Research on the Electrooptical Effect of ER Fluids
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Abstract. An investigation was made to observe the electrooptical effect of ER fluids prepared with starch and silicon oil through experiments, in which the transmitted light intensity of ER fluid samples with different concentration were measured under varying external electric field. The results show that the detected photocurrent increases first and then decreases with the increasing of electric field; the sample with higher concentration reaching the peak value of photocurrent requires a lower external electric field, but it has an opposite effect for the sample with lower concentration. The electric field has better tunability for the refractive index of sample with lower concentration than for that with higher concentration.

Instruction
ER fluids are usually a suspension of small particles of high dielectric constant dispersed in a insulating liquid, under the application of external electric field, it is able to produce phase transition instantly, from liquid to a sort of solid-like substance with high viscosity; and it returns to its original liquid state rapidly when the electric field is canceled. This change is not only rapid and reversible, but also continuous and regulable. The electrorheological macroscopic behavior of ER fluids originates from the particles interacting to form chain/column-like structure parallel to the applied electric field under the influence of external electric field. Such structure transformation of ER fluids not only influence its mechanical properties, but also has significance effect on its electrical, optical, electromagnetic and acoustical properties. Zhao, etc. have made some investigations on the optical characteristics of ER fluids such as transmission, diffraction, near-infrared, etc. and also studied its regulating effect on the transmission and reflection of microwave [1-7].

In this paper we will investigate the electrooptical effect of ER fluids of starch dispersed in silicon oil under the application of external electric field, and measure the transmitted light intensity of ER fluid samples with different concentration under varying external electric field.

Experiment
Materials
Samples of ER fluids were prepared by putting starch particles into silicon oil and then stirring them to form opalescent suspension. Samples with three different concentrations were made with their mass percent being 0.5%, 0.75% and 1.0% respectively.
Experimental Setup and Process

The experimental setup is shown in Figure 1 which consists of a laser, polarizer, high voltage DC supply, analyzer and electrooptical detector arranged in sequence.

Each sample of ER fluids was placed into a container which is a plastic cuboid. Two copper sheet electrodes were adhered to two opposite side faces of the container, with a distance of 13mm between them, and the width of which is large enough to ignore the influence of fringe field. An adjustable high voltage DC supply was connected to both electrodes. An electrooptical detector was used to detect the light passing through the ER fluid sample in the form of photocurrent. Two polarizers have mutually perpendicular polarization orientation, and both perpendicular to the electric field. When no sample was placed there, there was no transmission of light from these two orthogonal polarizers. After putting in the ER fluid sample, if no electric field was applied, no light passed through; however, when the electric field was increased to a certain extent, light transmission can be found in this optical system.

In this experiment, we changed the voltage applied to the ER fluid sample step by step, observing the variation of light intensity, so as to investigate the relationship between the light transmission and the electric field. The photocurrent value was detected at intervals of 1kV, while considering the external interference this value had been recorded every second for five times.

Results and Analysis

The resulting I-E curves of ER fluid samples with three different concentrations are given in Figure 2, Figure 3 and Figure 4, with its horizontal axis as the applied electric field and vertical axis as the detected photocurrent. They display the variations of transmission light along with the changing of electric field strength.

Figure 2. The variation of photocurrent with electric field (0.5% concentration).

In Figure 2, when the electric field is in low range, the curve goes up slowly, approximating linear variation; when the electric field strength reaches 0.6-0.7kV/mm, the curve suddenly rises to its peak and then decline abruptly.
From Figure 3, it can be seen that for the sample of 0.75% concentration the photocurrent value changes gently as the electric field is less than 0.3kV/mm, after that, it increases very rapidly, reaching its maximum point at 0.5kV/mm, then starts to decrease.

It can be known from Figure 4 that, when the electric field being increased to beyond 0.15dV/mm, the curve starts to rise rapidly, and the photocurrent reaches its maximum value at about 0.4kV/mm, then it decreases with a relatively lower speed than the above two cases.

After taking an average of the photocurrent values from Figure 2, Figure 3 and Figure 4 respectively and plotting them in one single diagram, Figure 5 is obtained then. Through comparing the three curves in Figure 5, it can be found that:
The changing trends of the above three curves are all first rising then declining.

(2) For the ER fluid sample with higher concentration, reaching its maximum photocurrent value requires lower electric field strength, while for those with lower concentration, the opposite effect is presented.

(3) The curves for 0.75% and 0.5% concentration both have intense fluctuations with similar maximum photocurrent value, but the curve for 1.0% concentration exhibits a relatively slower changing trend.

Discussion

Here, some discussion will be made to explain the above phenomena. At the beginning, since the electric field strength is not high enough, the starch particles in ER fluid are still in the state of uniform distribution, leading to no transmission lights. When the electric field is increasing gradually, the starch particles are becoming polarized and interacting with each other, thus forming chain- or column-like structures parallel to the electric field, then the ER fluid changes from isotropy to anisotropy, turning into a sort of analogous birefringence material with the application of electric field, hence it produces birefringence phenomenon with the light incident upon, thus the transmission light gradually increases, so does the photocurrent detected. Then, as the electric field increases to a certain value, the chain- or column-like structures and the corresponding gaps between them become more and more regular and orderly, therefore, the transmission light increases rapidly, so does the corresponding photocurrent, thus leading to the fast rise of the I-E curve. Afterwards, with the further increasing of the electric field, much more chain- or column-like structures are formed, giving rise to the blocking of light, hence the photocurrent decreases, and the characteristic curve begins to decline accordingly.

The curve for higher concentration ER fluid is much smoother, due to the more starch particles forming thicker chain- or column-like structures with narrower gaps, and it is possible that there are also particles in those gaps. So it has weaker birefringence phenomenon for ER fluid with higher concentration, with smaller transmission light intensity.

Conclusions

The paper has conducted some investigation on the electrooptical effect of starch ER fluid. Samples with three different concentration were prepared and their I-E characteristic curves have been plotted through experiments, obtaining the variation of the transmission light intensity with the electric field, then a discussion has been made accordingly. Some conclusions are drawn as follows.

(1) The starch ER fluid has electrooptical effect under the application of external electric field. Those I-E curves for ER fluid with different concentration have the same changing trend, all first rising then declining. The higher the ER fluid concentration is, the lower electric field strength is required to reach the maximum photocurrent value.

(2) With the increasing of concentration, the electrooptical effect of starch ER fluid becomes weakening and the transmittivity of light decreases. So the voltage has stronger regulation effect on the refractive index of starch ER fluid with lower concentration than that with higher concentration.

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References


