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FRICTION CHARACTERISTICS OF R. F. MAGNETRON SPUTTERED C AND C:N THIN FILMS

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Carbon and C:N layers were prepared using the commercially available Leybold-Heraeus Z 550 radio frequency magnetron sputtering plant. A graphite target of high purity (99.999 % C) was used. The tribological testing was performed with a reciprocating ball-on-disc tribometer. The sliding distance on the coating was defined as the time at which a scoring occurs, and the friction coefficient exhibits an abrupt increase. From this, and from the known amplitude of the reciprocating ball, the sliding distance was evaluated.

1. Introduction

Carbon coatings turn out to be a superior layer for tribological protection. Potential applications for the tribological protection range from audio and video heads to surgical cutting instruments as well as to the devices for magnetic recording, such as rigid recording discs.

At present, these coatings are produced either by destruction of hydrocarbons [1] or directly from a beam of ionized carbon atoms [2]. The choice of technology and of deposition conditions depends on the material of the substrate and on the quality of the products.

In our opinion, the sputtering of carbon films seems to be promising, too. This paper reports on some successful depositions of carbon and C:N films using the method of radio-frequency magnetron sputtering.

2. Experimental details

Carbon layers were prepared using the commercially available Z 550 radio-frequency magnetron sputtering plant (Leybold-Heraeus) with three water cooled planar magnetron sources (type PK 150). A high purity material (99.9999%) was used as the carbon target of 152 mm in diameter and 6 mm thick. The sputtering of the C target was carried out in argon at a pressure of 0.22 Pa and in nitrogen at 0.2 Pa. 99.999% purity argon and nitrogen were used. The C layers were sputtered onto Si substrates, positioned on a stainless steel oven [3] at a distance of 51 mm from the target. Before the deposition, the substrates were annealed for 60 minutes at a temperature of 500 °C.

The C:N layer was sputtered at room temperature without annealing. In this case the Si substrates were plasma etched in argon for 2 minutes.

Tribological testings were performed with a reciprocating ball-on-disc tribometer [4]. A 5 mm 52 100 ball-bearing steel ball (hardness 750 kg mm^{-2} and surface roughness 3 nm) was oscillating on the specimen surface with an amplitude of 2 mm and a frequency of 1 Hz. The tribological tests were performed without applying any other lubricant at a static load 1N, in normal ambient conditions (35 % relative humidity). The friction force was continuously monitored and the data recorded in a personal computer, so a time dependent friction could be evaluated. The sliding distance of the coating was defined as the time at which scoring occurs and the friction coefficient exhibits an abrupt increase. From this and from the known amplitude of the reciprocating ball, the sliding distance was evaluated. Ion bombardment with nitrogen was performed using the Aarhus University 600 keV heavy ion accelerator at an energy of 400 keV, applying a dose of 10^{18} ions/cm^2.

3. Results

All measured C and C:N samples were sputtered on the Si substrates of 10 mm × 10 mm. The temperatures of the substrates were 195, 385, 450 and 535 °C for the C layers, and room temperature for the C:N layer. Figure 1 shows the time dependent friction coefficient for various substrate temperatures. The thickness of the layers was between 285 nm for the sample deposited at 195 °C, to 420 nm for the sample deposited at 535 °C.

Figure 2 is an example of the recording of the friction coefficient as a function of the sliding distance for carbon coatings bombarded with 10^{18} N_2^+ ions/cm^2.

Figure 3 shows the time dependent friction coefficient for C:N layer.

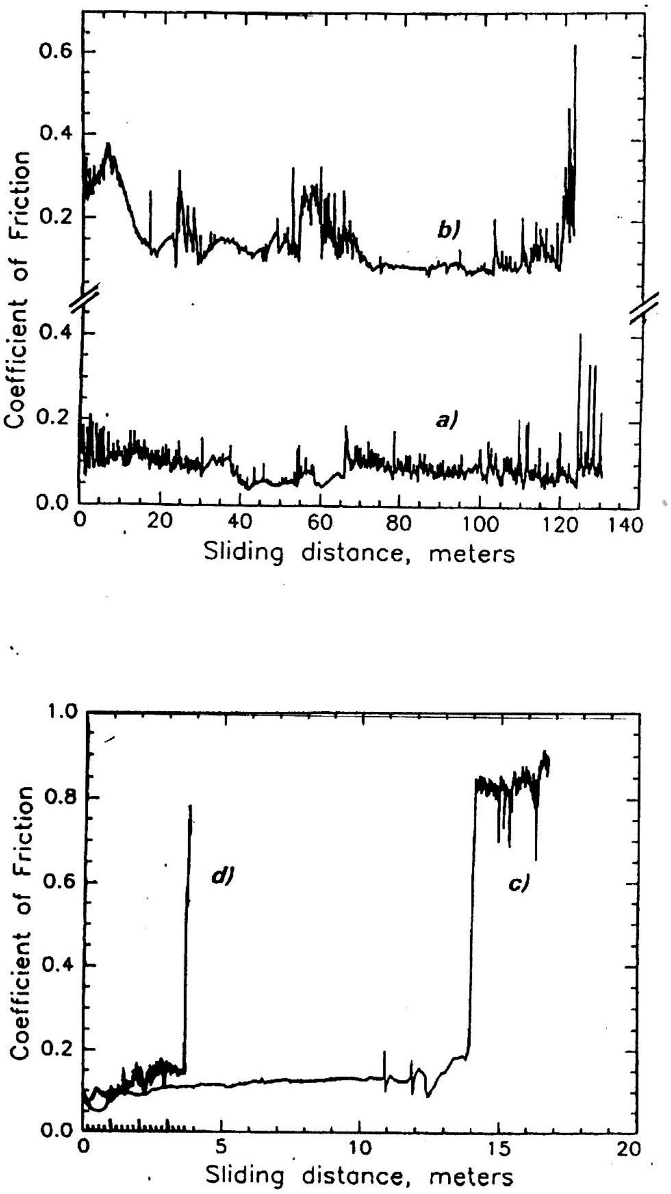

Fig. 1. Friction coefficient as a function of the sliding distance for substrate temperatures a) 195 °C *b) 385* °C, *c) 450* °C and *d) 535* °C.

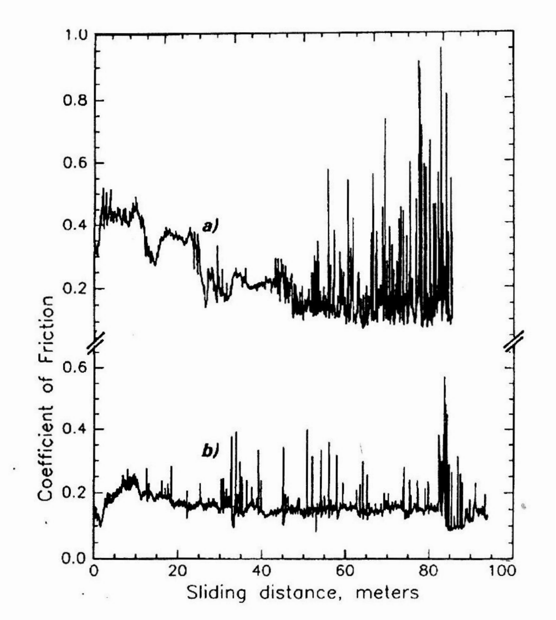

Fig. 2. Friction coefficient as a function of the sliding distance for carbon coatings bombarded with 10^{18} $N^{+}{}_{2}$ *ions* cm^2. *Substrate temperatures a) 195* °C *b) 535* °C.

4. *Discussion and conclusion*

The sliding distance on C layers is strongly dependent on deposition temperature of the substrate. The best results were achieved at lower temperatures (see Fig. 1). For higher temperatures, there is initially a slight increase in the friction coefficient, which remains below 0.15 during the reciprocating ball-on-disk test. The oscillatory dependence (Fig. 1) is assumed to be due to the transport of the lubricant. Using a dose of 10^{18} ions/cm^2 nitrogen ion bombardment of the carbon layers remarkably changes the tribological performance of the coating (Fig. 2). At a low deposition temperature (Fig. 1a) carbon coatings exhibit an increase of the friction coefficient from 0.1 to 0.4 and a decrease in the sliding distance. On the other hand, at high deposition temperatures the sliding distance remarkably increases.

The friction coefficient of the C:N layer (Fig. 3) is considerably higher than that of the C layers, as of the sample of the C layer deposited at a low temperature and then submitted to nitrogen ion bombardment using the heavy ion accelerator.

These preliminary results of the tribological performance of carbon coatings show that these coatings are excellent solid lubricants and that ion bombardment process did result in structural changes in the surface layers.

It would be interesting to carry out an ion-beam modification for lower ion doses, which may considerably improve carbon lubrication [5].

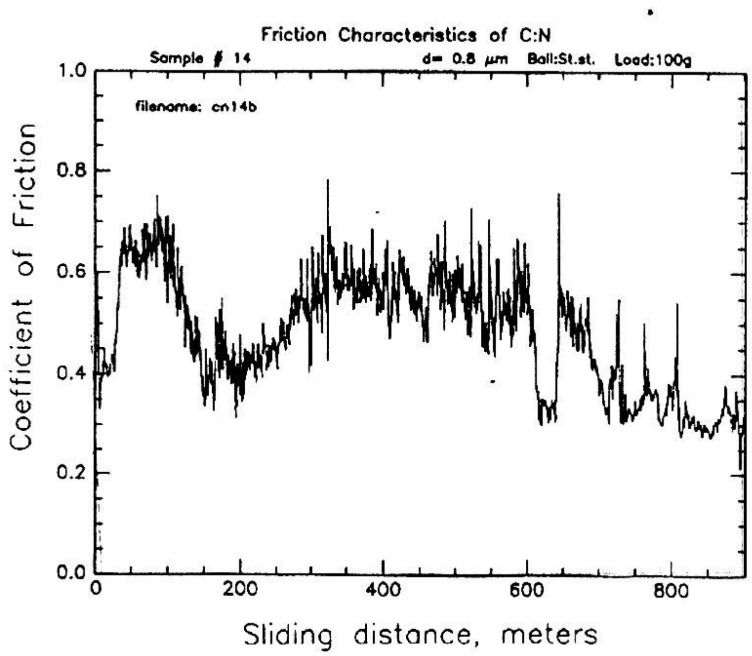

Fig. 3. Friction coefficient as a function of the sliding distance for C:N *deposited at room temperature.*

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References

1) P. K. Bachmann and D.U. Wiechert, Diamond Relat. Mater. **1** (1992) 422;
2) B. André, F. Rossi and H. Dunlop, Diamond Relat. Mater. **1** (1992) 307;
3) J. Sobota, J. Hrdina, V. Volíček, I. Gregora, P. Široký and V. Peřina, Proc. SPIE 2253 (1994) 208;
4) S. Lin, Carbon **3** (1993) 509;
5) B. K. Gupta, J. Jantin and G. Sorensen, Tribol Int. **27** (1994) 139.

ZNAČAJKE TRENJA C I C:N TANKIH SLOJEVA NAČINJENIH RF MAGNETRONSKIM RASPRAŠIVANJEM

Tanki slojevi C i C:N načinjeni su u standardnom sustavu za raspršivanje s RF magnetonom. Upotrebljavana je grafitna meta visoke (99.999 %) čistoće. Tribološka mjerenja načinjena su pomoću tribometra s kuglicom na disku. Klizni pomak na nanešenom sloju definira se preko trenutka kada nastane ogrebotina i faktor trenja naglo poraste.