Application of Ultrananocrystalline Diamond/Nonhydrogenated amorphous Carbon Composite Films to Hard Coating on Cemented Carbide

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Hard amorphous carbon, so-called diamond-like carbon, has attracted attention as a coating material alternative to diamond. In particular, nonhydrogenated amorphous carbon (a-C) films deposited by the filtered cathodic vacuum arc (FCVA) method and sputtering possess higher hardness than that of hydrogenated amorphous carbon (a-C:H) films prepared by CVD. Hard amorphous carbon films are deposited at low substrate temperatures, and a-C films can be deposited at lower substrate temperatures than a-C:H films prepared by CVD.

We have realized the formation of ultrananocrystalline diamond/nonhydrogenated amorphous carbon composite (UNCD/a-C) films by coaxial arc plasma deposition (CAPD). UNCD/a-C films comprise a large number of diamond grains with diameters less than 10 nm and an a-C matrix. CAPD is categorized as physical vapor deposition. The deposition of UNCD/a-C films by CAPD has the following distinctive features: i) hydrogen atmospheres are not necessarily required for the growth; ii) the growth of UNCD grains is possible at low substrate temperatures, even unheated substrates; and iii) the deposition rate is at least two orders of magnitude higher than that of CVD. In this study, the deposition of UNCD/a-C films by CAPD was carried out on unheated WC-Co substrates, and the possibility of the room temperature deposition of UNCD/a-C films by CAPD as the hard coating on WC-Co was experimentally investigated.

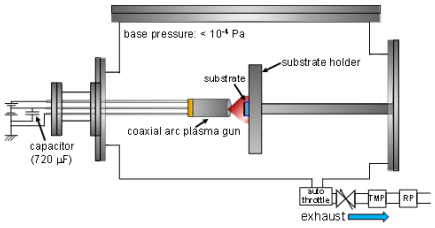

Fig. 1. Schematic diagram of CAPD apparatus.

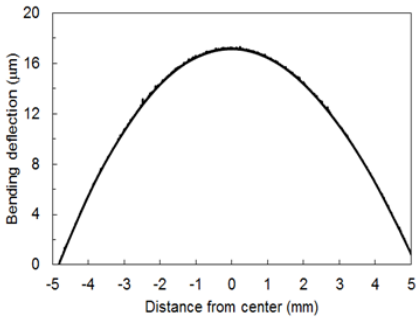

Fig. 2. Bending deflection curve of 134-nm UNCD/a-C film deposited on 260-μm Si (100) substrate at room temperature, measured along Si [110] by surface roughnessmeter.

UNCD/a-C films were deposited on cemented carbide containing Co by coaxial arc plasma deposition. With decreasing substrate temperature, the hardness were enhanced accompanied by an enhancement in the $sp^3/(sp^2 + sp^3)$. Energy dispersive X-ray and secondary ion mass spectrometry spectroscopic measurements exhibited that the diffusion of Co atoms from the substrates into the films hardly occurs. The film deposited at room temperature exhibited the maximum hardness of 51.3 GPa and Young's modulus of 520 GPa, which evidently indicates that graphitization induced by Co in the WC substrates and thermal deformation from sp^3 to sp^2 bonding are suppressed. The hard UNCD/a-C films can be deposited at a thickness of approximately 3 μm, which is an order larger than that of comparably hard a-C films. The internal compress-stress of the 51.3-GPa hardness film is 4.5 GPa, which is evidently smaller than that of comparably hard a-C films. This is a reason for the thick deposition. The presence of a large number of grain boundaries in the film, which is a structural specific to UNCD/a-C films, might play a role in releasing the internal stress of the films.

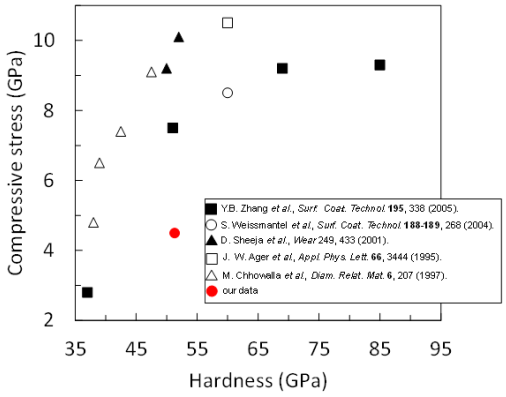

Fig. 3. Comparison in compressive internal stress between UNCD/a-C film deposited at room temperature and hard a-C films.