

## DERIVATOGRAPHIC INVESTIGATION OF ARC EVAPORATION PRODUCED ON DIFFERENT SUBSTRATES

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Thermal stability of a number of products formed on the surface of foils from Mo, Al, Ni, Cu, W, stainless steel, Fe, manganine, Ti which were fixed on the reactor walls has been investigated in the air medium. The aim of the investigation is to establish the influence of nature of the material from which the walls of the reactor for arc synthesis of fullerenes were made on the

composition of arc graphite evaporation products.

Thermal analysis of powders has been performed using the derivatograph Q-1500D in conditions of dynamic heating in air from room temperature to 1000°C.

The obtained results of thermal gravimetric studies and differential thermal analysis are given in Fig.1a-c and in Table 1.

Table. Results of thermal studies of the products formed on different substrates.

| № | Materials       | DTG                     |                         |                             |                             |                             | DTA                     | Temperature range for decomposition, °C | Mass loss, % |
|---|-----------------|-------------------------|-------------------------|-----------------------------|-----------------------------|-----------------------------|-------------------------|-----------------------------------------|--------------|
|   |                 | T <sub>1 max</sub> , °C | T <sub>2 max</sub> , °C | T <sub>shoulder1</sub> , °C | T <sub>shoulder2</sub> , °C | T <sub>shoulder3</sub> , °C | T <sub>1 max</sub> , °C |                                         |              |
| 1 | Mo              | 500                     |                         | 441                         | 478                         | 538                         | 535                     | 305-600                                 | 45           |
| 2 | Al              | 575                     |                         | 500                         |                             |                             | 585                     | 210-675                                 | 98           |
| 3 | Ni              | 580                     |                         | 500                         | 520                         |                             | 585                     | 200-660                                 | 91           |
| 4 | Cu              | 550                     |                         | 367                         | 507                         | 613                         | 550                     | 220-655                                 | 92           |
| 5 | W               | 617                     |                         | 588                         | 640                         | 648                         | 630                     | 200-715                                 | 99           |
| 6 | Stainless steel | 620                     |                         | 600                         | 650                         | 676                         | 635                     | 220-780                                 | 100          |
| 7 | Fe              | 610                     |                         | 573                         | 682                         |                             | 640                     | 210-785                                 | 92           |
| 8 | Manganine       | 660                     |                         | 602                         |                             |                             | 660                     | 210-705                                 | 98           |
| 9 | Ti              | 630                     | 660                     | 567                         | 680                         |                             | 660                     | 200-745                                 | 98           |

Oxidation of the product formed on the Mo substrate proceeds in the temperature range of 305-600°C (Fig.1a, № 1; table, № 1). When heated up to 1000°C, the product loses 45% of its mass. The dark brown powder has been found in the residue.

The peak at T<sub>max</sub>=500°C and three shoulders at T<sub>max</sub>=441, 478, 538°C correspond the above process in the DTG curve, and the rather wide asymmetric exopeak (T<sub>max</sub>=535°C) (Fig.1b,c, № 1; table, № 1) exists in the DTA curve.

The mass loss for the product formed on the rest of the substrates during their heating to 1000°C varies from 92 to 100% (table, No 2-9).

Oxidation of the products formed on Al, Ni, Cu substrates occurs in the temperature range of 200-675°C.

In oxidation of the product formed on the Al substrate there appears a shoulder in the DTG

curve at 500°C. The maximum rate of the process and the corresponding rather sharp peak shift to the range of higher temperatures (T<sub>max</sub>=575°C). In the DTA curve the exopeak that corresponds this process is also observed at higher temperature (T<sub>max</sub>=585°C) (Fig.1c, № 2; table, № 2). High-temperature behavior of the product formed on the Ni substrate is similar to that of the product on the Al substrate. The difference is that in the temperature range of 500-520°C there appears two shoulders (Fig.1b, № 3; table, № 3) in the DTG curve for oxidation of the product formed on the Ni substrate, and the temperature for the maximum rate of oxidation shifts slightly to the range of higher temperature (T<sub>max</sub>=580°C). In the DTA curve the maximum for the more diffuse exopeak is observed at 585°C, like for the product on the Al substrate (Fig.1c, № 3; table, № 3).

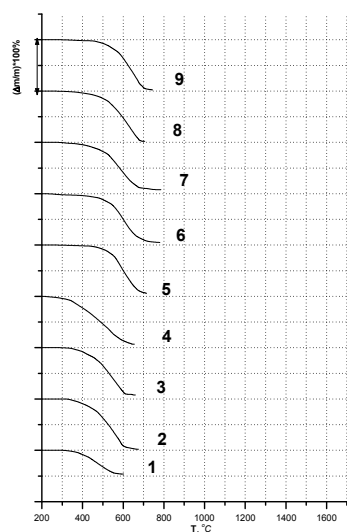


Fig. 1a. TG curves for oxidation of the products formed on the different substrates:  
Mo (1), Al (2), Ni (3), Cu (4), W (5), stainless steel (6), Fe (7), manganine (8), Ti (9)

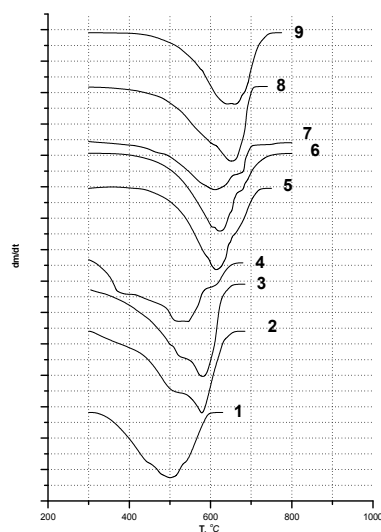


Fig. 1b. DTG curves for oxidation of the products formed on the different substrates: Mo (1), Al (2), Ni (3), Cu (4), W (5), stainless steel (6), Fe (7), manganine (8), Ti (9)

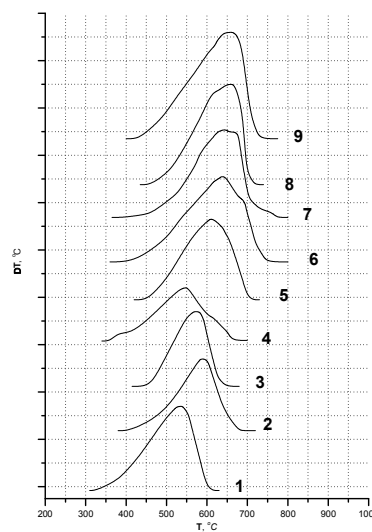


Fig. 1c. DTA curves for oxidation of the products formed on the different substrates:  
Mo (1), Al (2), Ni (3), Cu (4), W (5), stainless steel (6), Fe (7), manganine (8), Ti (9)

In oxidation of the product formed on the Cu substrate there appear three shoulders in the DTG curve in the wide temperature range (367-613°C). At 370 and 600°C there appear two small exopeaks in the DTA curve. These peaks are overlapped with the main wide peak which maximum is observed at lower temperature (550°C). The maximum rate of oxidation for this product is also observed at this temperature (Fig. 1b, № 4; table, № 4).

Oxidation of the products formed on the rest of the substrates (W, stainless steel, Fe, manganine, Ti) occurs in the wider temperature range (200-785°C). Oxidation temperatures and the forms of curves that reflect interaction of products with air are different and depend on the substrate material. The general peculiarity of their high-temperature behavior is that the maximum rates of their oxidation shift to the higher temperature range (617-660°C) in the following sequence: Mo, Al, Cu, W, stainless steel, Fe, manganine, Ti. As a rule the shoulders, which number varies from one to four in the DTG curves for oxidation of the products formed on different substrates, are also observed in the higher temperature range (600-675°C). In the DTA curves the wide exopeaks that comprise a number of overlapped peaks ( $T_{\max}=630, 660^{\circ}\text{C}$ ) (Fig. 1b,c, № 5-9; table, № 5-9) correspond this process.

### Discussion of results

The investigations into high-temperature interaction of products of arc graphite sputtering

with oxygen of air have shown that their oxidation starts above 200°C. The form of thermal gravimetric curves points to that the composition of these products is multiphase and varies depending on the substrate material. The structures in the products exhibit different thermal stability.

Literature data [1,2] show that amorphous carbon burns out mainly in the range of 300-550°C. The ignition temperature of monolayer nanotubes is close to that for amorphous graphite [2]. Temperatures for the maximum oxidation rate of amorphous carbon, monolayer nanotubes and carbon nanoparticles are 381, 471, 635°C, respectively [2]. Interaction of graphitized particles with oxygen from air is known to occur at 550-770°C, and for graphite – at 700-900°C.

Hence the maximums, which appear in the low-temperature range (441-538°C) in the DTG curve for oxidation of the product formed on the Mo substrate, can indicate the presence of different carbon compounds with different modifications and monolayer nanotubes.

The products formed on the Cu substrate comprise large amounts of nanocompounds with low thermal stability.

The maximums that appear in the DTG curve for oxidation of the products formed on Al and Ni substrates at higher temperatures (580°C) seem to be conditioned by not only amorphous carbon and nanotubes, but also certain amounts of compounds from these metals and carbon and their

polymorphous structures.

Shifting the temperature maximums in the oxidation curves for the products formed on W, stainless steel, Fe, manganese, Ti in the range of high temperatures (617-660°C) indicates the presence of different carbon-containing compounds of the above metals or the carbon structures doped with nanoparticles of metals, and carbon nanoparticles that differ by their form, size, morphology and microstructure.

The products formed on W and stainless steel shows the largest variety in thermal stability of nanoparticles.

### **Conclusions**

It has been established that the substrate material affects significantly the composition of arc sputtering products.

It has been suggested that monolayer nanotubes and carbon-containing compounds preferably form on Mo, Al, Ni, Cu substrates. Multilayer nanotubes and more thermally stable carbon-containing compounds form on W, stainless steel, Fe, manganese and Ti.

### **References**

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