PREPARATION OF AMORPHOUS CARBON NITRIDE FILMS AND DLC FILMS BY SHIELDED ARC ION PLATING AND THEIR TRIBOLOGICAL PROPERTIES

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Many researchers are interested in the synthesis and characterization of carbon nitride and diamond-like carbon (DLC) because they show excellent mechanical properties such as low friction and high wear resistance and excellent electrical properties such as controllable electical resistivity and good field electron emission. We have deposited amorphous carbon nitride (a-C:N) thin films and DLC thin films by shielded arc ion plating (SAIP) and evaluated the structural and tribological properties. The application of appropriate negative bias on substrates is effective to increase the film hardness and wear resistance.

This paper reports on the deposition and tribological properties of the a-C:N and DLC films in relation to the substrate bias voltage (Vs). The properties of the a-C:N films are compared with those of the DLC films.

A high purity sintered graphite target was mounted on a cathode as a carbon source. Nitrogen or argon was introduced into a deposition chamber through each mass flow controller. After the initiation of an arc plasma at 60 A and 1 Pa, the target surface was heated and evaporated by the plasma. Carbon atoms and clusters evaporated from the target were ionized partially and reacted with activated nitrogen species, and a carbon nitride film was deposited onto a Si (100) substrate when we used nitrogen as a reactant gas. The surface of the growing film also reacted with activated nitrogen species. Carbon macroparticles (0.1 -100 maicro-m) evaporated from the target at the same time were not ionized and did not react fully with nitrogen species. These macroparticles interfered with the formation of the carbon nitride film. Therefore we set a shielding plate made of stainless steel between the target and the substrate to trap the macroparticles. This shielding method is very effective to prepare smooth a-C:N films. We, therefore, call this method "shielded arc ion plating (SAIP)". For the deposition of DLC films we used argon instead of nitrogen.

Films of about 150 nm in thickness were deposited onto Si substrates. Their structures, chemical compositions and chemical bonding states were analyzed by using X-ray diffraction, Raman spectroscopy, X-ray photoelectron spectroscopy and infrared spectroscopy. Hardness of the films was measured with a nanointender interfaced with an atomic force microscope (AFM). A Berkovich-type diamond tip whose radius was less than 100 nm was used for the measurement. A force-displacement curve of each film was measured at a peak load force of 250 maicro-N. Load, hold and unload times for each indentation were 2.5, 0 and 2.5 s, respectively. Hardness of each film was determined from five force-displacement curves. Wear resistance of the films was analyzed as follows. First, each film surface was scanned with the diamond tip at a constant load force of 20 maicro-N. The tip scanning was repeated 30 times in a 1 um-square region with 512 lines at a scanning rate of 2 um/s. After this tip-scanning, the film surface was observed in the AFM mode at a constant force of 5 maicro-N with the same Berkovich-type tip.

The hardness of a-C:N films was less dependent on Vs. The hardness of the film deposited at Vs=0 V in a nitrogen plasma was about 10 GPa and almost similar to that of Si. It slightly increased to 12 - 15 GPa when a bias voltage of -100 - -500 V was applied to the substrate with showing its maximum at Vs=-300 V. The film deposited at Vs=0 V was least wear resistant which was consistent with its lowest hardness. The biased films became more wear resistant. Particularly the film deposited at Vs=-300 V showed remarkable wear resistance. Its wear depth was too shallow to be measured with AFM. On the other hand, the DLC film, deposited at Vs=-100 V in an argon plasma, whose hardness was 35 GPa was obviously worn under the same wear test conditions. The a-C:N films show higher wear resistance than DLC films and are useful for wear resistant coatings on various mechanical and electronic parts.