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Investigation of Ashing Mechanism for Various Polymer Films using Microwave Excited Plasma under Water Vapor Atmosphere

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1. Introduction

We have developed water plasma ashing (WPA) process using microwave for photoresist removal. This method is environmentally-friendly one because it uses only ultrapure water as an operating gas vapor. This method has high cooling effect for wafer due to direct contact with water. Since high density plasma is generated near the wafer, high photoresist removal rate (> 1 μm / min) is realized [1]. These remarkable advantages may overcome recent several difficulties in photoresist ashing process.

Presently, in a semiconductor device manufacturing process, a photoresist film has a different chemical structure taking into account an exposure light source. In this report we investigated a removal characteristics of water plasma ashing for five polymer films of PVP (polyvinyl phenol), PBeMA (polybenzyl methacrylate), and PEMA (polyethyl methacrylate). In this abstract, we discuss the mechanism of polymer removal from ashing rate and spectroscopic method.

2. Experimental setup for water plasma ashing process

The experimental equipment used in this study is shown in Fig. 1. A quartz-filled rectangular waveguide was equipped on the stainless steel chamber. A Si slot antenna was located at the end of a quartz-filled. The slot antenna has a width of 0.5 mm and a length of 20 mm. The ultrapure water was partially filled in the chamber so that the slot antenna was maintained under water vapor environment. The pressure was set at about 1.5 kPa using a scroll pump. A continuous 2.45 GHz microwave was injected from the quartz-filled rectangular waveguide into the water vapor through the slot antenna. The non-thermal water plasma was produced along the slot antenna. Optical emission spectra were measured by a compact spectrometer (USB2000+UV-VIS, Ocean optics). The optical fiber rod was installed at a viewing port. Si wafer was located 5 mm below the slot antenna. Three kinds of polymer materials were coated on rhe Si wafer.

3. Experimental results

Figure 2 shows polymer film thickness variation as a function of plasma irradiation time. The ashing rate was calculated from the slope on the graph. The ashing rate of PVP was 1.0 μm / min, which is the lowest among the three polymers. PVP has a hydroxy group and benzene ring in the side chain. Under strong energy, it is known that PVP is main-chain cross-linked polymer, and PBeMA and PEMA are main-chain scisson polymers. These chemical structure differences may contribute to decreasing the ashing rate. Figure 3 shows the temporal variation of H_α radiation intensity for each polymer film. The H_α radiation intensity is normalized with the maximum value. During the plasma irradiation time, the radiation intensity of H_α decreased for PVP. Conversely, it increased for PEMA. These results suggest dissociation of H occurs from -CH_2- and -CH_3 in the polymer structure during water plasma ashing process.

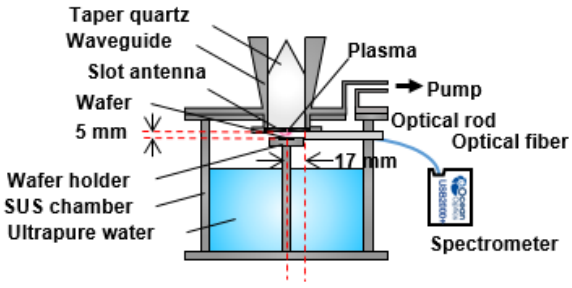

Fig.1 Experimental set up

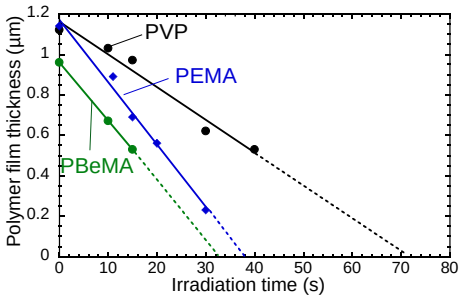

Fig. 2 Polymer film thickness variation as a function of plasma irradiation time.

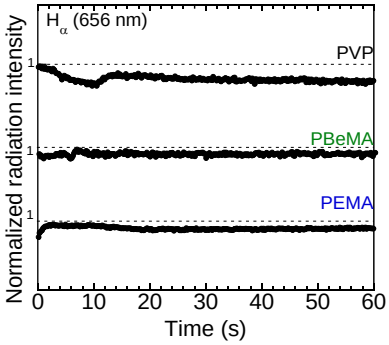

Fig. 3 Temporal variations of radiation intensity of H_α(656 nm).

Reference

[1] T. Ishijima, K. Nosaka, Y. Tanaka, Y. Uesugi, Y. Goto, and H. Horibe : Appl. Phys. Lett., **103**, 142101 (2013).