MEASURING THE plasma destruction rate for THERMAL-RESISTANT MATERIALS

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Using the means of spectral diagnostics and high-speed visualization, the study of spatial and temporal changes in temperatures (electron, vibrational and rotational) and the rate of material loss in the area of the nitrogen plasma jet damaging interaction with the surface of isotropic and pyrolytic graphites was performed. With a prolonged exposure of a nitrogen plasma jet
(T∞ ≈ 9000 K) on to the graphites, which provides heating of samples to a temperature of
3000 ÷ 3500 K in the stagnation zone, using the methods of two-position high-speed visualization and the laser knife method the isotropic and pyrolytic graphite mass loss was studied.
At the quasi-stationary stage of sample heating, a quantitative relation was established between the spectroscopically determined concentration of atomic carbon — the main product of the destruction of graphite, and the measurements of its mass loss rate: [C] ≈ (1 ÷ 2)·1015cm–3; ≈ 5·10–3 g/cm2s.

The experimental complex created at JIHT RAS [1] provides the means to obtain and study the plasma of various gases (Ar, He, N2, air) and their mixtures in a wide range of temperatures
(T = 10–30 kK), mass flow rates of 0.2–5 g/s , speeds of 50–1000 m/s in the outlet section of plasma torches. Experimental estimation of the mass loss rate of the sample material in real time is carried out using two-stage high-speed video recording and the laser profilometry method developed by the authors using a “laser knife” [2]. The studies used cylindrically shaped isotropic graphite of the MPG-6 brand with a density of ρ ≈ 1.70–1.8 g/cm3 and anisotropic graphite UPV-1T with a density of ρ ≈ 2.1–2.2 g/cm3 in the shape of a parallelepiped with a characteristic thickness of 3–5 mm and 15–25 mm sides. Using the “laser knife” method, as a result of video surveillance, the dynamics of crater growth on the ablating side of a graphite sample was investigated.

The effect of a nitrogen plasma jet (arc current 150 A, burning voltage 110 V, gas flow rate 1.5 g/s, diameter of the plasma torch output nozzle 6 mm) on a “NIIGRAFIT” pyrolytic graphite sample of 12 x 18 x 3 mm was also investigated. At specific heat loads of 1–2 kW/cm2, spatial-temporal changes in the sample material loss rate (3 ÷ 20 mg/cm2s), their surface temperatures (2000 ÷ 3500 K), and the electron temperature of the incoming plasma stream (12000 ÷ 6000 K), and plasma-chemical composition in the region of "blow in" of destruction products were all experimentally established. The joint analysis of spatial and temporal changes in the concentration of the main products of destruction - carbon atoms and CN radical and the rate of loss of the carbon-containing sample material allows us to establish the relative role of the processes of heterogeneous (Csolid + N → CN) and homogeneous (Cgas + N + M → CN + M) carbon nitrization in the interaction zone.

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References

1. V.F. Chinnov, A.S. Tyuftyaev, D.I. Kavyrshin, A.G. Ageev, M.A. Sargsyan and M.Kh. Gadzhiev Comprehensive Study of the Effect of Plasma Stream on Heat-Resistant Materials // High Temp (2018) https://doi.org/10.1134/S0018151X18010224
2. A.G. Ageev, D.I. Kavyrshin, M.A. Sargsyan, M.Kh. Gadzhiev, V.F. Chinnov Determination of graphite sublimation rate in high enthalpy plasma flow using ‘laser knife’ method // International Journal of Heat and Mass Transfer 107 (2017) 146–153.