Expansion of laser plasma in hydrogen sulfide and formation of thin-film a-C (S, H) coatings with high-quality antifriction properties

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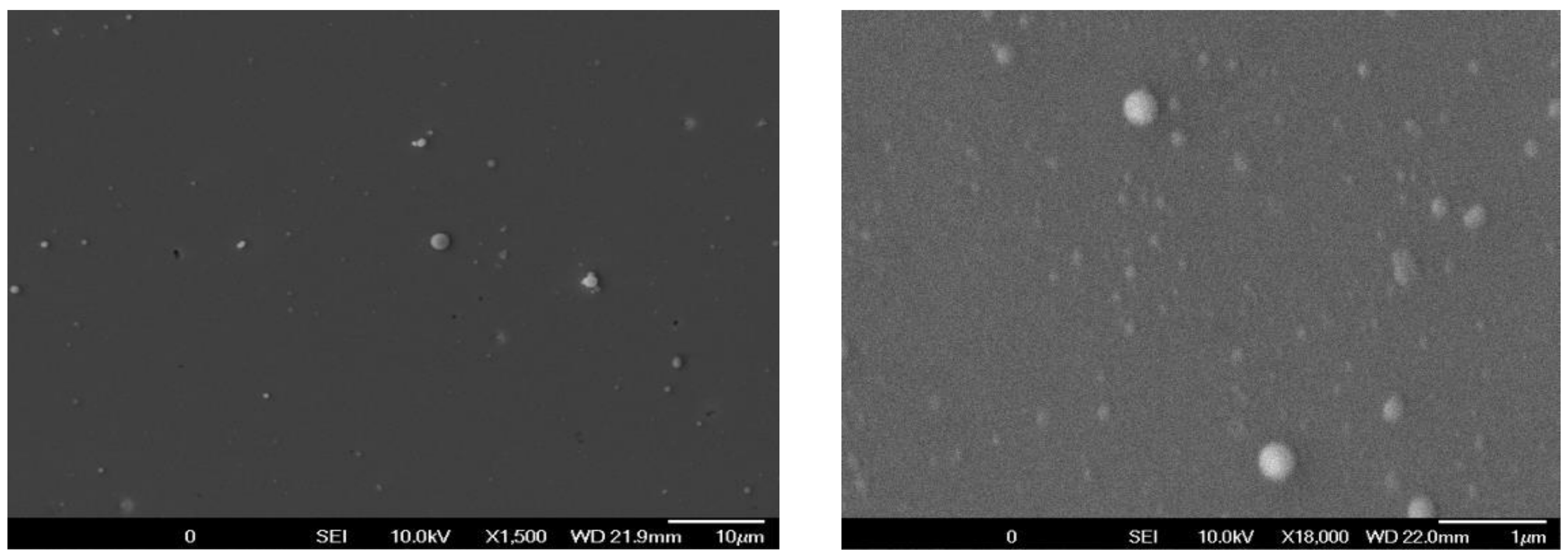
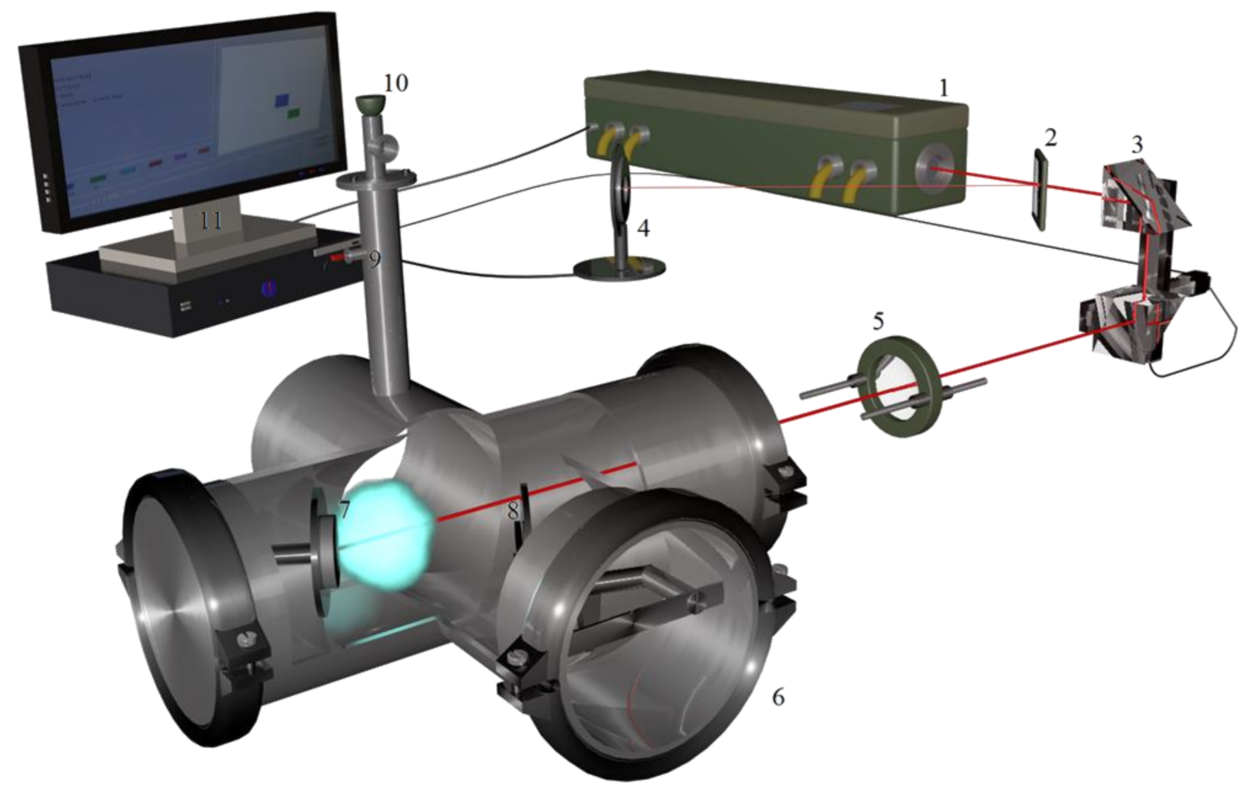
The effect of reactive pulsed laser deposition of carbon on the tribological properties of the surface of steel materials was investigated. The influence of H_2S pressure on the chemical state and composition of a-C(S,H) film was investigated. For the optimal pressure, the obtained coatings have high wear resistance and low coefficient of friction.

To obtain coatings a-C (S, H) by the method of reactive pulsed laser deposition (RPLD), pulsed laser ablation of a graphite target was carried out using laser radiation, Nd: YAG with a wavelength of 1064 nm. To obtain thin-film coatings, the standard RPLD configuration was used. Typical electron microscopic images of the formed coating, which shows a smooth surface and high density are presented.

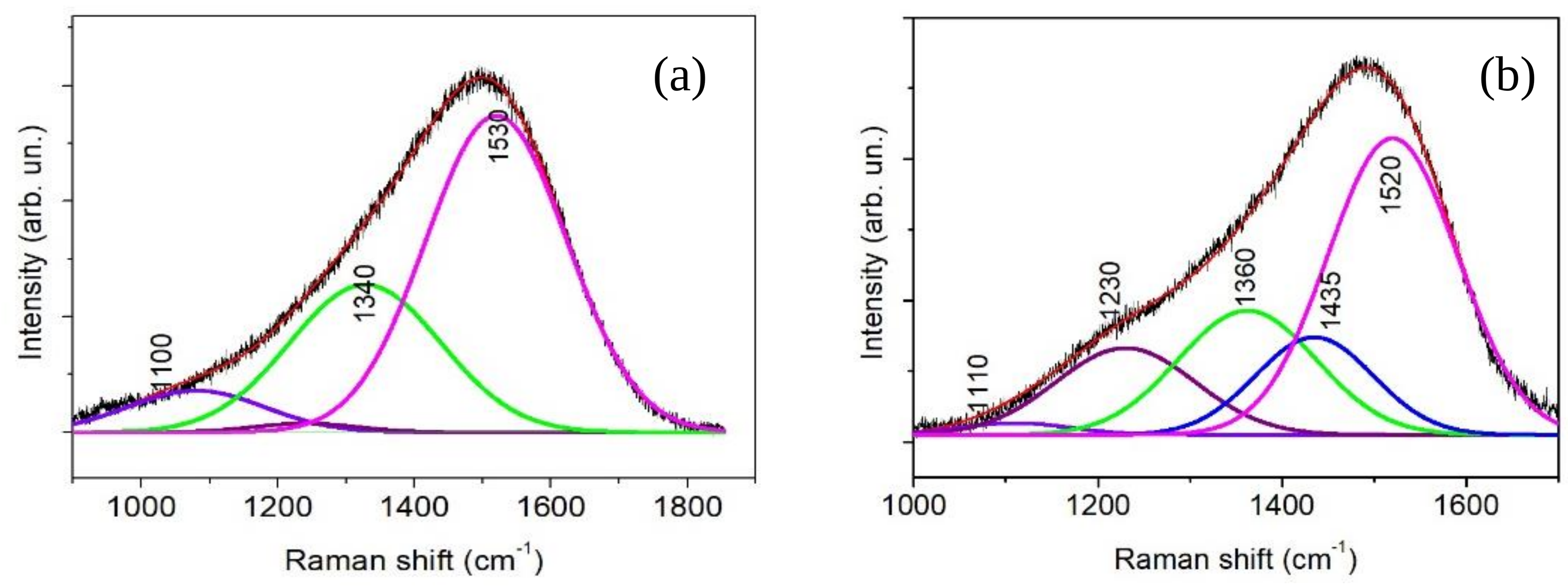
The study of the microstructure and elemental composition of the surface of the samples was carried out using an EVO 50 XVP scanning electron microscope manufactured by CarlZeiss (Germany). SEM image was obtained in secondary and backscattered electrons



Typical micro-images (at two magnifications) of the surface of a-C (S, H) film obtained on a steel substrate by the RPLD method in H_2S.



Experimental installation for pulsed laser deposition (PLD) of thin film coatings: 1 - laser; 2 - mirror; 3 – scanning system; 4 – laser power meter; 5 – focusing system; 6 – vacuum chamber; 7 - target; 8 - substrate; 9 – vacuum gauge; 10 – gas inlet; 11 - PC



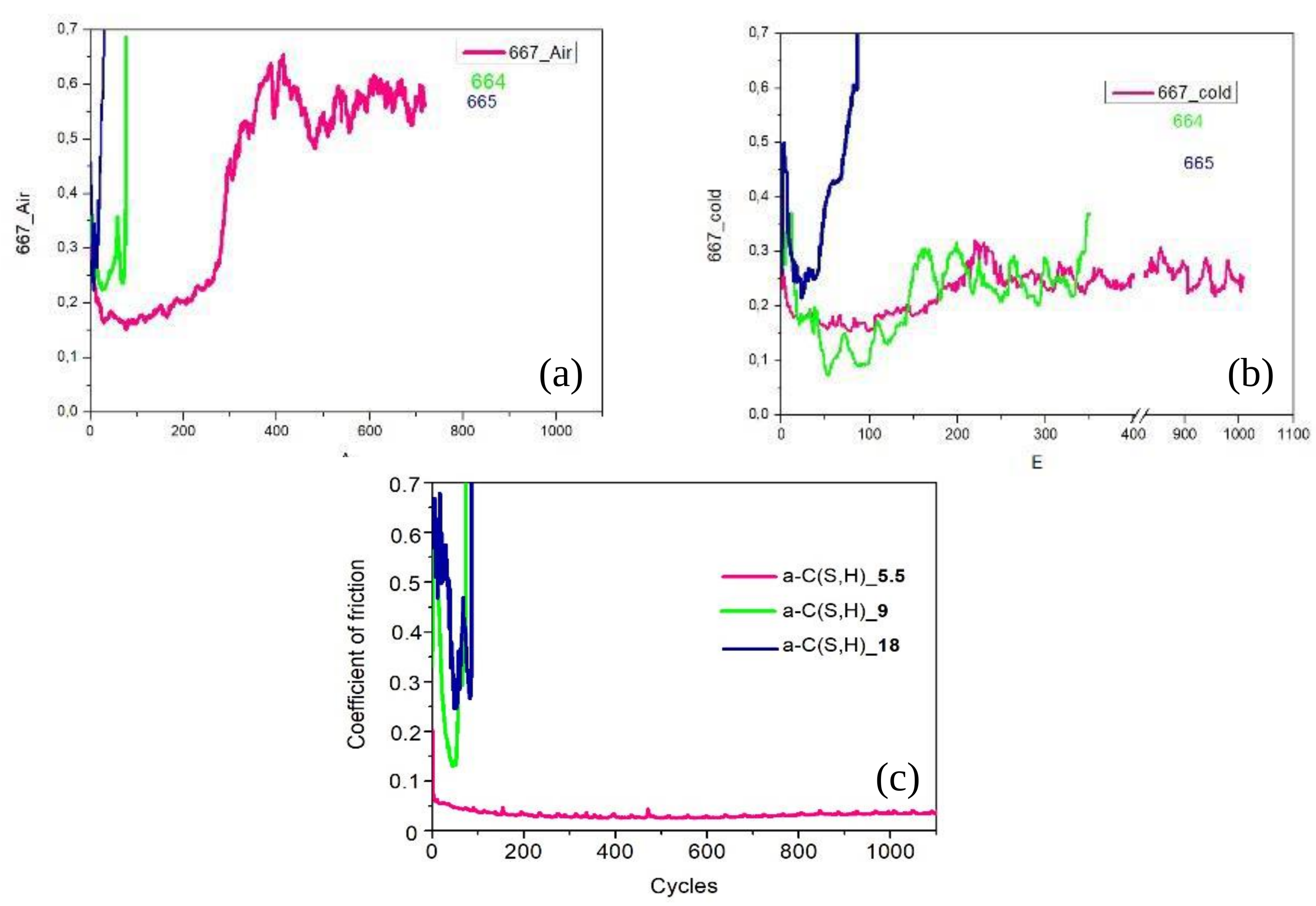
MR spectra for (a) a-C (H) and (b) a-C (S, H) coatings obtained by the RPLD method on silicon substrates in vacuum (a) and reactive H_2S gas at a pressure of 5.5 Pa

Polished discs made of stainless steel 95X18 and polished silicon plates were used as substrates for the deposition of thin-film coatings. The deposition chamber was evacuated to a pressure of 10^{-2} Pa, and then hydrogen sulfide was introduced into the deposition chamber. The deposition of the films was carried out at three different pressures of the H_2S gas. It was found that upon ablation of the target C in hydrogen sulfide, the deposited a-C (S, H) layer effectively captures the S and H atoms. The introduction of these atoms has an important effect on the chemical state and tribological properties of the coatings.

The composition of the coatings was investigated by the method of elastic ion scattering. H_2S had a significant effect on the rate of carbon deposition. At a pressure of 18 Pa, the rate of carbon deposition dropped almost 5 times compared to the rate of deposition under vacuum conditions. When colliding with H_2S molecules, carbon atoms are scattered at large angles and leave the region where deposition on the substrate took place. Also, the possibility of reaction collisions of carbon ions with H_2S molecules cannot be ruled out. The result of these collisions could be the formation of volatile hydrocarbon molecules. It is possible that this very phenomenon is responsible for such an important fact that the rate of saturation of the films with hydrogen practically did not change with an increase in the pressure of hydrogen sulfide.

Structural studies by micro-Raman spectroscopy showed that with increasing H_2S pressure, i.e. With an increase in the concentration of sulfur and hydrogen in a-C (S, H) films, the contribution to the Raman spectra of two peaks at frequencies of ~ 1220 cm^{-1} and ~ 1440 cm^{-1} increased. In this case, the intensity of these peaks in films with the highest S concentration even exceeded the intensity of D (at ~ 1340 cm^{-1}) and G (at ~ 1530 cm^{-1}) peaks characteristic of pure a-C films. In this case, with an increase in the sulfur concentration, the I_D / I_G ratio increased, which indicated an increase in the disordering (defectiveness) of atomic packing in graphite clusters. The Raman spectra for a-C (H) and a-C (S, H) coatings are presented.

Tribotests were carried out using the method of back-and-forth sliding of a ball on a disk. The best antifriction properties were possessed by the a-C (S, H) coating obtained by RPLD from an H_2S pressure of 5.5 Pa in the case of tribotesting under dry friction conditions. The composition of the coating was described by the formula $C_{0.65}S_{0.21}H_{0.14}$. The friction coefficient did not exceed 0.03 during 10^3 sliding cycles of the ball, which is presented. At the same time, the surface of the coating a-C (S, H) underwent slight wear, and the wear area on the surface of the steel counterbody was just incipient.



Characteristic evolution of the friction coefficient as a function of the cycle number for a-C(S,H) thin-film coatings obtained by reactive PLD at the pressures of H_2S gas of 5.5, 9 and 18 Pa. Pin-on-disk tribometer testing was conducted in wet air (RH ~58%) at 22 ℃ (a); in dry friction conditions (air+Ar mixture, RH ~8%) at 22 ℃ (b); in dry friction conditions at -100℃ (c)

Conclusion

Investigations showed that upon ablation of the target C in hydrogen sulfide, the deposited a-C (S, H) layer effectively captures the S and H atoms. The introduction of these atoms has an important effect on the chemical state and tribological properties of the coatings. The best antifriction properties were possessed by the a-C (S, H) coating described by the formula $C_{0.65}S_{0.21}H_{0.14}$. The surface of the coating a-C (S, H) underwent slight wear, and the wear area on the surface of the steel counterbody was just incipient.