Topic number

Plasma-material Interactions: diagnostics and control

M. Hori[1]

[1] Institute of Future Society for Innovation, Nagoya University, Japan

In order to realize high performances of plasma material processes, various kinds of plasma diagnostics techniques have been developed. These processes were basically determined by the interaction of plasma with the surface of materials. Therefore, it is extremely important to diagnose and control the kinetics of the surface reactions with a high accuracy. The science and technologies on plasma-material interactions will be overviewed and the forward prospective is mentioned.

1. Introduction

Plasma etching and deposition processes have been core technologies to make the manufacturing innovation, such ultralarge integrated circuits (ULSIs) etc. In these processes, the quantitative measurement and the spatiotemporal control of ion, radical and light in the reactive plasma became key issues to obtain high processing performances as well as the establishment of the plasma process science. Here, the interaction of plasma with the material surfaces has been investigated by employing various kinds of diagnostics techniques not only in the gas phase but also in the surface. The advanced methods to control them have been introduced.

2. Experimental and results

The solar cell devices with a-Si and μc-Si thin films have been fabricated employing a plasma enhanced chemical vapor deposition (PECVD) with SiH_4/H_2 gases. In this processing, SiH_3 and H radicals which were reported to play important roles were measured at a relatively high pressure of 1 kPa in a capacitively coupled VHF of 60 MHz excited plasma by using the cavity ring down spectroscopy (CRDS) and the vacuum violet laser absorption spectroscopy (VUVLAS), respectively. Additionally, the behaviors of higher order species in the condition were evaluated by using the quadruple mass spectroscopy. The systematical measurement of behaviors of species in the gas phase enabled us to evaluate the sticking coefficiencies of these species on material surfaces. Considering the surface loss probability of 0.5 for SiH_3 radical and 1 for H radical, it was found that SiH_3 radical constituted 45% of the deposition precursors and the others will be higher order radicals [1]. On the basis of these diagnostics results, the control technology to synthesize films of high quality at a higher deposition rate was proposed.

The SiO_2 etching processes with a high aspect ratio in ULSIs have been investigated employing the fluorocarbon gas chemistry. In this processing, synergetic effects of fluorocarbon radicals with the ion bombardment with a high energy formed the intermediated layers between fluorocarbon films and the SiO_2 surfaces during the etching. Control of such a layer induced by the plasma is a key issue for the etching of SiO_2. It is so difficult, however, to identify the chemical composition of layers and design the structures for obtaining the high performances of etching. Then, the thin SiOF intermediate layer < 2 nm in thickness induced by the $C_4F_6/O_2/Ar$ etching plasma was precisely analysed by the ex situ time-of-flight secondary ion mass spectroscopy (TOF-SIMS) using a C_{60}^{2+} sputtering. The clearly observed signal of $SiOF^-$, SiO_2F^- and $Si_2O_4F^-$ between the top fluorocarbon film and the SiO_2 were found to be a key layer to be controlled for the etching [2].

Recently, the non-equilibrium atmospheric pressure plasma was applied to the cleaning and modification of the material surfaces. The O and N atoms together with UV were measured by the VUV absorption spectroscopy and optical emission spectroscopy (OES). The interaction of O radical and UV attributed to NO-γ with the organic contamination of glass decomposed organic monolayers for the surface cleaning [3].

3. References

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