Principal Research Results

Establishment of the Base Technology of Large-Capacitance SiC Semiconductor
– Development of High Growth Rate and Large-Diameter Epitaxy Technique –

Background

Since the power electronics devices applying SiC semiconductor can realize high efficiency compared to devices using the present Si semiconductor, the SiC devices are expected as high-voltage and low-loss devices. We have been developing SiC epitaxy technique [*1] aiming to adopt SiC devices to the electric power industry. The development of the 4H-SiC [*2] epitaxy technique achieving high-quality, high growth rate and large-diameter is essential to realize the SiC semiconductor devices for electric power industry as well as public use.

Objectives

This study aims to develop the epitaxy technique for the growth of high-quality 4H-SiC epilayers achieving large-diameter uniformity and high growth rate.

Principal Results

1. Development of high growth rate and large-diameter epitaxy reactor (CVD [*3] reactor)

The inside design of the CVD reactor was examined. The vertical position of the susceptor and induction coil can be modified to adjust the temperature gradient in the CVD reactor. To obtain large-diameter uniformity, we modified the diameter and horizontal/vertical position of the gas inlet as well as the rotation system of the susceptor (Fig. 1).

2. Performance of the developed CVD reactor

Growth rate increases with the increase in source gas concentration. A maximum growth rate of up to 250 μm/h is achieved. This growth rate is the highest in recently reported high speed 4H-SiC epitaxy (Fig. 2).

The modification of the CVD reactor for the large-diameter uniformity makes it possible to obtain simultaneously high growth rate and large-diameter uniformity in the level capable for practical use (Fig. 3). This is the first report that achieves a high growth rate more than 20 μm/h in a large-area over 4-in. diameter.

3. Quality of the as-grown epilayer

The quality of epilayers is investigated using low-temperature photoluminescence (PL) (Fig. 4(a)), atomic force microscopy (AFM) (Fig. 4(b)), and PL decay time measurement (Fig. 4(c)). In each measurement, the results indicate the as-grown epilayers have high purity and a high quality.

From the above-mentioned results, we developed high growth rate and large-diameter 4H-SiC epitaxy technique with the quality that was enough for the practical use of the SiC devices and demonstrated it. This result won a research encouragement prize in 16th Meeting on SiC and Related Wide Bandgap Semiconductors, the Japan Society of Applied Physics, in 2007.

Future Developments

It is planned to practically develop the high growth rate and large-diameter epitaxy technique and apply it to high-voltage devices.

Main Researcher: Masahiko Ito, Ph. D.,
Visiting Researcher, Advanced Functional Materials Sector, Materials Science Research Laboratory

Reference

M. Ito et al, “Development of 4H-SiC epitaxial growth technique achieving high growth rate and large-area uniformity”: Applied Physics Express 1 (2008) 015001

＊1：Technique for depositing high-quality SiC single crystal film on the substrates.
＊2：One of the polytypes of SiC single crystal. It has suitable physical properties as power devices.
＊3：Abbreviation of “Chemical Vapor Deposition”. The chemical process to produce thin films from the source gases.

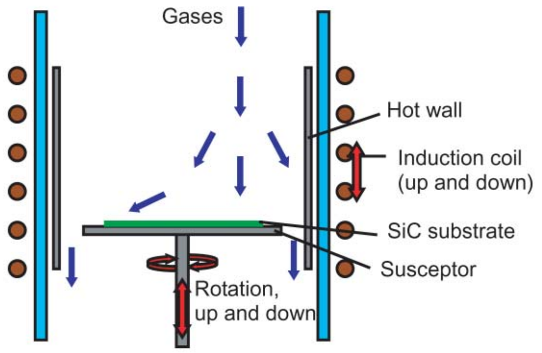

Fig.1 Cross-sectional schematic drawing of the CVD reactor

Induction heating is applied mainly to the hot wall, and the susceptor is heated by radiation from the hot wall. To optimize the growth condition, the diameter and position of the gas inlet as well as the vertical position of the induction coil and the susceptor can be modified.

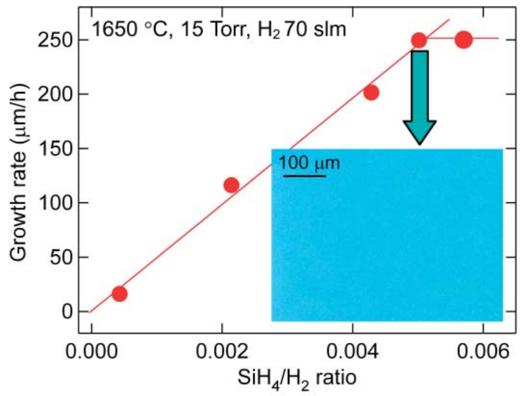

Fig.2 Growth rate as a function of source gas concentration. The insert shows a Nomarski microscope image of an epilayer surface grown at a 250 μm/h.

The growth rate of 250 μm/h is more than 10 times higher than the typical growth rate in recent multi-wafer reactors.

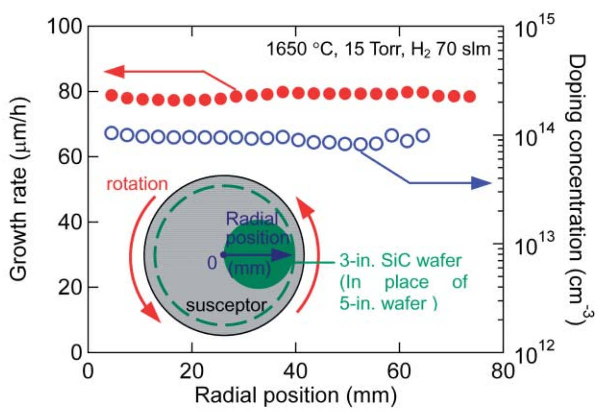

Fig.3 Radial direction distribution of the growth rate (red) and intentional n-type doping concentration (blue) on the susceptor

The mean growth rate of 79 μm/h, and both the growth rate uniformity and the n-type doping concentration uniformity for practical use are achieved in a 5-in. diameter area.

Uniformity of the growth rate σ/mean= 1.1%,
Mean growth rate 79 μm/h,
Uniformity of the n-type doping concentration σ/mean= 6.7%,
Mean n-type doping concentration 9.3 $\times 10^{13}$ cm^{-3}

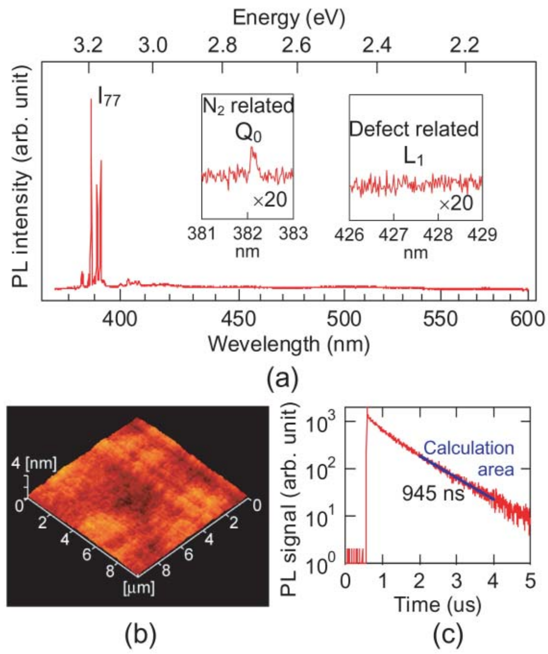

Fig.4 (a) Low-temperature PL spectra taken from an epilayer grown at a 75 μm/h. (b) AFM surface image, and (c) typical decay curve obtained for a 280-μm-thick epilayer

The PL of free-exiton (I_{77}), which suggests high quality of the crystal, is notably predominant. The surface of thick epilayer has good morphology (RMS=0.20 nm), and the epilayer has long carrier lifetime (1.0 μs on average). These results indicate high quality of the crystals on the level sufficient for practical use.