42. V. K. Goncharov, V. I. Karaban', A. V. Kolesnik, et al., Zh. Prikl. Spektrosk., **51**, No. 1, 16-22 (1989).
43. G. G. Vilenskaya and I. V. Nemchinov, Zh. Prikl. Mekh. Tekh. Fiz., No. 6, 3-19 (1969).
44. G. G. Vilenskaya and I. V. Nemchinov, Dokl. Akad. Nauk SSSR, **186**, 1048-1051 (1969).

# PHYSICAL ESSENCE OF EROSIONAL PLASMA FORMATION AND THE FORMATION OF PLASMA FLOWS BY THE ACTION OF DIFFERENT TYPES OF HIGH-ENERGY SOURCES ON ABSORBING CONDENSED MEDIA

**L. Ya. Min'ko**

UDC 539.95

*A study is made of erosional plasma processes occurring with the exposure of metals to a laser beam, a plasma, and a combination of the two. It is found that the ionization of the initially heated vapors is of a thermal nature, whether an erosional plasma is formed by an impulsive electrical discharge or a near-surface optical discharge.*

Different types of energy sources – electrical discharges, plasma discharges, laser beams, and beams of electrons and ions – are used to obtain low-temperature plasmas. Practical applications of these energy sources for the welding, cutting, and heat treatment of materials shows that the physical processes involved in the high-energy loading of materials have much in common with one another. This commonality is based foremost on the similarity of the thermophysical processes that take place when absorbing condensed media are acted upon by different types of high-energy sources within the power-density range $10^5$-$10^7$ W/cm$^2$. Evidence of this comes from the effective use of classical thermophysical representations [1] in descriptions of the above-mentioned manufacturing processes [2]. The subsequent refinement of these concepts for the high-energy loading of materials by different types of sources led to the discovery of a universal mechanism entailing oscillation of the surface temperature of the material [3]. When high-energy sources with a power density $10^3$-$10^7$ W/cm$^2$ which remains constant over time act on the interface between the gaseous medium and the material, a heat flux which is variable over time may be created in the material. This heat flux is due to the screening of the material from the energy associated with near-surface gases or plasma by the flow of atoms (in the case of vaporization of the material) or electrons (in the case of thermionic emission) from the material's surface. The conclusion that the mechanism of oscillation of the surface temperature of the material and the density of the near-surface gas or plasma medium is universal is based on the following fact. For high-intensity loading involving different sources and different materials, there are certain vaporization or thermionic emission regimes which are governed by the same gasdynamic or plasmodynamic laws and in which the gas or plasma medium that is formed has the same surface-screening effect. This effect amounts to a reduction in the energy flux reaching the surface of the material. The above-described oscillation mechanism can, in conjunction with stability theory and the theory of nonlinear oscillations, be used to explain a large number of empirical phenomena that were previously not fully understood. These phenomena include pulsative vaporization, periodic explosive vaporization, and fusion and vaporization instability. The mechanism can also help explain the pulsating, nonmontonic time dependences of the physical quantities that characterize the loading process.

Detailed studies have been made of erosional plasma processes in the treatment of metals by laser beams, plasmas, and combinations of the two. Previous representations on the characteristics that plasma formation by the optico- and electroerosive mechanisms have in common [4] have been refined by using analogies between the physical processes which take place during electrical discharges and laser irradiation [5]. It was shown that erosional plasma formation in an impulsive electric discharge is

Institute of Physics, Academy of Sciences of Belarus, Minsk. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 62, No. 5, pp. 685-686, May, 1992. Original article submitted December 16, 1991.

of the same nature as erosional plasma formation in a near-surface optical discharge, i.e. the ionization of the initially heated vapors is thermal in character in each case. Drawing an analogy with impulsive electrical discharges, researchers have developed representations not only on the action of relatively long ($10^{-3}$-$10^{-5}$ sec) pulses of laser radiation on solids (with the formation of an erosional plasma), but also on the effects of self-generating impulsive optical surface discharges [6, 7]. A great deal of attention has been given to vaporization and initial plasma formation in the case of the action of a laser beam on absorbing condensed media with broadly varying pulse durations and radiation wavelengths. It has been established that the generation of the plasma in the laser irradiation of metals at moderate levels of intensity is of a nonuniformly local, erosional character for a broad range of wavelengths ($\lambda$ = 0.248-10.6 $\mu$m) and pulse durations [8].

The large amount of empirical data accumulated on the properties of near-surface plasma structures under different high-energy loading conditions makes it possible to conclude that the origin of an erosional plasma is thermal in nature. In many cases involving high-energy loading, the plasma initiates a discharge and, in some instances, it is the decisive factor in sustaining the discharge (quasisteady optical and electrical erosional discharges). It has been determined that the thermal radiation of the plasma has an important role in sustaining both electrical and optical discharges.

Electrical and optical erosional plasma flows are also characterized by similar plasmodynamic processes, i.e. similar laws govern the formation and development of the plasma flow in these two cases. Studies have been made of the degree to which near-surface plasmas are structured as a result of supersonic discharge of the plasma under conditions of underexpansion and discrete inflow of the plasma-forming substance. The latter is manifest is the discontinuous nature of photographic scans of plasma flows. The findings in [5, 9] also show similarities in the origin of the structure in electrical and optical erosional plasma flows. Here, particular attention was given to vortex generation in optico- and electroerosional near-surface plasma structures. A special effort was made to draw analogies between the two cases in regard to the origination and manifestation of turbulence.

## LITERATURE CITED


1. N. N. Rykalin, Calculations of Thermal Processes in Welding [in Russian], Moscow (1961).
2. N. N. Rykalin, A. A. Uglov, and A. N. Kokora, Laser and Electron-Beam Treatment of Materials (Handbook) [in Russian], Moscow (1985).
3. A. A. Uglov and S. V. Selishchev, Oscillatory Processes in the Action of Condensed Energy Flows [in Russian], Moscow (1987).
4. L. Ya. Min'ko, Transactions of a Conference on Electrode Phenomena in Gas Discharges. Bucharest, **1974**, No. 5, 15.
5. L. I. Grechikhin and L. Ya. Min'ko, Zh. Tekh. Fiz., **37**, 1169-1172 (1967).
6. V. K. Goncharov, A. N. Loparev, and L. Ya. Min'ko, Zh. Éksp. Teor. Fiz., **62**, No. 6, 447-449 (1972).
7. L. Ya. Min'ko, VII All-Union Conference on the Interaction of Light Radiation with Substances: Summary of Documents. Leningrad, 1988. pp. 10-11.
8. L. Ya. Min'ko and A. N. Chumakov, First All-Union Symposium on Radiative Plasmodynamics: Summary of Documents. Moscow, 1989. Part I. pp. 13-14.
9. B. B. Davydov and L. Ya. Min'ko, Inzh. Fiz. Zh., **21**, No. 2, 172-175 (1971).