Surface treatment of SiC using NF3/O2 plasma

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ABSTRACT

b-SiC is a promising semiconductor material for high temperature, high frequency, and high power electronic devices, because it has wide band gap (2.3 eV) at 300 K, short carrier lifetime, low coefficient of thermal expansion, and high thermal conductivity1-3). It is easily imagined that the machining property of SiC is poor, because of its high mechanical strength and chemical stability. Although the chemical etching of this compound with a wet process was conducted in the molten KOH or NaOH at 873 to 1073 K, the shape of the etching cross-section was isotropic4). Also, the dry etching of SiC has been reported in CF4/O2, CHF3/O2, CBrF3/O2, or SF6/O2 plasmas. However, the polymerization products of these gases were deposited on the surface of a specimen and/or the inside wall of the chamber, and this phenomenon caused the problems such as contamination of the SiC surface. In the semiconductor industry in Japan, a large amount of nitrogen trifluoride (NF3) is used as a dry etchant and a cleaner gas for the CVD chamber. NF3 is chosen as a F radical source, because it is efficiently broken down into free radicals, and all of the possible byproducts are volatile, thus avoiding possible contamination or polymer formation in the chamber. Surface treatment of poly-b-SiC prepared with chemical vapor deposition (CVD) has been conducted in NF3 and the mixture gas plasma of NF3 and O2 by the reactive ion etching (RIE). The etching rate with pure NF3 plasma was large under pressures ranging from 0.5 Pa to 1 Pa and its maximum value was 87 nm/min. The etching rate had a minimum value under pressure of 2 Pa or 3 Pa and then increased gradually with the increase of NF3 pressure. The surface of polished SiC specimen with treatment by RIE under conditions such as NF3 pressure of 1 Pa and RF power of 100 W remained smooth in the scale of nm within 30 minutes, whereas it became rough in the scale of 20 nm over 60 minutes. On the other hand, the SiC surface became carbon-rich by RIE under NF3 pressures higher than 3 Pa, because of the reaction of fluorine radicals (F) with Si on the SiC surface, and the carbon-rich part of SiC surface acted as a micromask to form spikes on it. Figure 1 shows the etching rate of SiC using the mixture gas plasma of NF3 and O2 under total pressure of 20 Pa. The etching rate increased with increasing O2 content and reached the maximum value of ca. 1 mm min.-1 at 10Figure 2 shows the SEM images of the SiC surface etched by both pure NF3 plasma and the mixture gas plasma of NF3 and 10of 20 Pa with RF power of 100 W. These photos revealed that the surface etched by the mixture gas plasma of NF3 and 10compared with that by pure NF3 plasma. We considered that the carbon component of SiC was etched away as CO and/or CO2 in the mixture gas plasma of NF3 and 10smooth surface of the etched SiC. From XPS data, it is found that SiO2 was formed on the substrate of SiC and etching of the Si component of SiC was prevented by its formation in the higher O2 content than 10the elimination process of SiO2 from the surface may become the rate- determining step in the etching of SiC using the mixture gas plasma of NF3 and O2. A typical emission spectrum in the wavelength region from 200 to 900 nm during etching of SiC by the mixture gas plasma of NF3 and 10in Figure 3. In the spectrum, F2+, N+, N2+, N2, O2+, O, and F lines can be identified. From this result, it is considered that O radicals may react with the carbon component of SiC to form CO and/or CO2.