Electrical and Optical Properties of Si-Incorporated a-C:H Films via the Radio Frequency Plasma-Enhanced Chemical Vapor Deposition Method

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The optical and electrical properties of silicon-incorporated hydrogenated amorphous carbon (a-C:H:Si) films deposited via the radio frequency (RF) plasma-enhanced chemical vapor deposition (PECVD) method using a mixture of CH4, H2, and SiH4 were observed. The silane gas whose range was increased from 0 to 25 vol.% [SiH4/([SiH4 + CH4])] was fed into the reactor while the other deposition parameters were kept constant. The basic properties of these films were investigated via Raman spectroscopy, UV-visible spectrometry, I–V measurement, and surface profiling. The experiment results showed that the film thickness increased from 300 nm to 800 nm for the same deposition time as the silane gas increased. The Raman spectrum obtained from the silicon-incorporated a-C:H films suggested that the film property changed from graphitic-like to more diamond-like. As the silane gas increased, the optical gap, Eopt, slightly increased from 1.98 eV to 2.62 eV. It was shown that the Si atoms incorporated into the a-C:H films reduced the size of the sp3 clusters. As for the I–V characteristics, the Si-incorporated a-C:H films had a lower leakage current than the a-C:H films without Si.

Keywords: Amorphous Carbon, RF PECVD, Optical Properties.

1. INTRODUCTION

Hydrogenated amorphous carbon (a-C:H) films have a number of unique properties such as a high degree of hardness, high wear resistance, infrared transparency, and high electrical resistance, depending on the deposition conditions.1-4 Such films generally have an amorphous structure, in which sp2, sp3, and sp4 bonds coexist.5,6 In DLC or a-C materials, these bondings determine the optical, electronic, and mechanical properties.

The doping of different elements has been proposed to improve certain mechanical, chemical, and tribological properties. In particular, interesting results of studies of Si-incorporated a-C:H films have been reported. They have shown that silicon contributes to the shrinkage of the sp2 clusters and the stabilization of the sp3 carbon phase.7,8 These films have remarkable properties such as good adhesion and reduced internal stress,8 a low friction coefficient,7,9 and a high degree of hardness,10 etc.

However, the electrical and optical properties of silicon-incorporated hydrogenated amorphous carbon (a-C:H:Si) films still require investigation.

In this paper, we present the results of an investigation of the electrical and optical properties of a-C:H:Si films deposited on Si (100) wafer and Corning glass using the radio frequency (RF) plasma-enhanced chemical vapor deposition (PECVD) method. The structural variations of the a-C:H:Si films according to the Si doping contents were investigated via Raman spectrometry, and the effects of the Si doping on the optical and electrical properties of the a-C:H:Si films were analyzed via UV-VIS spectrometry and current–voltage (I–V) measurement, respectively.

2. EXPERIMENTAL DETAILS

Si-incorporated a-C:H films were prepared using the RF (13.56 MHz) PECVD system. The two plates had 12 cm diameters and were 8 cm apart. The schematic of the apparatus is shown in Figure 1. Before the deposition, the chamber was evacuated to 1 mTorr with a mechanical