THE ORDERING AND LONG DISTANCE EFFECTS AT THE DEFECTS' CREATION IN SILICON IRRADIATED WITH HIGH ENERGY HIDROGEN AND GELLIUM IONS

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Optical and structural properties of silicon single crystals irradiated with energy 6,8 MeV protons (F = (1 - 3)·10^{17} cm^{-2}) and 27,2 MeV alpha-particles (F = 1·10^{17} cm^{-2}) have been studied. As the path length of such ions are nearly the same than high defect concentrations are formed by ions with different masses and energies in small silicon thickness. Due to defects' interaction new conditions for defect creation are formed. At high protons' and alpha-particles' fluences (10^{17} cm^{-2}) defect "walls' are formed perpendicularly to the ion fluence. It testifies about defect ordering due to self-organization – the high dose effects. Defects' "walls" spreading behind braking region of ions in silicon is the long distance effect. The both discovered effects might be useful in order to create modern theory of high energy ion interaction with matter.

LAMINAR PLASMA JET AS AN INSTRUMENT TO TEST FIREPROOF COATINGS

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The laminar plasma jet generated by an arc plasmatron is described. The structure and temperature fields of the plasma flow near to exit of plasma nozzle are studied by means of optical and spectroscopic methods. Due to high stability, high temperature (up to 10000 K) and weak gas-dynamic pressure the laminar plasma jet can be effectively used to determine fireproof properties of coatings developed especially for the electrotechnical equipment subjected to an arc of short circuit.

Introduction

Considerable thermal pulses, originating in a short circuit arc, can destroy the walls of electrotechnical equipment followed by development of a fire. In large power networks the short circuit arc can result in heavy system crashes and failure of the expensive equipment (boards, assemblies, distribution boxes). Therefore fire and failure should be restricted within the closed compartment or assembly unit.

Covering of metal surfaces with thermally swelling coatings is one of the most efficient ways of short circuit arc (SCA) protection. Such coatings are usually applied to raise flame-resistance of metalworks when temperature-temporal parameters of a fire have low values (rate of temperature rise during first five minutes is equal to 100-110 K/minute). At the same time application of fireproof paints for SCA protection is problematic due to lack of data about their properties under action of a pulsing high-energy source.

To estimate the fireproof efficiency of materials manifold methods are used, including effect of gas burner flame, heated wire, arc discharge plasma radiation, and short circuit electric arc. It is obvious, that test conditions for fireproof coatings should be as much as possible close to real conditions. However application of short circuit arc for these purposes is expensive and requires complex equipment and high energy consumptions.

The present paper is aimed to application of the laminar plasma jet of an arc plasmatron to determine fireproof properties of coatings developed especially for the electrotechnical equipment subjected to an arc of short circuit.

Experiment

The principle of plasmatron operation is generation of electric arc plasma in a stream of inertial gas at atmospheric pressure at low rate in a wide range of currents. The 6 mm tungsten rod cathode shaped to a 60° cone with a plane area 1 mm in diameter was installed at a distance of about 1 gauge from the nozzle exit section. Nitrogen or argon was used as a plasma-forming gas. By means of varying of operating mode parameters (current intensity I = 200–500 A, voltage U = 12–40 V, working gas rate (nitrogen) R = 5–20 l/min., nozzle outlet diameter d = 6 mm) plasma formation stable in space and time have been obtained.

The maximum temperature of nitrogen plasma jet at 300 A at a distance of 0.15 mm from the nozzle exit is about 14000 K [1]. At 3 mm length from the jet axis the temperature goes down to ~ 7500 K. Variation of the discharge current from 300 to 400 A does not result in noticeable growth of plasma temperature.

It was shown that argon laminar plasma jet (current is near 200 A, gas flow rate is 5 to 20 liters per minute) is the most preferable to test fireproof coatings [2]. The plasma formation represents a high-intensity cone-shaped cathode jet (fig. 1). An erosionless operation mode of plasmatron nozzle is observed in this case. The shape of plasma jet in horizontal and vertical position is almost identical, so the convection plays a minor role in its formation.

According to spectroscopic study the plasma temperature near the nozzle exit exceeds 12000 K decreasing down to ~ 8000 K at a distance of 25 mm.
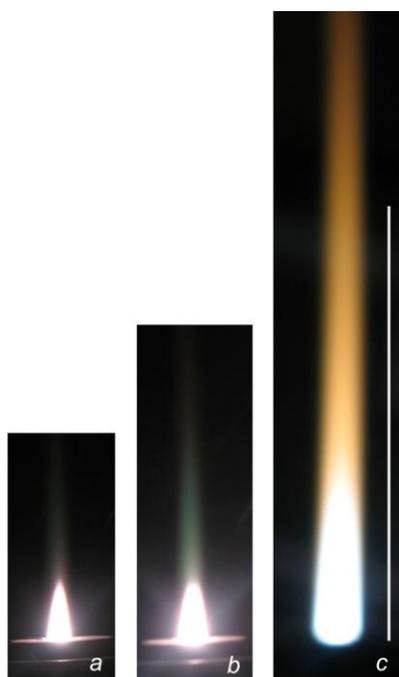

Fig. 1. Pictures of the laminar plasma jet at a current of 200 A and an argon flow rate of 10 l/min obtained at different exposures (a, b, c). The length of the scale risk is 100 mm

Thermal flux density from the plasma was estimated to be higher than 10^3 W/cm^2. The plasma jet velocity, determined by means of high-speed imaging, amounts to 5–20 m/s at a distance of ~ 10 mm from the nozzle exit while the plasma velocity near the cathode can reach of some hundreds meters per second [3]. Thus, stability of the laminar plasma jet, its high temperature and weak gas-dynamic pressure give a possibility of its use for test of fireproof coatings.

It was found that when increasing the plasma-forming gas rate the length of plasma jet decreases and the plasma temperature increases.

The tests of fireproof coatings were carried out at following parameters of the discharge: I = 200 A, U = 12 V, R_{Ar} = 14 l/min. Steel plates 0.3 mm in thickness with fireproof coatings of various composition and thickness were placed at a distance of 10 mm from the nozzle exit and were subjected to action of plasma jet. It was found previously that the initial plate without a coating is cut with plasma jet at velocity V_{max} = 16 mm/s.

The relative coefficient FP describing fireproof efficiency of coatings of investigated composition under the effect of laminar plasma jet of is calculated by formula:

$$FP = V_{max} / V_{im},$$

where V_{im} is the maximum velocity of coated plate movement when the plate is cut with plasma jet. It was found out that the coefficient FP is in the range

of 1.8 to 3.0. The tracks on various steel plates with fireproof coatings after effect of plasma jet are given in fig. 2.
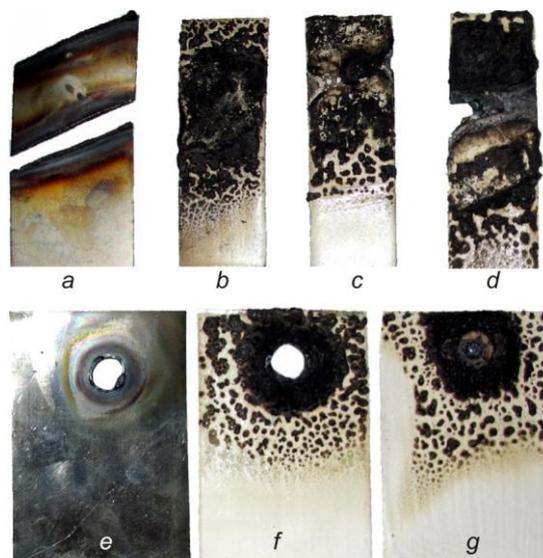

Fig. 2. The tracks of plasma jet effect on moving (*a, b, c, d*) and fixed (*e, f, g*) steel plates with (*b, c, d, f, g*) and without (*a, e*) fireproof coatings

The images *a*, *b*, *c* and *d* correspond to the movement speed of 16, 16, 9 and 6 mm/s respectively. Images *e*, *f*, and *g* correspond to the distances from the nozzle exit of 15, 10 and 15 mm respectively at plasma jet exposure time of 1 (*e*), 3 (*f*) and 4 (*g*) s.

Conclusion

The jet arc plasma generator with cathode installed at a distance of approximately one caliber from the nozzle exit allows generating plasma with a temperature of > 10000 K. Stability of the laminar plasma jet, its high temperature and feeble gas-dynamic pressure give a possibility of its use for test of fireproof coatings of the electrotechnical equipment. It was shown, that the developed coatings can be used effectively for the purpose of the equipment protection against fire spread in a case of short circuit arc origination.

References

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