GeSn film deposition using Metal Organic Chemical Vapor Deposition

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Introduction

The size of LSI has become smaller following the Moore's law, and the computing power of LSI has also become faster accordingly. However, in recent years, it is becoming increasingly difficult to reduce the size of LSI because of the complexity and high cost of the technology associated with reducing the size of LSI. It is, thus, important to establish a post-scaling technique to improve the LSI performance. An approach of creating CMOS channel from GeSn is a post-scaling technique and is widely considered a promising approach to improve LSI performance. GeSn has characteristics that are suitable for a pMOSFET channel material. For instance, it is reported that GeSn as a pMOSFET channel material has higher hole mobility compared to other possible channel materials such as Ge[1]. Due to its high potential, there exist a large number of researches on GeSn. Many existing studies conducted MBE (Molecular Beam Epitaxy) as the GeSn growing method[1]. However, the authors of this paper believe that CVD (Chemical Vapor Deposition) is more suitable than MBE in producing large quantity GeSn, because CVD enables deposition of a larger area film with higher productivity.

In this paper, we selected the metal-organic (MO) precursors to deposit GeSn and confirmed that it is possible to deposit GeSn on a substrate using the MOCVD technique.

Experiments

First, we carefully selected tertiary-butyl-german ($t\text{-}C_4H_9GeH_3$) and tetra-ethyl-tin ($(C_2H_5)_4Sn$) as Ge and Sn precursors, respectively. Characteristics of the selected Ge precursor include high vapor pressure, low deposition temperature, and low carbon impurity incorporation[2]. Selected Sn precursor also has high vapor pressure. Many researchers utilize Ge_2H_6 as Ge precursor[3], and SnH_4 as Sn precursor[4]. However, Ge_2H_6 and SnH_4 are very dangerous because of the pyrophoric and the explosive. Some researchers use $SnCl_4$ as Sn precursor[3]. However, it reacts with H_2O and generates HCl. The residual chlorines of the decomposed precursor can cause damages to devices. Our selected precursors do not have such problems.

Fig.1 shows a schematic illustration of the MOCVD system used in the experiment in this paper. This MOCVD system can simultaneously deposit GeSn films on a substrate at 10 ^oC intervals from 220 ^oC to 380 ^oC. In the MOCVD system used in the experiments, our selected precursor vapor was controlled by the N_2 carrier gas flow rate, bottle temperature, and bottle pressure. In the experiments, Si substrates were used to deposit GeSn. After heating the substrates to the deposition temperature in the chamber, precursor vapor was injected into the chamber. The deposition temperature was varied from 220 ^oC to 380 ^oC, while the deposition pressure was kept at 30 Torr. Deposition duration was 120 minutes.

The structures of the deposited GeSn films were observed using SEM (Scanning Electron Microscopy). The atomic concentrations of Ge and Sn, as well as their element distributions were measured using EDX (Energy Dispersive X-ray spectroscopy).

Results and Discussion

In the experiments, we successfully deposited GeSn films on a Si substrate at the deposition temperature from 350 ^oC to 380 ^oC by MOCVD. Fig.2 is the SEM image of GeSn film at 350 ^oC. The thickness of this GeSn film was approximately 100 nm. As the deposition temperature increased by 10 ^oC in the 350 ^oC to 380 ^oC range, the thickness of the deposited GeSn film also increased by approximately 40 nm. When the temperature was under 350 ^oC, Sn was hardly incorporated in the film.

The atomic concentrations of Ge and Sn in the GeSn film deposited on a Si substrate were measured using EDX. Ge and Sn concentrations were approximately 96-92 and 4-8 atomic percent depending on the precursor flow ratio. In the film with 4% Sn, the atomic composition showed constant and independent of the deposition temperature between 350 ^oC to 380 ^oC. We also confirmed that Ge and Sn elements were uniformly distributed in the film. However, in the films with Sn more than 6%, the film composition depended on the deposition temperature, and some Sn precipitates were observed in the film.

In summary, the experimental results described above confirmed that tertiary-butyl-german and tetra-ethyl-tin for Ge and Sn precursors, respectively, can be used as precursors for MOCVD GeSn film fabrication.

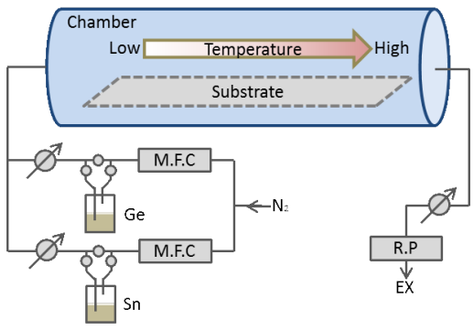

Fig.1 MOCVD system used in the experiments.

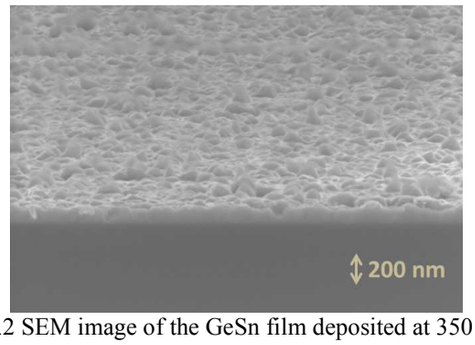

Fig.2 SEM image of the GeSn film deposited at 350 ^oC.

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