Deposition of fluoropolymer coating on a metal mesh for manufacturing of oil-water emulsion separating membranes

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Abstract. The membranes were synthesized by deposition of fluoropolymer coatings on metal meshes using the Hot Wire Chemical Vapor Deposition (HW CVD). The obtained membranes were used for the separation of an oil-water emulsion in a simple filtration facility. The main process parameters influencing the separation efficiency were determined and the optimal separation mode was selected. It was shown that the highest efficiency on the obtained membranes is achieved by separating emulsions containing water less than 10%.

1. Introduction
The oil industry is the main part for the development of the innovative economy of Russia. But oil production is complicated by huge technological problems associated with the peculiarities of extracting oil from the earth's interior. One of the main problems is the presence of a large amount of water in the oil well. As a result, the contact of water and oil leads to the formation of an oil-water emulsion, which must be separated. Existing methods [1], such as: mechanical; thermal; chemical; electrical; are complex and quite energy-intensive, which affects the cost of the final product. One of the most promising is the membrane method, in which the separation of water and oil products occurs on the membrane surface.

The main goal of the presented work was to fabricate separation membranes consisting of metal meshes on the surface of which hydrophobic fluoropolymer coatings were deposited; and also to study the process of separation of oil-water emulsion through the membranes obtained.

2. Experimental details

2.1. Experimental setup
The Hot Wire Chemical Vapor Deposition (HW CVD) method was used for the deposition of hydrophobic fluoropolymer coatings [2-6]. The scheme of the method is shown in figure 1. The main idea of the method is to activate the precursor gas flow on a resistively heated catalytic metal filament – an activator. The experimental setup is described in [4]. In this work, nichrome (Ni80/Cr20) wire was used as an activator and Hexafluoropropylene oxide (C₃F₆O) as a precursor gas. As a result of activation, radicals are formed. Then these radicals move to the deposited surface, where they polymerize, forming a coating [3]. The resulting structure depends on the temperature of the catalyst, the pressure of the precursor gas, and the distance between the catalyst and the substrate [4]. In order to manufacture separation membranes for the filter, fluoropolymer coatings were deposited on the surface of the metal mesh. Two types of metal mesh were used: a copper with a large weave and a...
double close weave stainless steel. The deposition parameters were the same for both types: precursor gas pressure was 67 Pa; activator filament temperature – 640 °C; distance between activator and sample – 50 mm; sample temperature – 30 °C and precursor gas flow – 100 sccm.

![Diagram](image)

**Figure 1.** Scheme of the experimental facility: 1 – gas shower; 2 – activating catalytic hot wire; 3 – holder; 4 – metal net; 5 – vacuum pump system.

2.2. *Diagnostic methods*

The surface morphology of the obtained membranes is analyzed using the JEOL JSM6700F scanning electron microscope. The water contact angle (CA) was measured using a DSA-100E device, KRÜSS GmbH.

2.3. *Description of the separation facility*

To study the process of separation of oil-water emulsion by the membrane method, a membrane filter was developed and assembled. The filter scheme is shown in Figure 2. The filter consists of two tanks: upper and lower. A membrane is located between the tanks. The membrane is tilted at an angle of 45°. The oil-water emulsion is poured into the upper tank to a certain level. After the separation process, the water remains above the membrane surface, and the oil flows into a container under the filter. The separation process is considered complete when the volume of the emulsion in the upper tank does not change for 20 minutes.
3. Result and discussion
Figure 3 shows micrographs of metal meshes after deposition of hydrophobic fluoropolymer coatings. It can be noted that the fluoropolymer coating evenly covers the entire surface of the mesh. The morphology of the fluoropolymer coating on both meshes is identical. The water contact angle (CA) of the resulting coatings is $120^\circ$.

![Figure 2. Scheme of the membrane filter: 1 – emulsion; 2 – water; 3 – membrane; 4 – oil.](image)

![Figure 3. Micrographs of the surface of metal meshes and fluoropolymer coatings deposited on them: copper mesh (a) and coating on it (b); double weave stainless steel mesh (c) and coating on it (d).](image)
For experimental modeling of the separation process, an emulsion with water concentrations of 1, 10, 25, 50, and 90% was made from commercial oil (water content less than 1%) and distilled water. Then the emulsion was separated on the assembled filtration facility. The separation time and efficiency were determined. Efficiency was determined as the ratio of the extracted volume of water from the emulsion to the initial volume of water taken to prepare the emulsion multiplied by 100%.

It was experimentally found that the maximum separation efficiency is achieved when separating emulsions with a water content of 10% and less. Efficiency for copper mesh membranes reaches 80%, and for stainless steel membranes it is about 99%. The separation rate is also determined by the water concentration in the emulsion. With an increase in the amount of water from 10 to 50%, the separation time increases by ~ 8 times. At the same time, the membrane separation efficiency did not decrease even after 10 cycles.

These are preliminary data showing the possibility of using the HW CVD method for the manufacture of separation membranes by depositing hydrophobic fluoropolymer coatings on metal meshes.

4. Summary
Separation membranes were manufactured by deposition of hydrophobic fluoropolymer coatings on the surface of metal meshes using the HW CVD method.

A test filtration facility based on the obtained membranes was assembled. Exploratory experiments showing the effectiveness of using fluoropolymer coatings on metal meshes as membranes in the separation of oil-water emulsions were carried out.

It is shown that the highest efficiency on the obtained membranes is achieved by separating emulsions containing less water (less than 10%).

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