Anaysis of photoresist surface modified by fluorocarbon ions and radicals*

Makoto Sekine, Takuya Takeuchi, Sinpei Amasaki, Keigo Takeda, Kenji Ishikawa, Hiroki Kondo, Toshio Hayashi, Masaru Hori

Graduate School of Engineering, Nagoya University
C3-1(631), Furo, Nagoya 464-8603 Japan

Photoresist is indispensable material for the pattern formation using lithography and subsequent etching processes. It is well known that the photoresist for ArF (193 nm) excimer laser lithography have poor tolerability against etching plasmas and they may often be deformed and some roughness on the and surface and sidewall of the photoresist patterns are developed. This roughness will cause the hindrance of exact nano fabrication. In order to improve process condition and resist materials to reduce such roughness, it is indispensable to understand the reaction mechanism of photoresist and reactive species. We investigated the reaction of ArF photoresist with the mass-separated fluorocarbon ions, CF$_x^+$ (x=1~3).

Furthermore, we employed a plasma beam system to expose ArF photoresist to active species, ions and radicals, produced in the inductively coupled plasma of fluorocarbon gases. The ion species are accelerated to specific energy to bombard the photoresist surface. The modified surface layers were analyzed by using an in-situ XPS.

It was found that the fluorinated carbon layer was formed on photoresist surface, and oxygen was decreased by CF$_4$ plasma beam exposure. The C1s XPS spectra of photoresist after the beam exposure show not only C-F$_x$ peaks but also C-C graphite peak. For the Ar ion bombardment with the same dosage, C-C graphite peaks was not observed. It is considered that fluorocarbon active species has high chemical effect and they changes photoresist structure into fluorinated carbon and graphite-like structure. The surface roughness were estimated using AFM after the plasma beam exposure. We will discuss the roughness formation mechanism based on these results.

1. T. Takeuchi et al., "Impacts of CF$^+$, CF$_2^+$, CF$_3^+$, and Ar Ion Beam Bombardment with Energies of 100 and 400 eV on Surface Modification of Photoresist", Jpn. J. Appl. Phys. 50 (2011) 08JE05.

* Work partially supported by Tokyo Electron Limited.