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FIBER DECORATED WITH MAGNETITE USING HETEROCOAGULATION

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The ability to fabricate magnetic synthetic fibers by synthesizing a magnetite dispersion in a dyeing vat and precipitating colloidal particles onto the surface of polyamide fibers using heterocoagulation was demonstrated experimentally and validated.

Heterocoagulation can deposit magnetic layers on natural non-magnetic materials (wool, catgut) without destroying their structure [1, 2] because other methods for producing magnetic fibers from polymers involve adding magnetic particles during the spinning stage. It seemed interesting to develop the technology for producing synthetic fibers with magnetic properties using nanotechnology.

The goals of the present work were to demonstrate experimentally and validate the ability to create fibers with magnetic properties from synthetic fibers using heterocoagulation and to determine the influence of processing parameters such as the concentrations of iron salts and surfactants (SA) on the content of magnetic particles on the fibers.

We used knitted polyamide cloth of complex polyamide threads as the fibrous material. The magnetite dispersion was prepared by co-precipitation of iron salts [Fe(II) and Fe(III)] using aqueous ammonia at pH = 10 [3] in the presence of the polyamide fibrous material and SA in the dye vat. Classical methods of chemical textile technology were used for the research.

One method for producing nanosystems is to precipitate dispersed particles by synthesizing an insoluble compound in the liquid phase. In this instance, formation of the dispersed phase must be stopped at the nanoparticle-formation stage. A common approach is to use SA that prevent the size from increasing by adsorbing to the surface of the newly formed phase. Also, the dispersion particles are prevented from aggregating and the colloid becomes more resistant to aggregation.

The SA play a multi-faceted role in the dye vat. On one hand, SA affect the structure of the dispersed synthesized magnetite. On the other, they affect the ability to carry out heterocoagulation and the interaction strength of the nanoparticles with the fiber surface because they are adsorbed to it. Therefore, we studied the influence of the concentrations of both iron salts and various SA on the adsorption of the magnetite dispersion using heterocoagulation onto the surface of polyamide fibers.

We used a method for synthesizing magnetite with SA stabilization that produced magnetite nanoparticles from 10 to 30 nm [3]. The effects of the iron sulfate and chloride concentration (from 5 to 60 g/L) in the presence of various SA with concentrations up to and exceeding the critical micelle-formation concentration (CMC) [4] on the synthesis of the magnetite nanoparticles and the formation of the nanoparticle layer using heterocoagulation on the surface of the polyamide fibers were investigated.

Classical heterocoagulation [5-7] typically involves deposition of oppositely charged particles by neutralizing their charges during the interaction. Polyamide fiber in alkaline solution (pH > 5) has a negative ξ-potential. However, dispersed magnetite particles stabilized by the cationic SA alkamon OS 2 have a positive ξ-potential. Therefore, if magnetite is synthesized in the dye vat at pH 10-11 in the presence of alkamon OS 2, positively charged magnetite particles are deposited onto the negatively charged fiber surface through electrostatic interaction or heterocoagulation of

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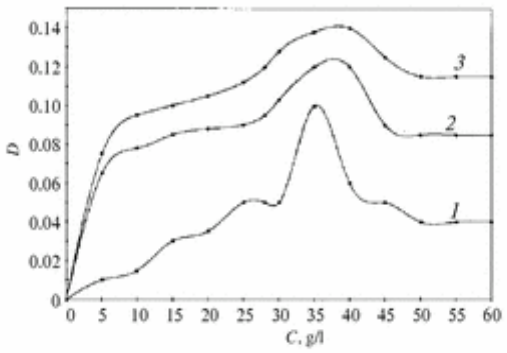

Fig. 1. Optical density (D) of solutions of polyamide fibers decorated with magnetite in the presence of cationic SA as a function of $FeSO_4$ concentration (C, g/L) in dyeing vat: without preliminary processing, magnetite synthesis "in the cold" (1); without preliminary processing, magnetite synthesis at 95-98°C (2); with preliminary processing, magnetite synthesis at 95-98°C (3).

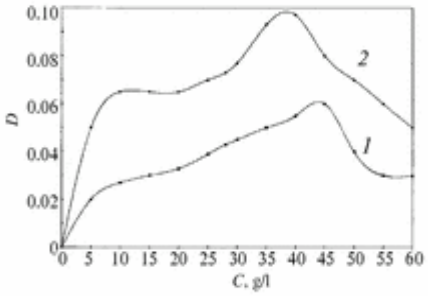

Fig. 2.

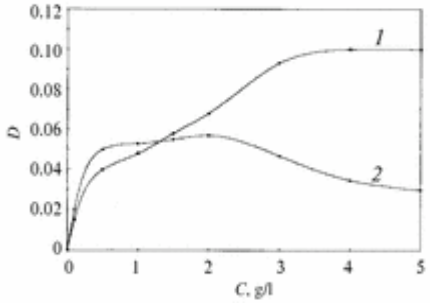

Fig. 3.

Fig. 2. Optical density (D) of solutions of polyamide fibers decorated with magnetite in the presence of anionic SA as a function of $FeSO_4$ concentration (C, g/L) in dyeing vat: without preliminary processing, magnetite synthesis "in the cold" (1); with preliminary processing, magnetite synthesis at 95-98°C (2).

Fig. 3. Optical density (D) of solutions of polyamide fibers decorated with magnetite synthesized in the presence of cationic (1) and anionic (2) SA as a function of NaCl concentration (C, g/L) in the vat for preliminary processing.

the magnetite nanoparticles onto the polyamide fiber surface. The experimental results obeyed an inverse quadratic function and an equation with correlation coefficient 0.999 that were obtained using the CurveExpert 1.3 program:

$$D = 1/(a + bC + cC^2)$$

for $a = -62.587$, $b = 2.931$, $c = -0.025$,

where D is the optical density of the solution of fibers decorated with magnetite and C, the iron sulfate concentration in the dye vat (g/L).

Magnetite nanoparticles were distributed on the fiber surface more evenly through heterocoagulation if the magnetite was synthesized in the cold in the presence of a cationic SA at the CMC. The maximum sorption was practically the same if cationic and anionic SA were used. However, magnetite synthesis in the presence of an anionic SA deposited rust-colored iron hydrous oxides and oxides. The fibrous material did not interact with a permanent magnet.

Solutions of magnetite in H_2SO_4 obeyed Beer's law. As a result, the optical density of a solution of decorated fibers was proportional to the particle concentration on the fiber. Because the maximum amount of magnetite on the