# THERMAL PROPERTY AND TRIBOLOGICAL PROPERTY OF AMORPHOUS CARBON NITRIDE FILM

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**Abstract**

In this paper, the relationship of the thermal conductivity measured by 3$\omega$ method and the hardness measured by nanoindentation method of amorphous carbon nitride films deposited on Si wafers and the influence of the properties on tribological characteristics measured by the ball-on disc method was investigated.

**Introduction**

Recently, amorphous carbon nitride has been attracted much attention because of high hardness, low frictional coefficient and chemical stability, as well as amorphous hydrogenated carbon, or diamond-like carbon (Kakiuchi, H). Mechanical properties and tribological properties have been well investigated by many researchers (Freire Jr, F.L.). Although it is considered that thermal properties are related to mechanical properties and tribological properties, it has not been investigated intensively, so far (Zhou, Z.F.). The purpose of this paper is to correlate thermal conductivity with hardness and to investigate the influence of thermal conductivity on tribological measurements.

**Experimental**

Amorphous carbon nitride films were deposited on Si wafers (100) from acetylene and nitrogen ($C_2H_2$:$N_2$=3:1) by RF plasma enhanced plasma CVD. The RF power was applied from 100W to 1500W and the thickness of the film was over 500nm. Thermal conductivity as thermal property was investigated by 3$\omega$ method, in which the temperature rise of the Al thin film is detected by 3$\omega$ component of the alternating current (Yamane, T.). As shown in Fig. 1 and 2, alternating current was generated by a function generator and applied to an Al thin film(25$\mu$m×3mm×600nm) patterned on amorphous carbon nitride film on Si substrate placed in the bridge circuit. The 3$\omega$ component in the alternating current was detected by a lock-in amplifier when generated heat conducted from the Al thin line to the Si substrate through the amorphous carbon nitride film. The frequency of the current was varied from 10Hz to 200Hz. The measurement was carried out in a vacuum chamber of 10E-1Pa at 25℃. The temperature of the sample holder in the vacuum chamber was controlled by circulating water. Hardness was investigated by the nanoindentation method with the indenting load of 500$\mu$N and indenting depth less than 1/10 of film thickness. Tribological property was investigated by the sliding tests for period of 1.5 hours by the ball-on disk method in normal air at ambient temperature against the aluminum ball. The sliding speed was kept constant at 10cm/sec in the sliding tests.

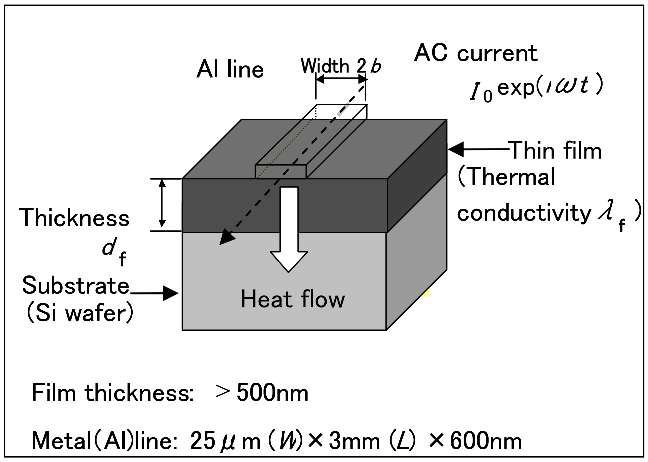


**Fig. 1** Principle of 3 ω method

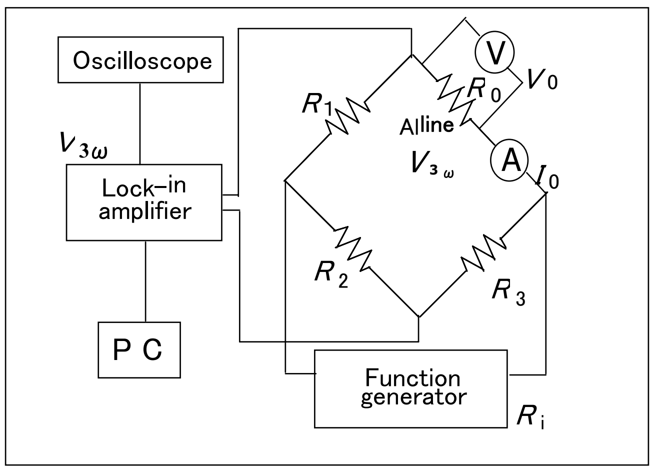


**Fig. 2** measuring system of 3 ω method

The results of thermal conductivity were discussed in terms of $I_D/I_G$ by Raman spectroscopy (Ar laser: λ = 514.5nm), density and $N/C$ by RBS/ERDA to correlate physical and chemical bonding properties and hardness by nanoindentation and tribological properties to correlate mechanical properties and thermal properties.

## Results and discussion

Fig.3 shows the Raman spectra of investigated amorphous carbon nitride films. The each spectra was deconvoluted into D-peak and G-peak by the fitting curve of Gaussian-Lorentzian approximation. As it can be seen, the shape of spectra changed, or the intensity of D-peak increased as RF power increased from 100W to 1500W, which indicated the increase of random graphite bonds. Fig. 4 shows the dependence of $I_D/I_G$ on RF power calculated by comparing the intensity of D-peak and G-peak from Fig. 3. $I_D/I_G$ showed minimum around 300 to 500W and

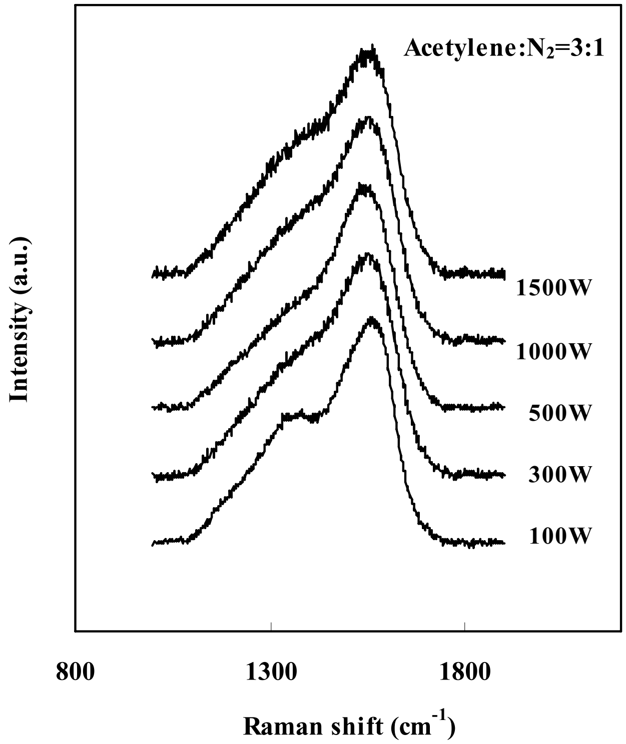


**Fig. 4** Change of Raman spectra of amorphous carbon nitride films

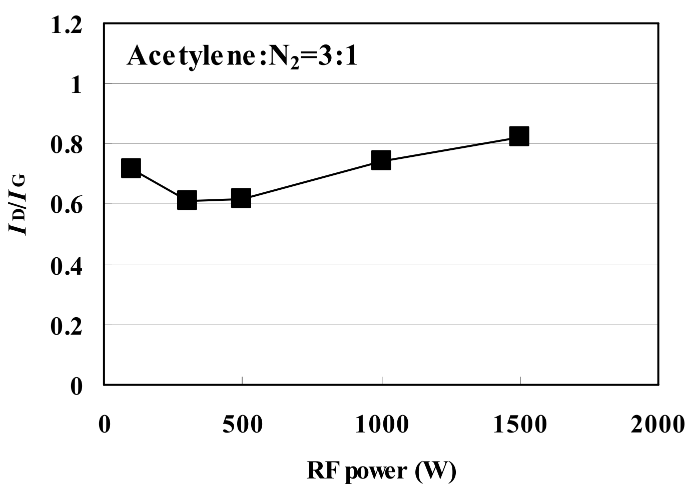


**Fig. 5** Dependence of $I_D/I_G$ on RF power

increased with RF power. From RBS/ERDA measurements, the density of amorphous carbon nitride film increased from 1.6 to 1.8g/cm$^3$ and the ratio of nitrogen to carbon in the films, or N/C linearly increased from 0.03 to 0.05 with the increasing of RF power. Fig. 6 shows the dependence of thermal conductivity on RF power. Thermal conductivity reached the maximum at the RF power of 500W. Fig. 7 shows the dependence of hardness on RF power.

Hardness reached maximum around 500W. These maxima corresponds to the minimum of $I_D/I_G$. From the paper of Ferrari, $I_D/I_G$ increases with the grain size of graphite in the amorphous carbon film, or $I_D/I_G = cLa^2$ and $La$ can be calculated as approximately 1nm at the RF power of 500W smaller than 1.3nm at the RF power of 1500W. This difference in $La$ is likely to illustrate the maximum of thermal conductivity at 500W. Fig. 8 shows the relation between thermal conductivity and hardness. Approximately, thermal conductivity increases with hardness. With the highest hardness samples with different thermal conductivity, tribological measurements were carried out. The results of the tribological measurements and discussions will be presented in the conference.

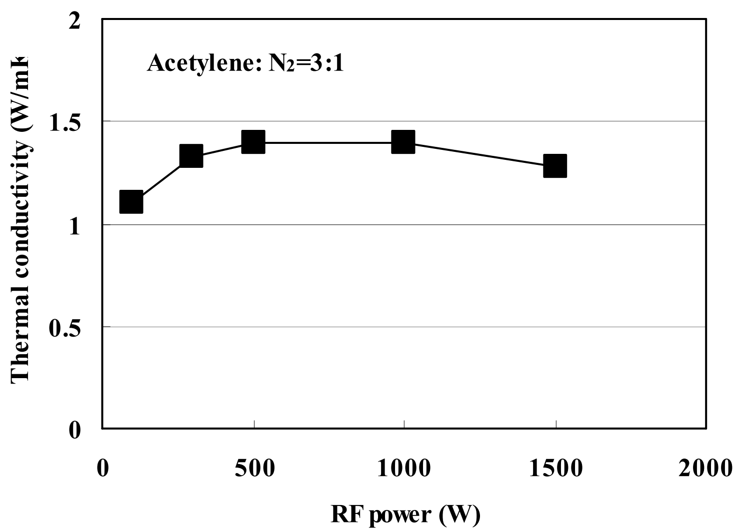


**Fig. 6** Dependence of thermal conductivity on RF power

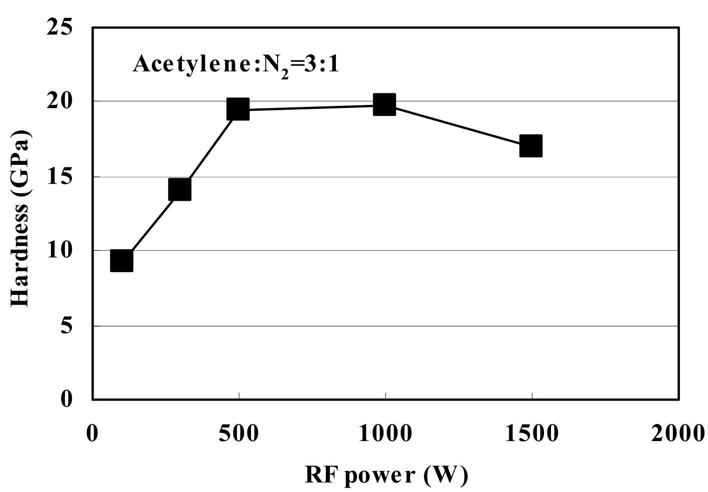


**Fig. 7** Dependence of hardness on RF power

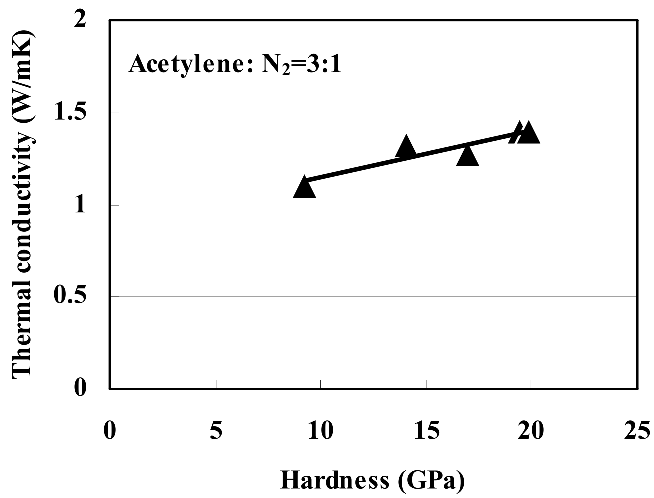


**Fig. 8** Dependence of thermal conductivity on hardness

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