

LONG LIFE ARC PLASMATRON

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Simplicity and reliability of the arc plasmatrons using cylindrical copper cathode and air as plasma forming gas predestine their application at heat and power engineering for plasma aided coal combustion [1]. Life time of these plasmatrons electrodes is critical and usually limited to 500 hours. Considered in this paper the long life direct current (DC) arc plasmatron has the cathode life significantly exceeded 500 hours. To ensure the electrodes long life the process of hydrocarbon gas dissociation in the electric arc discharge is used. In accordance to this method atoms and ions of carbon from near-electrode plasma deposit on the active surface of the electrodes and form electrode carbon condensate which operates as "actual" electrode [2]. To realize aforesaid the construction of electro arc generator of air plasma has been developed and tested. Fig.1 gives the photo of the plasmatron.



Fig.1. Long life DC arc plasmatron of 350 kW power

Propane/butane mixture is supplied to the zone of the arc conjunction to the copper water-cooled electrodes (cathode and anode). Linked with the arc in series, the magnetic coils guaranty stabilization of the discharge on the electrodes. Arisen from ionization positive carbon ions deposit onto the electrodes surface under the influence of near-cathode decline in potential and form coating of the electrode condensate. This coating is "actual" cathode, deterioration of which is compensated by the flow of carbon ions and atoms. The coating thickness depends mainly on ratio of the flows propane/butane and air and the arc current. The results of complex physicochemical investigation of phase, structure and element

compound of the material of carbon nanostructural coating which is generated from propane-butane mixture on the cathode of the plasmatron are the following.

Some measurements of the long life plasmatron work regimes are gathered in Table 1 [2]. In these experiments the plasma forming gas (air) consumption was 300 l/min. It is seen that when power of the plasmatron was in interval 76 – 132 kW and propane/butane flow in range of 0.4 – 0.7 l/min thermal efficiency of the plasmatron (η) reached 90 %. At that mass averaged temperature at the exit of the plasmatron (T) increased from 3500 to 5000 K.

Table 1. The results of the experiments.

N	I, A	U, V	P, kW	Q_{gas} , l/min	η	T, K
1	200	380	76	0.4	0.9	3500
2	300	360	108	0.4	0.89	4100
3	400	330	132	0.4	0.88	5000
4	300	360	108	0.7	0.89	4200
5	300	380	114	0.7	0.9	4500

Fig. 2 demonstrates photos of the cathode spots of the arc conjunction made during some experiments. Square of the cathode spots depends not only on the power of the plasmatron but also on propane/butane mixture flow. As it is seen area and intensity of the cathode spot is increased with increase of the arc power P (experiments 1-3) and propane/butane flow rate Q_{gas} (experiments 2 and 4).



Fig. 2. Cathode spots of the arc conjunction at different regimes (Table 1).

During the plasmatron operation a film of the cathode condensate is formed in accordance with the processes of propane/butane molecules dissociation and carbon atoms ionization. Arisen from ionization positive carbon ions deposit onto the cathode surface under the influence of near-cathode decline in potential and form the film of the electrode condensate. It was determined the following parameters of the films. The film consists of carbon of 96.74-98.47 mass %, hydrogen of 1.24-2.26 mass % and cuprum of 0.30-1 mass %. Interplanar spacing is 0.333, 0.207 and 0.168 nm with the intensity of the X-ray picks of 100, 1 and 5 % correspondingly. Specific electrical resistance of the electrode condensate is less than 10^{-7} $\Omega \cdot \text{m}$. Thus the film of the cathode condensate is current installing polycrystalline graphitic material.

Fig. 3 presents Raman-spectra of the cathode condensate film. The spectrum was received using infrared laser with wave-length of 1.064 μm . In the Raman-spectra there are three intense bands of 1290.0 cm^{-1} , 1581.9 cm^{-1} , and 2564.5 cm^{-1} with the intensity 0.04, 0.05, and 0.05 of relative unit respectively.

Comparison of the Raman-spectra of the condensate with the spectra of carbon materials known from Ref. [3] gives their coincidence with Raman-spectra of multi-walled carbon nanotube (MWNT) with some injection of the other forms of carbon, including single-walled carbon nanotube (SWNT).

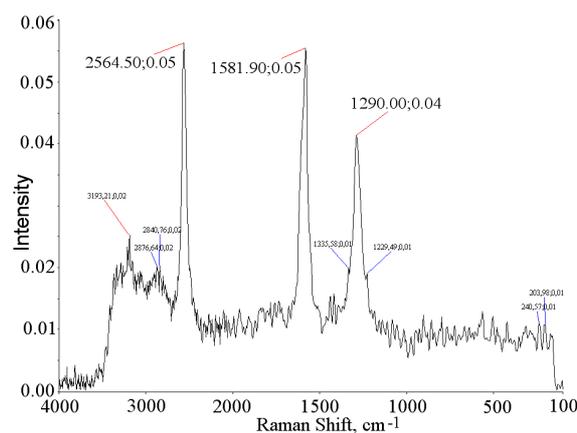


Fig. 3. Raman-spectrum of the carbon condensate from copper cathode of the plasmatron fulfilled using Fourier spectrometer SPECTRUM GX (PerkinElmer, USA).
The spectrum registration conditions: $\lambda=1.064 \mu\text{m}$, 100 scans, 1500 mW.

Now it is well known that physical-chemical properties of carbon nanotubes are unique. Their conductivity is better than conductivity of all conventional conductors and nanotubes can withstand current density 102-103 times more than metals. Also they have high heat conductivity, they are very mechanically firm, 1000 times firmer than steel and they gain the properties of semiconductors at their curling or flexion. For long-live work of the electrodes it is of especial importance that carbon nanotubes have high emission of electrons, they are chemically inert at high electric field intensity ($10^7 - 10^8 \text{ V/m}$) and residual gas ions bombardment. All these properties indicate that nanotubes and the composites on their base are ideal materials to protect the plasmatron electrodes and as a consequence to prolong their life. Thus the cathode condensate is produced in accordance with propane/butane oxidative pyrolysis in conditions of high-accuracy arc discharge with magnet focusing without use of rare gas (argon or helium).

The electrode condensate was examined using atomic power microscope, scanning electron microscope (SEM) (Fig. 4 a) and transmission electron microscope (TEM) (Figs. 4 b). As it is seen the basic mass of the carbon sample (about 80 %) is represented as film and band

graphite particles collected to aggregates of various size and density. Basal cleavage spacing of these particles is a little more than one of “ideal” graphite. It is $d_{002} = 3.45\text{-}3.55 \text{ \AA}$, in contrast to $d_{002} = 3.35 \text{ \AA}$ of “ideal” graphite. Width of the bands varies from 40 to 160 nm. Sometimes film and band nanoparticles are collected into stratified packages. Fig. 4 a demonstrates that the last-named are gathered to well-ordered microstructures.

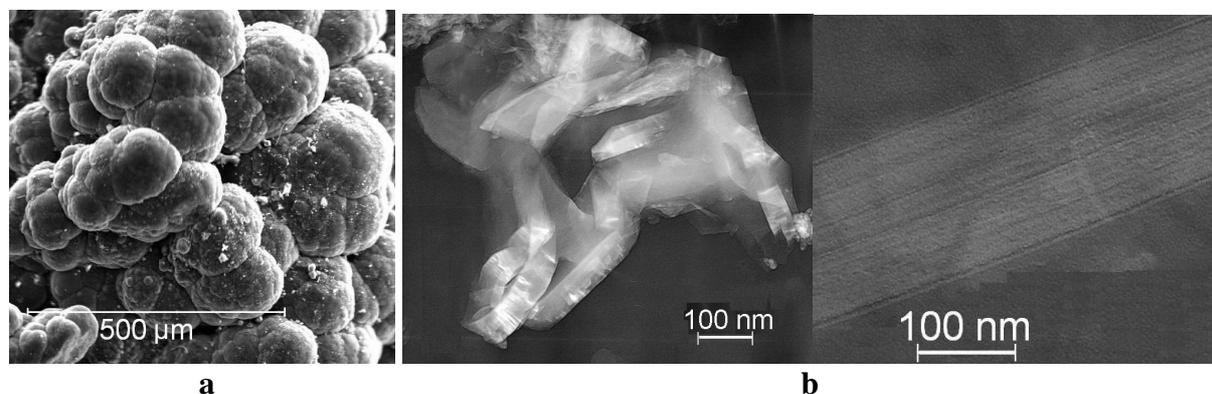


Fig.4. SEM (a) and TEM (b) images of a sample of the cathode condensate.

Conclusion

On the base of the microscopy and the Raman-spectroscopy investigation, it can be concluded that the cathode condensate is composite carbonic stuff made of carbon nanoclusters which consists mainly of single and multi-walled carbon nanotubes and other carbonic forms including some quantity of the copper atoms intercalated to the carbonic matrix.

Life length of the cathode totals more than 1000 hours. The experiments confirmed principal possibility for unlimited long-life of the cathode filmed with carbon nanostructural material.

References

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