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Preparation and Characterization of Dysprosium-neodymium Modified Magnetic Fluid Coated by Agar

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Abstract: The experiment used agar as a coating agent to manufacture dysprosium-neodymium modified water-based magnetic fluid coated by agar with the method of chemical co-precipitation when the two rare-earth element dysprosium and neodymium were precipitated with Fe$^{3+}$ and Fe$^{2+}$ together, which has high stability and a strong magnetic field. After the experimental research on all aspects of factors influencing the magnetic fluid, the best conditions were summarized as follows: Under the premises those the mol ratio between Fe and (Nd$^{3+}$+Dy$^{3+}$) is 29:1 and it between Fe$^{3+}$ and Fe$^{2+}$ is 1.70 to 1.75, the mol ratio between Nd$^{3+}$ and Dy$^{3+}$ should be 1:1; 25%NH$_3$·H$_2$O is the precipitation reagent and the pH value regulator, which is used to control the pH value between 9 and 11; Under the above-mentioned conditions, dysprosium-neodymium modified water-based magnetic fluid is manufactured at the reaction temperature 35°C. And then the agar with a high degree of biological affinity is used as a coating agent to coat the above product, under the conditions of the temperature 55°C and the pH value 2.5, whose best dosage is 0.0100g each 55mL liquid. The dysprosium-neodymium ferrite water-based magnetic fluid manufactured under the best conditions has black color, and its stability and magnetic properties are better than those of the ordinary one. It will appear a bright magnetic halo under the combined effect of the visible light irradiation and the role of magnetic fields. In addition, its characterization was tested in this experiment, such as the situation of surface coating, the stability, the viscosity, the magnetization intensity, etc.

Keywords: Agar, co-precipitation method, influencing factors

Introductions
Magnetic fluid is a novel functional nano-material. In the present study, highly magnetized material...
has been intensively studied. A number of researchers prepared the material with mixing Dy. However, the previous research has been limited to adding less than one element. In the work here, we describe a process to fabricate dysprosium-neodymium modified magnetic fluid coated by agar. The effect of various parameters like pH, temperature, viscosity, magnetization, coating and stability are investigated and data on viscosity and magnetization are presented. In addition, IR and spectrophotometry are performed for characterization of materials.

2. Materials and method

2.1 Apparatus
In this study, IR has been used for the determination of coating; viscosity and magnetic susceptibility were measured with NDJ-1 rotation viscometer and magnetic balance, respectively. Spectrophotometric measurements of Fe% were performed with UV-2401PC spectrophotometer.

2.2 Materials and reagents
FeCl$_2$$\cdot$4H$_2$O, FeCl$_3$$\cdot$6H$_2$O, NH$_3$$\cdot$H$_2$O were all analytical reagent grade, Dy$_2$O$_3$ ($\geq$99.5%) and Nd$_2$O$_3$(99.9%), agar was C.P.

2.3 Preparation
Magnetic fluid was prepared with co-precipitation method\cite{1-4}; the factors affecting the temperature, pH and ratio of Dy and Nd, as well as the coating performance were investigated.

3. Results and discussion

3.1 Effect of Temperature
The optimal coating time of agar was at 55°C. It can be assumed that this reaction, on base of coating, was a chemical reaction, the higher temperature could be beneficial to it. However, the temperature over 55°C, particles tended to be oxidized or desorbed, at the same time, the coating was not complete at temperature lower than 55°C.

3.2 The dosage of agar
The quality of agar was taken 0.0010g, 0.0050g, 0.0100g, 0.0200g, 0.0300g respectively; the best quality is 0.0100g. If the amount of agar was low, the coating was not perfect, conversely, multilayer sorption could be formed and it leaded the magnetic properties reduced\cite{5}.

3.3 The effect of pH
The pH of co-precipitation: the Dy$_x$Nd$_y$Fe$_{(3-x-y)}$O$_4$ was prepared by co-precipitation method, the condition was controlled that the Fe$^{2+}$, Fe$^{3+}$, Nd$^{3+}$, Dy$^{3+}$ which were simultaneously precipitated. The pH ranged 9 from11, due to the Fe$^{3+}$ was more easily precipitated, but Fe$^{2+}$, Nd$^{3+}$, Dy$^{3+}$ precipitated could be high concentration of OH$^-$. The pH of coating: the pH from 2 to 3 was best. Keeping pH 2, the magnetic liquid was received oxidation resistance. However, Zeta Potential could be produced by the lower pH and it had negative effects to liquid\cite{7}.

3.4 Character of products
3.4.1 IR studies
Using the IR spectrometer to detect surface active agent was adsorbed on materials. From the spectrogram, it demonstrated the magnetofluid was loaded by agar.

3.4.2 Settleability
Let it stand for one year or stirring 3000r/min for 30 min, the colloid had not laminating and precipitation, the result indicated that it was stability and good coating; Of all the reasons, the grain
diameter was less than 16nm, it due to the more stability.

3.4.3 Thermal stability

The magnetofluid was not stability, it lost magnetism and became the brick red fluid, when the temperature was over 75°C.

3.4.4 Calculating of Fe%

The percentage of Fe was analyzed by colorimetry of Sulphosalicylic acid, at the 450nm. The computing formula as shown:

\[
Fe\% = \frac{C \times 100 \times 10^{-6} \times 100}{m} \times \frac{250}{5} 
\]

(c: concentration of Fe; m: quality of sample)

The ratio of ideal magnetofluid was n(Fe): [n(Dy\(^{3+}\))+n(Nd\(^{3+}\))]=29:1, total mol of Dy and Nd had 1/30; the molecular formula was \((\text{DyNd})_{0.0483}\) \(\text{Fe}_{2.9033}\)\(\text{O}_{4}\). The true value of Fe% was 61.36% using the 1.1 computing formula to calculate. Comparing with theoretical value the 67.34%, the result could be acceptable.

3.4.5 Viscosity and percentage

The viscosities were monitored by using a rotation viscometer at 30°C, it was 2.07 mPa·s. In the continuous mechanics opinion, the viscosity increases with the increase of internal friction of solid particle as fluid flow. Using Einstein formula\(^{[1]}\) to calculate \(\Phi\), it was 0.43. Einstein formula:

\[
\eta = \eta_0 (1 + 5\phi / 2)
\]

\(\eta\) viscosity of magnetic liquid; \(\eta_0\) viscosity of non-magnetic liquid; \(\Phi\) percent by volume

3.4.6 Magnetic property

The magnetofluid prepared by different mixing ratios of Dy and Nd was determined by magnetic balance at the H=100mT, the results were showed in table 1.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>magnetization of magnetofluid with different ration of Dy and Nd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mol ratio of Dy and Nd</td>
<td>0:10</td>
</tr>
<tr>
<td>Dosage of Dy/mL</td>
<td>0.0</td>
</tr>
<tr>
<td>Dosage of Nd/mL</td>
<td>10.0</td>
</tr>
<tr>
<td>(d) (g/mL)</td>
<td>1.0010</td>
</tr>
<tr>
<td>Mass susceptibility (\chi)</td>
<td>13.1068</td>
</tr>
</tbody>
</table>

continuing

| Mol ratio of Dy and Nd | 6:4 | 8:2 | 10:0 | 0:0 |
| Dosage of Dy/mL | 6.0 | 8.0 | 10.0 | 0.0 |
| Dosage of Nd/mL | 4.0 | 2.0 | 0.0 | 0.0 |
| \(d\) (g/mL) | 1.0040 | 1.0088 | 1.0102 | 0.9937 |
| Mass susceptibility \(\chi\) | 17.2700 | 15.6474 | 13.2724 | 7.8544 |

Table 1 reveals that the products prepared by adding Dy and Nd has the 2.6 times magnetism than not adding Dy and Nd, the best condition is that the mol ratio of 1:1 and the dosage of Dy and Nd is 5.0mL. The structure of Fe\(_5\)O\(_4\) with spinel-type: \((\text{Fe}\(^{3+}\)[Fe\(^{3+}\)Fe\(^{2+}\)]\)\(\text{O}_4\), (Fe\(^{3+}\)) as the A and [Fe\(^{3+}\)Fe\(^{2+}\)] as B. The metal can be padded and replaced Fe of \((\text{Fe}\(^{3+}\)[Fe\(^{3+}\)Fe\(^{2+}\)]\)\(\text{O}_4\), because of the A and B had many gaps\(^{[8]}\). The magnetic moment can be improved due to Dy\(^{3+}\) and Nd\(^{3+}\) padded and replaced the B. Reaction principle was suggested as follow:

\[(1-x-y)\text{Fe}^{2+}+2\text{Fe}^{3+}+8\text{OH}^-+(y)\text{Nd}^{3+}+(x)\text{Dy}^{3+} \rightleftharpoons \text{Dy}_x\text{Nd}_y\text{Fe}_{(1-3-x-y)}\text{O}_4 + 4\text{H}_2\text{O} \]
4. Conclusions
Finding showed that the dysprosium-neodymium modified magnetic fluid was obtained by coprecipitation method at the $n(\text{Fe}) : [n(\text{Nd}^{3+}) + n(\text{Dy}^{3+})] = 29:1, \ n(\text{Fe}^{3+}) : n(\text{Fe}^{2+}) = 1.70 \sim 1.75, \ n(\text{Nd}^{3+}) : n(\text{Dy}^{3+}) = 1:1, \ T = 35 \ ^\circ \text{C}, \ \text{pH rang 9 from 11}, \ \text{stirring at 3000r/min}, \ \text{ammonia as precipitator and regulator.}$

The products coating by agar was stability when agar as surface active agent was 0.0100g/55mL, pH 2.5, $T = 55 \ ^\circ \text{C}, \ \text{stirring at 3000r/min}.$

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References