High-Mobility Ge on Insulator (GOI) by SiGe Mixing-Triggered Rapid-Melting-Growth

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INTRODUCTION

In order to break through the scaling limit of the transistor performance, research and development of new functional devices which enable ultrahigh speed operation, ultralow power dissipation, and multi-functional operation are strongly required. In line with this, group IV-based heterostructure technologies have been widely developed in a quarter century [1]. The high quality Ge layers on insulators (GOI) are promising materials for this purpose. High-speed Ge-channel thin film transistors (TFTs) are essential devices to realize system-in-displays and three-dimensional (3-D) large scale integrated circuits (LSIs). Moreover, GOI structures are also important as channel materials of spintransistors and virtual substrates of direct-band gap materials with optical functions to create multifunctional 3-D LSIs [2].

In line with this, we have been developing SiGe mixing triggered liquid-phase epitaxy (LPE) [3]. This achieves high-mobility Ge single crystals on transparent insulating substrates [4]. Present paper reviews our recent progress in this novel growth technique [3-6].

SiGe MIXING-TRIGGERED GROWTH

The seeding rapid-melting-growth [7] of amorphous-Ge (a-Ge), similar to the laser induced lateral growth of Si [8], was recently examined to obtain single-crystal GOI structures, where a-Ge layers deposited on SiO_2 films were first grown vertically from Si substrates through opening window formed in SiO_2 films, and then propagated laterally over SiO_2. These efforts achieved defect-free single-crystal Ge wires (20-40 μm length, 2-3μm width) on insulating films.

To expand the application field of this method, we have examined the detail of this process, and clarified that the driving force to cause the lateral growth of Ge was not the thermal flow from the molten-Ge to the Si substrates through seeding windows, but the spatial gradient of the solidification temperature originating from Si-Ge mixing at seeding areas, as shown in Fig. 1 [3]. This triggered an idea of the directional lateral growth of a-Ge on transparent insulators using Si micro-crystals instead of Si-substrates.

GIANT Ge LATERAL GROWTH WITH Si ARTIFICIAL MICRO-SEED

Orientation control of the Si micro-crystal seeds is essential to obtain high-quality GOI structures with controlled crystal orientations. We have already established a technique to form Si crystal grains oriented to (100) or (111) by Al-induced crystallization [5], which can be employed as the artificial micro-seed.

By using the Si artificial micro-seeds with (100) and (111) orientations, we have succeeded in hetero-epitaxial growth of single crystalline (100) and (111)-oriented Ge stripes, respectively, on quartz substrates. The cross-sectional TEM observations revealed no-defects in the laterally grown Ge regions. In this way, high-quality single crystalline Ge layers have been realized on transparent insulating substrates.

The GOI structures show a high hole mobility (~1400 cm^2/Vs) with low hole concentration (~$2x10^{16}$ cm^{-3}) as shown in Fig. 2, which is superior to the conventional GOI structures obtained by solid-phase crystallization (SPC) and oxidation-induced Ge-condensation techniques [9,10]. This SiGe mixing-triggered growth technique opens up the possibility of high-performance TFTs and virtual substrates for multifunctional 3-dimensional LSIs.

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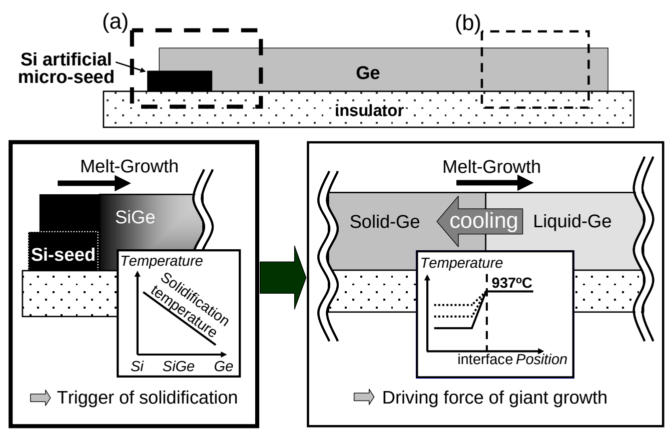

Fig.1 Growth mechanism of GOI near (a) and far beyond seeding area (b).

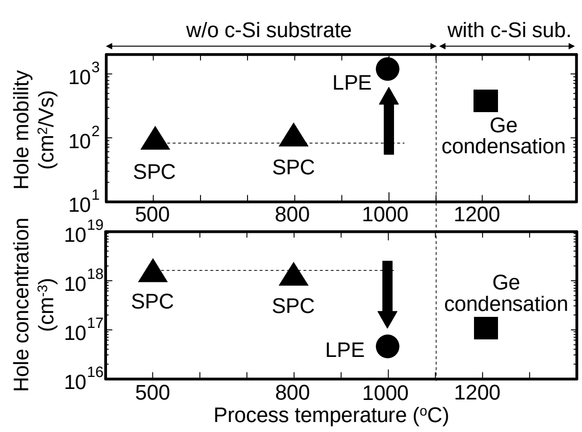

Fig.2 Comparison of hole mobility and concentration of in GOI grown by present method (LPE), SPC [9], and Ge-condensation [10].