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Thermal and electrical characteristics of flat heaters made of aluminum with nanoporous anodic aluminum oxide and a resistive element of carbon filament

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Abstract

The results of studies of the thermal characteristics of aluminum heaters with a layer of anodic aluminum oxide are presented. In the design of an aluminum heater, a carbon electrically conductive filament based on a viscose technical fiber was used as a heating element. To seal the heater design, a silicone compound was used.

Key words: flat heater, aluminum base, nanoporous anodic alumina, carbon filament, silicone compound.

1 Introduction

A wide variety of types and forms of flat heaters makes it possible to use them in various technical devices associated with the use of thermal processes. To increase their efficiency a significant number of technological processes in the industry require the heating of various surfaces, gases or liquids by means of electric heaters. Electronic equipment operating in climatic conditions with low negative temperatures, in order to ensure uninterrupted operation, requires forced heating. Also important role is played by the thermal processes in the daily activities of man. They allow to create comfortable conditions for work and rest, thus having a significant impact on labor productivity. All these examples show that heating elements play an important role in the development of technological progress and human activity.

Among the flat heaters, metal heating elements are most effective ones [1,2]. In the development of such heaters the main tasks is to provide reliable isolation of the electrical resistance circuit, both from the metal substrate and from the environment.

In the present work, to increase the operating temperature to 200 ° C, an aluminum flat heater is proposed with the use of a silicone compound as a sealing polymer. The results of studies of the thermal characteristics of such heaters are presented.

2 Experimental

The flat heating element had dimensions of 60x24 mm. The thickness of the anodized aluminum base was 0.5 mm. On the samples of anodized aluminum, the porous anodic aluminum oxide layer had a thickness of 20 μm. Such thickness of the porous anodic aluminum oxide provided the necessary insulation of the heating element from the metal substrate. In the design of a heater made of aluminum with nanoporous alumina, a carbon electrically conductive filament based on a viscose technical fiber was used as a heating element. For the production of resistive elements, a carbon fiber with dimensions of 80 μm (thickness) * 4 mm (width) * 170 (length) was used. The ends of the filament from the carbon fiber were metallized by a layer of copper (thickness 30 μm, galvanic deposition) for subsequent soldering during the assembly of the electric heater.

Fixation of the carbon filament on the surface of anodic alumina and then its sealing was carried out with the help of a silicone compound. An electric heater with a carbon filament had an electrical resistance of 30 Ohm and a power of 13.5 W (operating voltage 20 V).

Measurement of the resistance of dielectric insulation was carried out with a high-resistance ohmmeter F4101. To obtain the thermograms of the surface of the heater, a thermal imaging camera MobIR M4 was used.

3 Results and Discussion

For flat heaters, the most important characteristics are to ensure uniform heating across the area of the heater and a quick reaching of the given temperature. Therefore, in this paper these characteristics at various stages of heating were studied in detail.

Figure 1 shows the thermogram of the front heater's surface (Fig. 1a) and the profile of the temperature distribution along a given line that crosses the heater from the carbon filament (Fig. 1b) for 5 second of heating.

a *b*

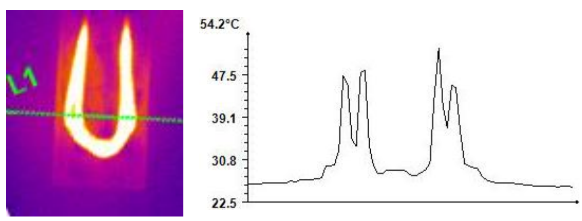

Figure 1 *Thermogram of the front surface of the aluminum heater with porous alumina and the resistive element of the carbon filament (a) and the temperature distribution profile (b) along given line for 5 second of heating*

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At the same time, working (heat-dissipating) side of the heater, as seen from the thermogram of the surface of the heater (Fig. 2a) and the profile of the temperature distribution along the given line (Fig. 2b), have a uniform temperature distribution over the surface with an average temperature of 51.2 °C.

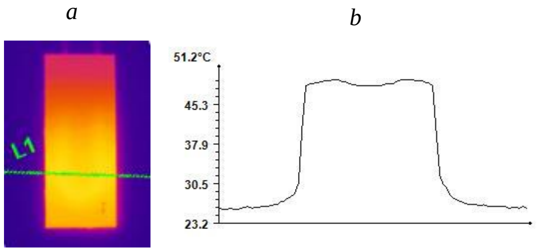

Figure 2 *Thermogram of the working (heat-dissipating) surface of a heater made of aluminum with porous alumina and a resistive element from the carbon filament (a) and the distribution profile of temperature (b) along a given line for 5 second of heating*

The plots of temperature vs. time on the surface of the heater with the resistive element and on the reverse side (heat sink) were obtained (Fig.3). Uniform temperature distribution over the surface was maintained up to 170°C.

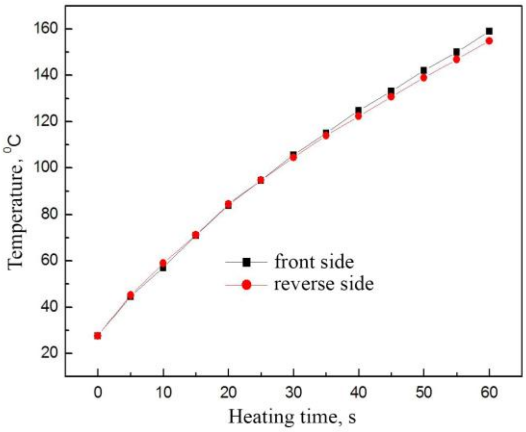

Figure 3 *Temperature vs. heating time on the front and reverse (heat-dissipating) side of the electric heater*

The results of the studies reveal that the temperatures of the heater on the surface with the resistive element of front side and on the reverse side have very close values at all stages of heating. Consequently, due to the high thermal conductivity of aluminum, generating heat can evenly dissipate throughout the volume of aluminum, providing a uniform profile of temperature distribution across the surface both on the front and reverse sides of the heater.

4 Conclusion

Flat electric heater on the base of anodized aluminum is characterized by a rapid output at the maximum operating temperature and reaches a temperature of 200 °C for a time of 60 s (power 13.5 W). Despite one-sided heating design using a linear heating element from the carbon filament, a uniform temperature distribution profile over the surface was provided at all heating stages on the reverse (heat sink) side. Use of silicone compound as a sealing polymer allowed to increase the upper operating temperature of the flat aluminum heater to 200 °C.

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