX-HS-700D) and ‘‘in situ’’ controlled (Ophir PE50-DIF) as described elsewhere [1, 2]. Bi-layers and hetero-structures have been analyzed through Interferometric profiler (NT 1100 Wyko), Raman spectroscopy (Horiba Jobin Yvon LabRam HR 800) and TOF-SIMS (IonTOF TOF-SIMS-IV)

As indicated in the introductory part and described in previous papers, the combined laser process produced the desired epitaxial growth in the PLIE irradiated spot, but also provokes Ge segregation that follows the movement of the solidification front [1,4]. A careful adjustment of the laser fluence and number of pulses for avoiding Ge island formation is therefore required. However, even if both parameters are optimized, the borders of the laser spot always will show an alteration of the structure, due to the reduction of the laser intensity and consequently the thermal profile of the treated material. Typical structures obtained in such zones can be observed in the AFM pictures (Fig.1). For avoiding these borders, patterned amorphous layers have therefore been produced through LCVD. Fig.2 shows images of a regular pattern obtained the using a SiN stencils as shadow masks. After the PLIE treatment of these patterns at conditions (10 pulses of 240 mJ/cm^2) that should guarantee the formation of an hetero-epitaxial alloy and also allow a good intermixing of the bi-layer elements, the size of the pattern features seems to remain similar, according to Interferometric profiler results. 488 nm Raman spectroscopy corroborated the formation of a crystalline Si, Ge and an SiGe alloy, thus the success of the PLIE process. However, the observation of the pattern with a optical microscopy revealed a new substructure that could be corroborated by TOF-SIMS analysis (Fig.3) revealing the existence of a Ge rich ring in the perimeter of each micro-structure. A careful analysis of the patterns by TOF-SIMS revealed that the inner part of each structure is a crystalline hetero-structure with a buried Ge rich layer, while the ring is a SiGe alloy. The results indicate that, in contrast to "conventional" treatment of large areas, a control of the process in the complete treated irradiated area can be achieved. The enrichment of Ge in the perimeter of each micro-structure can be attributed to the segregation of Ge following the PLIE induced solidification front. This movement should start from the Si substrate used as crystal seed and end on surface of each isolated microstructure. Since the lateral dimensions of these micro-structures are far bigger than their height and the temperature of solidification for the under-laying Ge rich layer is far lower than the one of the Si rich top layer, segregation to the lateral walls of the microstructures can be assumed.

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Figures:

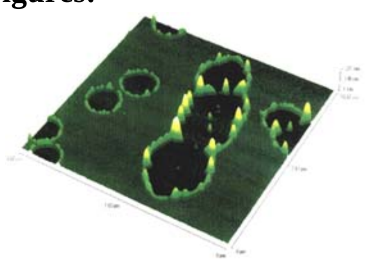

Fig.1

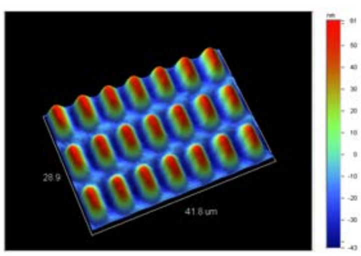

Fig.2

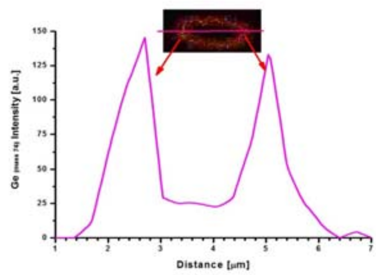

Fig.3