THE PASSAGE OF AN ELECTRICAL CURRENT THROUGH A FLUIDIZED BED OF ELECTRICALLY CONDUCTING PARTICLES

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The mechanism of the nonlinear relation between the specific resistance of a fluidized bed of graphite particles and the current density when a 50 hertz alternating current is supplied to the bed is discussed.

The effect of the filtration velocity, particle diameter, height of initial filling, current density, etc., on the specific electrical resistance of a fluidized bed of graphite particles was described in [1-3].

In this paper we consider in greater detail than before the mechanism of the relation between the specific electrical resistance of a fluidized bed ρ, and the current density.

As shown by the experimental results [1-3] and Fig. 1, ρ is a sharply decreasing nonlinear function of the current density. Previous experiments on the investigation of the effect of the current density on the specific electrical resistance of a fluidized bed [2] were made with the usual apparatus and a cylindrical bed with coaxial electrodes, and the analysis of the experimental results involved averaging the current density along the radius, since at each moment of time the current density was obviously greatest at the central electrode and least at the peripheral one, if we assume that the conducting chain branched at the input to the broad peripheral part of the cylindrical bed.

Hence there is certain interest in verifying the nature of the relation between the specific electrical resistance and the current density when the conductor to the dispersed system has a different geometry – in an apparatus of rectangular cross-section (Fig. 2). Here when the plane electrodes (45 × 100 mm), occupying the whole width of the bed and lowered almost to the top of the aluminum oxide charge (2 mm gap), there was a high probability that the current density along the whole path between the electrodes (104 mm) was the same.

The experimental results for a rectangular apparatus are compared with those for a cylindrical apparatus in Fig. 3, from which we see easily that the nature of the relation $\rho = f(i)$ does not change, i.e., averaging the current density, as done in [2] for a cylindrical apparatus, is permissible.

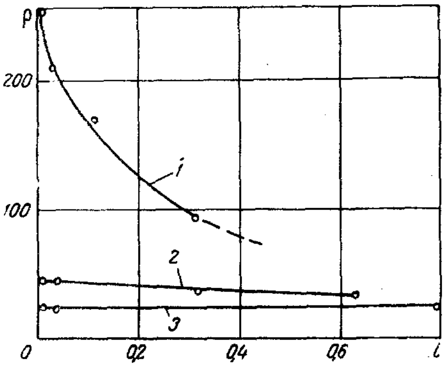

Fig. 1. The specific electrical resistance (ohm · cm) of a fluidized bed of graphite particles of diameter 0.1-0.16 mm as a function of the current density (A/cm^2) for an expansion factor of 1.2: 1) argon gas, 20°C; 2) helium gas, 2000°C; 3) argon gas, 2000°C.

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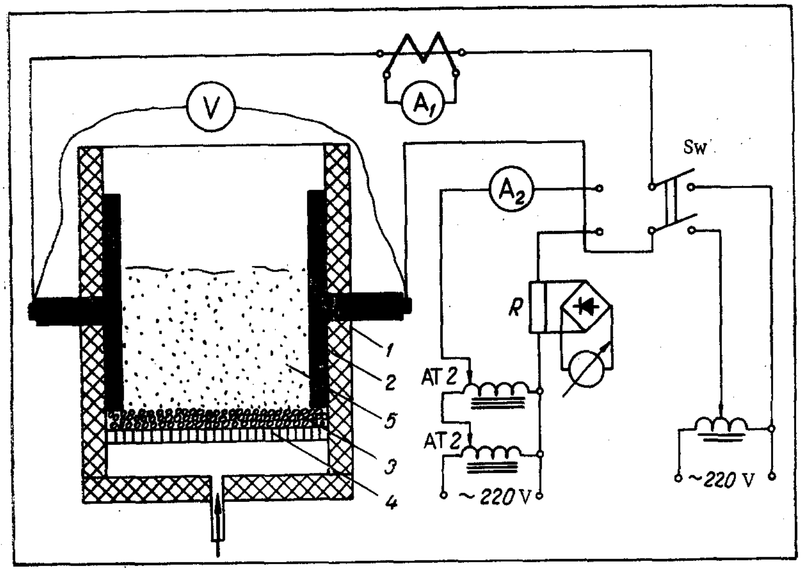

Fig.2. The experimental apparatus: 1) fireclay; 2) electrode; 3) charge of coarse aluminum oxide particles; 4) gas-distributing grating; 5) the fluidized bed.

The fundamental resistance to the electrical current is due to contact bridges between the particles, shunting the gas gaps, i.e., the fundamental heat liberation occurs at these points of contact which can be heated right up to the temperature at which the particle material softens and vaporizes. As the current increases so does the liberation of heat in the gaps between the particles, while the rigidity of the contacts is lowered due to material softening at the points of contact, the areas of contact between the particles increase and their electrical resistance diminishes.

In [2] we referred to the photoionization of the gas at the points of contact (in the gaps between the particles) of an electrically-conducting fluidized bed (i.e., between the particles and the electrodes) as one of the probable mechanisms for the reduction of the electrical resistance of the bed when the current density increased.

Indeed the development of other ionization mechanisms is doubtful here. Brief local heating arising when the conducting chain is broken or connected is accompanied by spark formation (micro-arc discharges) can lead to thermal ionization, which requires a temperature of the order of 10,000°K. Also, surface ionization, as we know, requires a high potential difference, which does not occur between the electrodes in the electrothermal fluidized bed [4]. A shock ionization cannot develop here because the distance between the particles in the chain is negligible.

But in [2] we did not refer to one other mechanism for reducing the electrical resistance of the fluidized bed when the current density increases, that is, an electrodynamic mechanism. When an electrothermal fluidized bed is heated by an alternating current at high current density significant electrodynamic forces must occur.

Although the effective current density is small the true value in various current-conducting chains can be very large, and this leads us to expect the appearance of electrodynamic forces.

As the current density increases, the electrodynamic forces which are trying to compress the randomly scattered current-conducting chains into certain dominant conducting channels become commensurable with the hydrodynamic forces preventing such an order. As they are compressed we can expect that the current conducting chains contract and that the density of the contacts increases, which must lead to a fall in the electrical resistance of the fluidized bed even to the point at which photoionization of the gas gaps develops. The conducting chains can be compressed because the viscosity of the fluidized bed has relatively little effect.

Evidently the various mechanisms for reducing the electrical resistance of a fluidized bed, considered above, operate at the same time, which complicates the description of the passage of an electrical current through the bed. But sometimes one of these becomes the controlling mechanism. We see that this is true

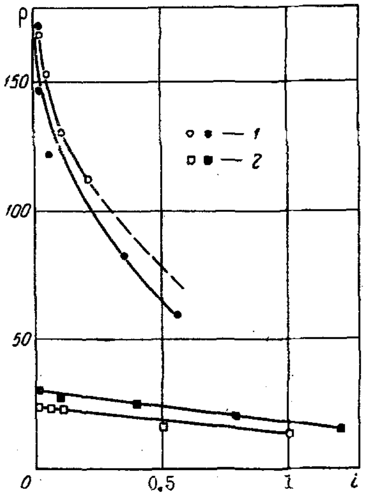

Fig. 3

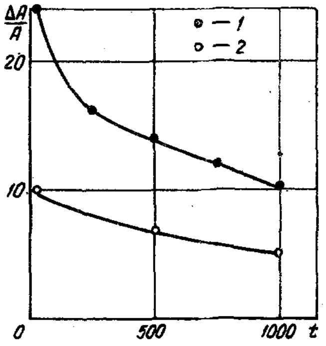

Fig. 4

Fig. 3. The equation $\rho = f(i)$ for graphite particles of diameter 0.16-0.2 mm and an expansion factor of 1.1 for a rectangular (open) and a cylindrical (black dots) apparatus (ρ, ohm·cm; i, A/cm^2): 1) temperature 20°C; 2) temperature 1000°C.

Fig. 4. The normalized amplitude (%) of the pulse current (5A) as a function of the temperature (°C) for particles of diameter 0.16-0.2 mm and an expansion factor of 1.1: 1) rectangular apparatus; 2) cylindrical apparatus.

when the mean temperature of the bed is comparatively high, approximately 2000°C. On Fig. 1 lines 2 and 3 show the specific resistance of graphite beds fluidized respectively by helium and argon at 2000°C. Primarily they indicate the very low electrical resistance of the fluidized bed under these conditions and that ρ depends weakly on the current density. At the same time, the resistance when fluidization is by helium remains much lower throughout the whole range of current densities than when fluidization is by argon, and this indicates the significant role of photoionization which begins at high temperature and low current density. The ionization mechanism is so powerful here that it ensures that the gaseous beds are highly conducting, and then additional reduction in the contact resistance between the particles due to their softening or the electrodynamical compression of the conducting chains with increase in current density does not cause any marked reduction in ρ for argon fluidization. When fluidization was by weakly-ionized helium the reduction in ρ was marked but smaller.

When we turn from a low temperature to a high temperature electrothermal fluidized bed and when the throughput of gas by weight is large enough to preserve the former expansion of the bed, pulsations of the electrical resistance (current) of the fluidized bed are sharply weakened and so are the hydrodynamical pulsations. Current pulsations were recorded in beds of ring-shaped (electrodes 5 × 55 × 120 mm with a separation of 50 mm and column diameter 96 mm) and of a rectangular cross-section for an average current of 5 A (current density of approximately 0.1 A/cm^2), an expansion factor of 1.1 and temperatures from 20 to 1000°C. The experimental results are shown on Fig. 4. They show that as the temperature of the bed increases from 20 to 1000°C current pulsations in the rectangular bed fall from 24 to 10% and in the ring-shaped bed from 10 to 5%. The lower pulsation intensity in the ring-shaped bed is probably explained by the smaller hydraulic diameter of its current-conducting medium as a result of which the hydrodynamic and electrical pulsations in the ring-shaped bed were weaker than those in the rectangular bed. For both beds the pulsation frequencies in the above experimental conditions were less at a temperature of 1000°C than at 20°C, which indicates that the diameter of the gas bubbles was smaller.

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