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CALCULATION OF METHANE BUBBLE OPTIMUM DIAMETER IN A BUBBLE REACTOR

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РАСЧЕТ ОПТИМАЛЬНОГО ДИАМЕТРА ПУЗЫРЬКА МЕТАНА В БАРБОТАЖНОМ РЕАКТОРЕ

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Аннотация. *В работе представлен расчет распределения напряженности электрического поля в объеме реактора, заполненного расплавом диэлектрика с одним микропузырьком. Распределение поля по диаметру пузырька вдоль и поперек силовых линий электрического поля.*

Introduction. Numerous studies of the conversion of gas-phase organic compounds have shown that in many cases the chemical process is realized as a radical chain [1, 2]. The chain process consists of three stages - initiation, chain continuation and chain termination. At the stage of initiation, radicals are formed during the decay of the original molecule. This stage requires a high activation energy and therefore can proceed at a noticeable rate only at high temperatures (more than 1000 °C for methane). At the stage of chain continuation, the radicals interact with the initial molecules to form a molecule of a stable product and a new radical. Chemical reactions involving radicals require a much lower activation energy, so a lower temperature is sufficient for the chain continuation step. One radical can initiate 10^3 – 10^5 reactions at the stage of development of the radical chain process.

To increase the rate of the chain process, it is promising to use plasma-chemical reactions [2, 3]. In a gas discharge, under the action of plasma, additional radicals are formed, which initiate a nonequilibrium radical chain process. Such a process will take place at a much higher speed, since the effect of plasma facilitates the slowest stage of the chain process - thermal initiation of the reaction. In addition, the formation of radicals in plasma-chemical reactions ensures the efficient conduct of the radical chain process at a lower temperature, which makes it possible to synthesize compounds that are unstable at high temperatures or whose synthesis selectivity is low at high temperatures.

Research methods. Simulation of radical chain pyrolysis of methane using reaction rate constants from the database NIST [4] done with Kintecus [5]. It has been found that during endothermic reactions of methane pyrolysis in a bubble reactor with a gas bubble diameter of 1 mm, the decrease in gas temperature does not exceed 10 degrees. Intensive supply of thermal energy to the zone of endothermic reactions in a bubble reactor increases the rate of methane pyrolysis reactions by 5-10 times.

To increase the productivity of a bubble reactor, it is promising to use nonequilibrium radical chain processes. Simulation of methane pyrolysis in a bubble reactor [6] showed that the nonequilibrium concentration of radicals, which does not exceed 0.1 % of the methane concentration, provides an additional increase in the rate of methane pyrolysis reactions by 5–10 times.

Research model. To develop a non-equilibrium concentration of radicals that initiate the radical-chain process of methane conversion, it can be used in a gas discharge in a bubbling bubble reactor with a dielectric melt.

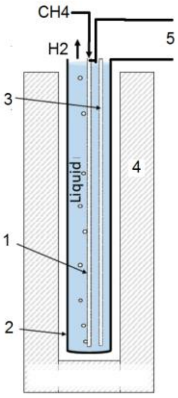

Fig. 1. Diagram of a bubbling reactor: 1 – central hollow electrode, 2 – reactor vessel, 3 – thermometer, 4 – thermal insulation, 5 – high voltage supply circuit

Breakdown voltage optimization. If a high voltage is applied between the reactor vessel and the central hollow electrode, through which methane is supplied to the lower part of the reactor, then the breakdown will take place in the volume of the bubble, and not in the melt. Based on the dependence of the minimum breakdown voltage of methane on the gap value multiplied by the gas pressure (Paschen curve), the dependence of the minimum diameter of a bubble with methane on the electric field strength is calculated.

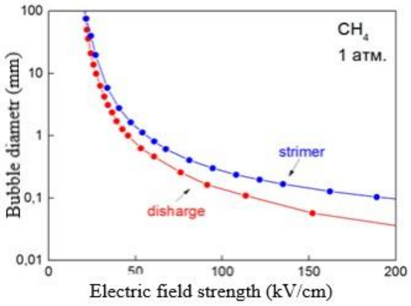

Fig. 2. Dependence of the min. diameter of a methane bubble on the electric field strength at a pressure of 1 atm

For independent avalanche breakdown in methane with a bubble diameter of less than 1 mm, the electric field strength must exceed 50 kV/cm.

Radical concentration optimization. To increase the concentration of radicals in the volume of a gas bubble, it is necessary to increase the plasma concentration, which is achieved when an avalanche discharge passes into a streamer one, which occurs under the condition [7]:

$$n_{\min} = n_0 e^{\alpha \cdot x_{\min}} \approx 10^8 \ cm^{-3},$$

where α - collisional ionization coefficient, $x_{\min}$ - critical distance.

Let us assume that the minimum bubble diameter $d_{\min}$ must exceed $x_{\min}$ it two times

$$d_{\min} = 2x_{\min} = \frac{2}{\alpha}\ln\left(\frac{10^8}{n_0}\right),$$

at α in cm^{-1} and n_0 it cm^{-3}.

For a single avalanche $n_0 = 1$ and the minimum bubble diameter is:

$$d_{\min} = \frac{2}{\alpha}\ln\left(10^8\right) = \frac{36.8}{\alpha}. \quad (1)$$

The results of calculation by relation (1) are shown in Figure 2.

Results. The performed studies have shown that for the plasma-chemical synthesis of radicals from methane in a bubbling reactor at a pressure of 1 atm. the diameter of the gas bubble must be greater than 1 mm. When the bubble diameter is less than 1 mm, the electric field strength must exceed 50 keV/cm.

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