Molibdenu legiruotų deimantų tipo anglies plėvelių mikrostruktūros ir nanotribologinių savybių tyrimas

Investigation of microstructure and nanotribological properties of molybdenum doped diamond-like carbon films

H. Zhairabany*[1], H. Khaksar[2], E. Vanags[3] , E. Gnecco[2], L. Marcinauskas[1]
[1] Kaunas University of Technology, Department of Physics, Studentų str. 50, Kaunas, Lithuania
[2] M. Smoluchowski Institute of Physics, Jagiellonian University, ul. Lojasiewicza 11, Krakow, Poland.
[3] Institute of Solid-State Physics, University of Latvia, Microscopy laboratory, Kengaraga Str 8. Riga, Latvia.
hassan.zhairabany@ktu.edu

Nowadays, by using metals such as Ag, Ti, Ni, Cr, and Ag, as well as non-metals elements Si, O, N, and F as alloying materials, it is possible to change and modify the structure and properties of diamond-like carbon (DLC) films. This has led to extensive studies on the formation of doped DLC coatings to expand the application areas of these films [1-3]. Some dopants have already demonstrated the possibility of enhancing desirable properties for the different types of DLC films and in different application areas, such as biological implants [1]. The doping of DLC films with molybdenum (Mo) has demonstrated its role in enhancing tribological and mechanical properties. It was found that the Mo-DLC films demonstrated a lower compressive stress, friction coefficient values, enhanced corrosion and wear resistance as well improved hardness and biocompatibility [4-6]. It should be noted that the bonding structure and final properties of the Mo-doped DLC films strongly depend on the molybdenum concentration in the film [5-6].

Molybdenum doped amorphous DLC films were deposited on Si (100) substrates by magnetron sputtering at fixed target-substrate distance (6 cm). The graphite and Mo targets were used. The graphite and the Mo targets currents were fixed at 1.5 A and 0.25 A respectively, while a slit opening on a shield mounted above the Mo target was changed to have gradually increased the Mo content embedded in the DLC films. The deposition duration was 600 s. The surface morphology, friction forces, elemental composition, structure, and hardness of the sputtered Mo-doped DLC films were investigated by atomic force microscopy (AFM), energy dispersive X-ray spectroscopy, Raman spectroscopy and nanoindenter.

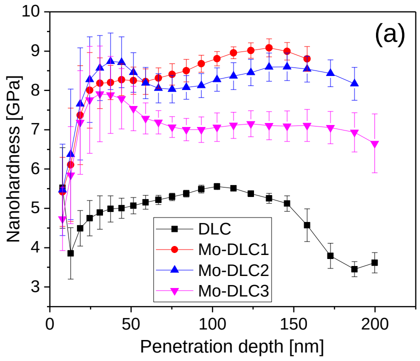

Figure 1: Average nano-hardness versus the indentation depth of DLC and Mo-DLC films.

It was obtained that the molybdenum doped diamond-like carbon films with a low concentration of oxygen were successfully deposited on a silicon substrate using direct current magnetron sputtering. The amount of molybdenum increased from 1.1 at.% to 6.2 at.%. The highest oxygen concentration was found in the Mo-DLC film with the highest molybdenum concentration. Surface roughness values decreased with the addition of a low amount up to 2.5 at.% of Mo in the films. Raman spectroscopy measurements showed that the sp^2/sp^3 ratio increased and a slight graphitization of the films was promoted with the increase in Mo concentration. DLC film without the molybdenum had the lowest nano-hardness and Youngs modulus values (Fig.1). The addition of the Mo enhanced the hardness of the Mo-DLC films. It was found that the highest nano-hardness and elastic modulus were obtained when the Mo concentration in the film was 2.5 at.% (Fig.1).

The nano-tribological measurements demonstrated that the friction coefficient of the DLC film was 1.16. The addition of Mo reduced the friction coefficient of DLC films. The friction coefficient of the Mo-DLC films varied from 0.86 to 0.97. This research has shown that doping DLC films with molybdenum is an effective way to enhance the nano-hardness, reduce surface roughness and friction coefficient, and control the fraction of sp^2 and sp^3 bonds in the amorphous carbon films.

Keywords: Mo-doped diamond-like carbon, microstructure, friction coefficient, nano-hardness.

Literature

[1] C. A. Love, R. B. Cook, T. J. Harvey, P. A. Dearnley, and R. J. K. Wood, Tribol Int, vol. 63, pp. 141–150, Jul. 2013, doi: 10.1016/j.triboint.2012.09.006.

[2] J. Jiang, J. Hao, X. Pang, P. Wang, and W. Liu. Diam Relat Mater, vol. 19, no. 10, pp. 1172–1177, Oct. 2010, doi: 10.1016/j.diamond.2010.05.005.

[3] M. Evaristo, R. Azevedo, C. Palacio, and A. Cavaleiro, . Diam Relat Mater, vol. 70, pp. 201–210, Nov. 2016, doi: 10.1016/j.diamond.2016.10.024.

[4] D. B. Padmanaban, L. Mohan, P. Giri, P. Bera, C. Anandan, and H. C. Barshilia. C (Basel), vol. 7, no. 1, p. 1, Dec. 2020, doi: 10.3390/c7010001.

[5] Y. Su, X. Gong, W. Huang, T. Zhang, R. Hu, P. Zhang, H. Ruan, Y. Ma, Diamond and Related Materials, vol 135, 2023, 109795, ISSN 0925-9635. https://doi.org/10.1016/j.diamond.2023.109795.

[6] Y. Su, W. Huang, L. Cai, X. Gong, T. Zhang, R. Hu, P. Zhang, H. Ruan, Tribology International, vol 174, 2022, 107774, ISSN 0301-679X, https://doi.org/10.1016/j.triboint.2022.107774.