STRUCTURAL AND MECHANICAL PROPERTIES OF NANOSTRUCTURED AND AMORPHOUS SiC:H FILMS

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Hydrogenated amorphous silicon carbide (a-SiC:H) thin films are very attractive for a wide range of applications ranging from opto-electronic devices [1] to protective and wear resistant coatings [2]. Plasma-enhanced chemical vapor deposition (PECVD) is the most commonly used technique to synthesize a-SiC:H films. The hydrogen-free films have been shown to exhibit mechanical properties that are superior to those of their hydrogenated counterpart [3], but the investigations [2,4] have shown that a-SiC:H films possessing comparatively low nanohardness (H) and elastic modulus (E) (up to 10 GPa and 120 GPa, respectively) have good abrasive wear resistance and adherence, which makes them suitable for protective coatings.

This paper deals with the investigations of the tribological behavior of PECVD a-SiC:H films initiated in our previous work [4]. The films are deposited using methiltrichlorosilane (MTCS) as a precursor, and therefore, are cheaper than those prepared from the traditional silane-methane mixture. The substrate temperature (T_S) ranged from 200 to 600 ^{0}C, applied bias and H_2:MTCS+H_2 ratio were –200 V and 5, respectively. Total pressure was up to 1 Torr. The thin coatings (0.2-0.3 μm) were deposited during 50 min.

Film composition was examined with the help of an JAMP-10S Auger spectrometer (JEOL, Japan). The film thickness was measured using an Alpha-Step 200 microprofilometer (Tencor Instruments, USA) and a calowear tester (for preliminary evaluating film thickness). Structural analysis was carried out with a X-Ray difractometer DRON-2 (USSR). Sharp indentation experiments were performed on a Nano Indenter II^{TM} (MTS Systems Inc., Oak Ridge, USA). To estimate abrasive wear resistance, the thin films were tested with a calowear tester using a ball of hard steel rotating against a sample in the presence of diamond paste (0.1μm). The wear crater structure was analyzed with a Non-Contact High Resolution Profilometer "Micron-alpha" (Ukraine).

Auger analysis showed that thin films consisted of about 60, 35 and 5 at% of silicon carbon and oxygen, respectively. The trace of chlorine, up to 0.8 at% was also detected.

We have measured the X-ray diffraction spectra of the films deposited on the Si(100) substrate at 200, 390 and 600 ^{0}C. The spectra are shown in Fig. 1. In contrast to the diffraction picture of the sample prepared at 200 ^{0}C, in the spectra of the high temperature films, several weakly intensive peaks were detected in the range of 2θ from 30^0 to 42^0. Taking into account the infrared (not shown here) and X-ray diffraction spectra, we suppose that the low temperature films (T_S<300 ^{0}C) are amorphous, while the samples prepared at T_S> 300 ^{0}C have more complex structures that consist of the crystalline islets embedded in the amorphous tissue.

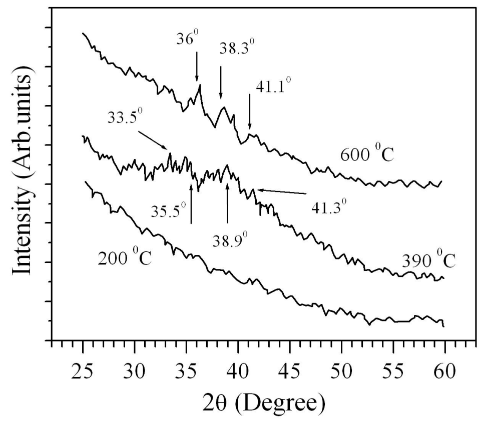

Fig. 1. X-Ray diffraction patterns for a-SiC:H samples.

Fig. 2 summarizes the effect of the deposition temperature on both the nanohardness and elastic modulus of the a-SiC:H films deposited on silicon substrate. One can clearly see that both the characteristics gradually increase around ~ 4 GPa (H) and ~ 60 GPa (E), when T_S rises from 200 to 250 ^{0}C, and then abruptly increase to values of ~ 19 GPa (H) and ~ 170 GPa (E), when T_S reaches 300-400 ^{0}C. Above T_S = 400 ^{0}C, the nanohardess and elastic modulus slightly increase with the deposition temperature. One can deduce from the X-Ray spectrum analysis that the threshold of the islet-like structure formation is 300-400 ^{0}C. On reaching these temperatures, the values of H and E increase in spurt, which is due to the formation of nanoparticles SiC.

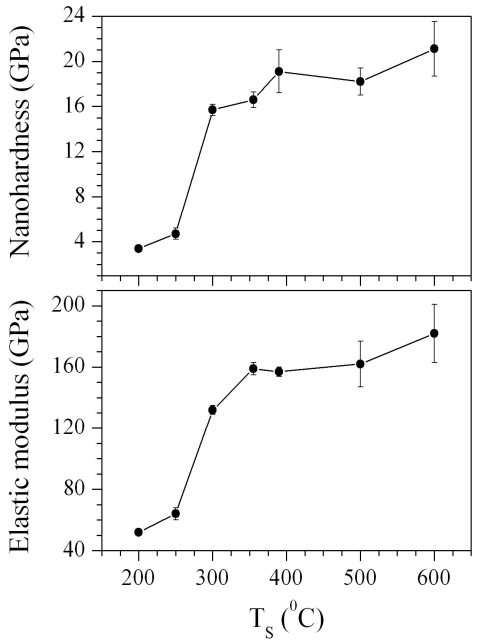

Fig. 2. Nanohardness and elastic modulus as functions of deposition temperature, T_S.

The coefficient of abrasive wear resistances, 1/k, of the films as a function of deposition temperature is shown in Fig. 3. As expected, the 400 ^{0}C film demonstrates the maximum resistance against abrasive wear. The high temperature coating shows higher wear than the films deposited at 200-400 ^{0}C. This means that the amorphous coatings with the small crystalline islets are more stable against abrasive wear.

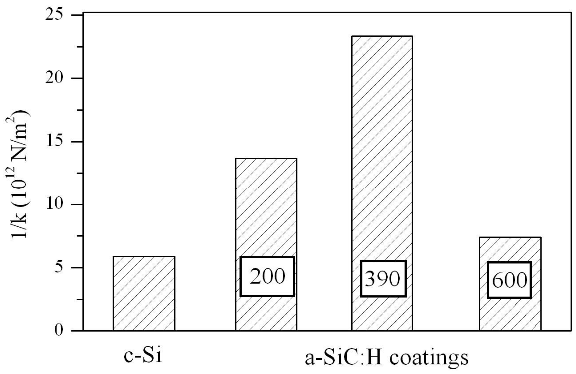

Fig. 3. Coefficients of abrasive wear resistance, 1/k, of c-Si substrate and a-SiC:H films.

Judging from the typical form of the wear craters shown in Fig. 4, one can say that the adhesion of all the films is good and it strengthens with deposition temperature. This finding is consistent with the results of the nanoindentations at high loads (L). The nanoindentation tests carried out at the indent depth higher than film thickness revealed that, for the 200 ^{0}C film, the film delamination occurred at L = 40 mN, while the high temperature films did not delaminate at L = 120 mN.

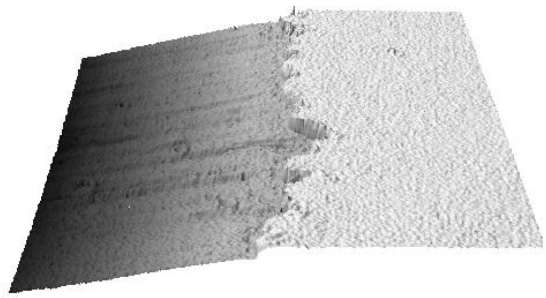

Fig. 4. "Micron-alpha" image of the wear crater zone.

In conclusion, we stress that the obtained results confirmed the conclusion that the wear resistance of a-SiC:H films does not always correlate with hardness and elastic modulus. The films with the islet-like structure, deposited at 300-400 ^{0}C, were found to be more stable against abrasive wear.

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References

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