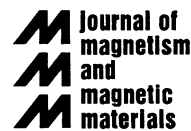




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# Preparation and properties of low boiling point of alcohol and acetone-based magnetic fluid

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## Abstract

Ultra-fine magnetic particles are difficult to be dispersed in low boiling point solvents such as alcohol ( $C_1$ – $C_4$ ) and acetone. In this paper, we report the preparation methods of several alcohol and acetone-based magnetic fluids. The stability of magnetic fluid depended on the HLB (hydrophile–lipophile balance) of the solvent and alkyl chain lengths of organic layers. The fluid was most stable only when the HLB value of surfactant and the solvents are similar. © 1999 Published by Elsevier Science B.V. All rights reserved.

*Keywords:* Low boiling point alcohol; Acetone; Magnetic fluid; HLB; Liquid crystals

## 1. Introduction

Many kinds of solvent-based magnetic fluids have been prepared and studied. Especially, as for alcohol-based magnetic fluids, alcohol series from butanol to nonanol ( $C_4$ – $C_9$ ) have been reported by Bica et al. [1,2]. However, low boiling point alcohols such as methanol, ethanol and acetone-based magnetic fluid have not been reported. When the magnetite particles are coated with a monolayer of oleate, these can never be dispersed in low boiling point alcohol ( $C_1$ – $C_4$ ) and acetone and usually these solvents coagulate the surfactant-coated magnetic particles dispersed in hydrocarbon. In this

paper, we report the preparation and properties of alcohol ( $C_1$ – $C_4$ ) or acetone-based magnetic fluid. To obtain the above, we have applied the preparation techniques used in methylphenyl silicone oil-based magnetic fluid [3] and liquid crystal-based magnetic fluid [4]. This knowledge can be used to magnetically control the alcohol fuel feeding system and also as low boiling point medium in heat pipe.

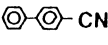
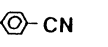
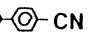
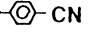
## 2. Materials and methods

Used and related materials are listed in Table 1. Magnetite particles for the preparation of magnetic fluid were synthesized by chemical coprecipitation. These particles were primarily coated with polyoxyethylene alkyl ether acetates. This was achieved by heating the magnetite suspension with surfactant at 363 K. The surfactant-coated magnetite

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Table 1  
Materials to prepare alcohol-based magnetic fluid

<b>1. Particle : Coprecipitated magnetite</b>				
<b>2. First layer on particle : Surfactant</b>				
				<b>HLB</b>
	Oleic acid			1
	Polyoxyethylene alkyl ether acetates			
	R-O-(CH <sub>2</sub> CH <sub>2</sub> O) <sub>n</sub> -CH <sub>2</sub> COONa			28
	R-O-(CH <sub>2</sub> CH <sub>2</sub> O) <sub>n</sub> -			(8)
	Sodium oleate			18
	Sodium dodecyl benzene sulfonate			37
<b>3. Second layer on particle : Liquid crystal</b>				
<b>Name</b>	<b>Composition</b>	<b>Crystal phase</b>	<b>Nematic phase</b>	<b>HLB</b>
		↓	↓	
		Nematic phase	Isotropic phase	
		K	K	
K-15	C <sub>5</sub> H <sub>11</sub> -  -CN (100%)	283-297	308	7.2
ZLI-1083	C <sub>3</sub> H <sub>7</sub> -  -CN (30%) C <sub>5</sub> H <sub>11</sub> -  -CN (40%) C <sub>7</sub> H <sub>15</sub> -  -CN (30%)	270	325	8.5
<b>4. Solvent</b>				
<b>Name</b>		<b>Boiling point</b>	<b>Melting point</b>	<b>HLB</b>
		K	K	
Methanol	CH <sub>3</sub> OH	337.7	177	8.4
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	351.3	158.5	8.0
1-Propanol	C <sub>3</sub> H <sub>7</sub> OH	370.2	146.5	7.5
1-Butanol	C <sub>4</sub> H <sub>9</sub> OH	390.3	183.5	6.8
1-Pentanol	C <sub>5</sub> H <sub>11</sub> OH	411.3	194.1	6.3
1-Hexanol	C <sub>6</sub> H <sub>13</sub> OH	430.9	226.9	5.8
Acetone	CH <sub>3</sub> COCH <sub>3</sub>	329.3	178.2	6.3

particles were coagulated by adding sulfuric acid and then filtered, dried and washed by ethanol to remove the excess amount of surfactant. Then, the surfactant-coated magnetite particles were dispersed into liquid crystal (cyanobiphenyl type K-15 or cyanophenyl cyclohexane type ZLI-1083) which formed the secondary surfactant layer on magnetite particles. Finally, the magnetic suspension obtained by dispersing these double-layer-coated magnetite particles in alcohol or acetone was centrifuged at 400g and the supernatant liquid was used in the experiments. The concentration of the magnetic particles was estimated from the magnetization measurement of the magnetic fluid.

### 3. Properties and discussion

The schematic diagram of a magnetic particle dispersed in alcohol and acetone is shown in Fig. 1. As molecules around magnetite gradually changes from hydrophobic to hydrophilic as we move from the surface of the particle towards the polar solvent, HLB (hydrophile–lipophile balance) is used as one of the parameter for the dispersion of particles in this study. Carboxyl ions adsorb well on magnetite particles. Hydrophobic chains in polyoxyethylene alkyl ether is believed to orient towards the secondary layer, i.e. liquid crystal. HLB of polyoxyethylene alkyl ether is about 8 and is higher than that of

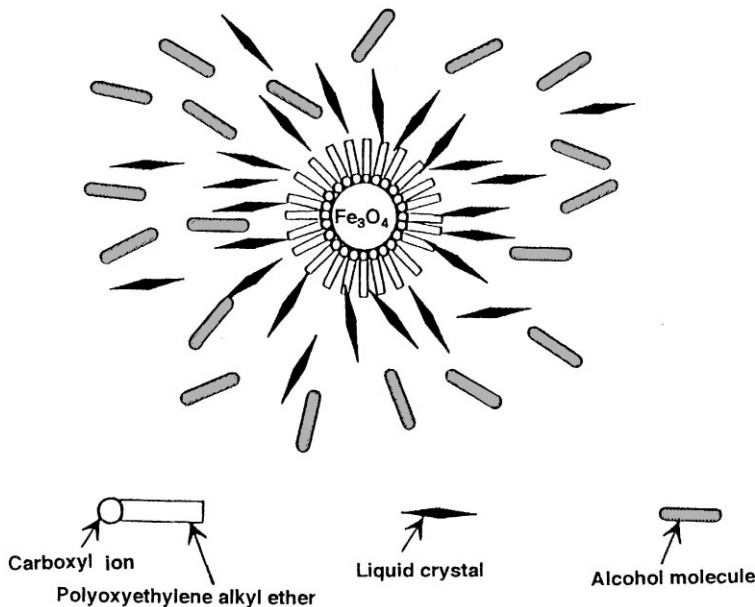


Fig. 1. Schematic diagram of surfactant-coated magnetite in alcohol.

oleic ion. HLB of liquid crystal covering magnetite as secondary layer takes a value between 7 and 9. We believe that the cyano group in liquid crystal orients towards the primary layer and are physically absorbed. At the same time, the alkyl chain faces the solvent alcohol and acetone. HLB values of alcohol and acetone are between 6 and 8 as listed in Table 1. The utilization of surfactant or organic molecules having HLB values similar to the solvent is important to obtain a stable dispersion.

The magnetization curves of ethanol-based magnetic fluids of different ethanol/magnetite weight ratios are shown in Fig. 2. The amount of liquid crystal and ethanol used were constant. Higher magnetization of the fluid means higher concentration of well-dispersed magnetite particles in ethanol. The amount of magnetite in the magnetic fluid with highest magnetization was 3.0 g in 5.0 g of ethanol. This coincides with the calculated value of magnetite that will receive complete coating with grams of liquid crystal molecule. When the amount of magnetite is increased beyond the optimum value, particles become partially covered with surfactant molecules and begin to coagulate and settle.

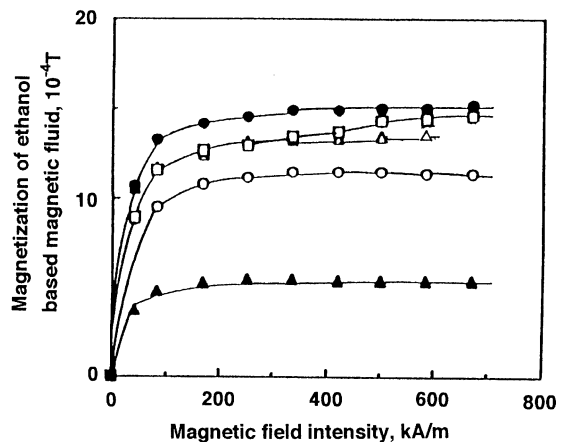


Fig. 2. Magnetization curves of stable ethanol-based magnetic fluids of different solid concentrations (liquid crystal 0.5 g, ethanol 5.0 g: constant). Added weight of surfactant-coated magnetite, g (○) 1.5, (△) 2.0, (□) 2.5, (●) 3.0, (▲) 3.5.

The stability of the magnetic fluid for varying solvent/magnetite weight ratio at 293 K was investigated and shown in Fig. 3. Saturation magnetization of alcohol-based magnetic fluid depends on the amount of solvent and is  $120 \times 10^{-4}$  T for the initial preparation condition of ethanol/magnetite

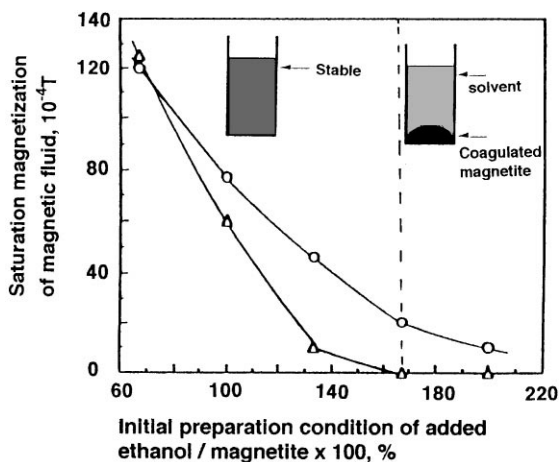


Fig. 3. Saturation magnetization of stable ethanol-based magnetic fluids for varying initial preparation condition of ethanol/magnetite weight. ( $\Delta$ ) K-15, ( $\circ$ ) ZLI-1083.

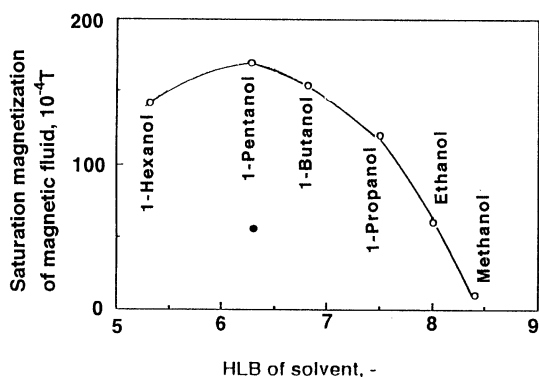


Fig. 4. Effect of solvent on the magnetization of alcohol- or acetone-based magnetic fluid. ( $\circ$ ) Alcohol ( $\bullet$ ) Acetone {(Surfactant-coated magnetite, 4.5 g); (Liquid crystal (ZLI-1083), 1.5 g); (Alcohol or acetone, 3.0 g)} constant.

weight ratio of 0.6, i.e., 80% of magnetite were sedimentated by centrifugal force and only 20% were dispersed stable. As the weight of ethanol per unit weight of magnetite increases, saturation magnetization of the fluid decreases. When cyanobiphenyl type K-15 was used as secondary layer, phase separation appeared for ethanol/magnetite weight ratio of 1.7 and the coagulated phase was re-dispersed by reducing the amount of ethanol added. Also, coagulation depended on the temperature, since K-15 undergoes phase change as shown

in Table 1. On the other hand, phase separation does not occur in the case of cyanophenyl cyclohexane type ZLI-1083 even at alcohol/magnetite ratio of 2. The ZLI-1083 molecule adsorption as secondary layer on magnetite is believed to be stronger than K-15.

The stability of surfactant-liquid crystal coated magnetite in different types of alcohol and acetone has been measured by dispersing 4.5 g of surfactant-coated magnetite, 1.5 g of liquid crystal and 3.0 g of solvent. The relationship between saturation magnetization and HLB of the solvents is shown in Fig. 4. The degree of dispersion is evaluated by the saturation magnetization of the fluid. The saturation magnetization increases with the increase in the alkyl chain length and shows maximum value when dispersed in 1-pentanol that has HLB value of 6.3. Although HLB of acetone is similar to 1-pentanol, the dispersion ratio is only equal to that of ethanol. The alkyl chain in liquid crystal is composed of 30% of  $C_3H_7$ , 40% of  $C_5H_{11}$  and 30% of  $C_7H_{15}$  as shown in Table 1. The dispersion ratio is largely related to the alkyl chain type of the secondary surfactant layer. This is believed to be the reason for high magnetite content in 1-pentanol.

#### 4. Conclusion

Low boiling point alcohol ( $C_1$ – $C_4$ ) and acetone-based magnetic fluid has been prepared by dispersing magnetite coated with polyoxyethylene alkyl ether acetates and nematic liquid crystal molecule as primary and secondary layers, respectively. HLB of surfactants and solvent was around 8 and similar HLB values of surfactants and solvents are very important for better dispersion.

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