Annals of R.S.C.B., ISSN: 1583-6258, Vol. 25, Issue 1, 2021, Pages. 5485 - 5493
Received 15 December 2020; Accepted 05 January 2021.

# Investigation of Magneto-Optical Properties of Ferro Fluid Nanoparticles by Optical Transmittance

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**Abstract**

Magnetite nanoparticles have been prepared by chemical co-precipitation method. The transmission of light through magnetic fluid has been investigated as a function of particles and thickness of the films with wavelength in between 450 and 750 nm, and parallel as well as perpendicular applied magnetic fields. It was found that the transmittance increased with the increasing applied magnetic field for both parallel and perpendicular directions. The onset of transmittance shifts to higher wavelength with increasing film thickness. For a given film thickness, the transmittance increases with increasing magnetic field. The ordered structures of the magnetic columns were formed in the magnetic fluid films under the influence of the external magnetic field are responsible for significant field dependent transmittance observed. We believe synthetized magnetic nanomaterial has a potential for magneto optic devices as well as biomedical applications.

**Keywords**: Magnetic fluid; Transmittance; perpendicular, magnetic field

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## 1. Introduction

Nanoscale particles showing a superparamagnetic behavior have been intensively studied these past years for both enhanced and novel applications in biomedical and diagnostic fields [1,2]. Such nanoparticle shapes, the particle size, composition and external magnetic field affect its magnetic, optical, chemical and mechanical properties.

Several synthesis processes are used in the development of magnetic nanoparticle. For this reason, the conditions of synthesis are crucial to determine the physicochemical properties of magnetic nanoparticle such as concentration and pH of the solution as well as the mode of heat treatment [3,4]. The most important methods described in the literature to prepare magnetic nanoparticle, which are suitable for biomedical applications [5-9], are: co-precipitation, microemulsions polyol process, high temperature decomposition of organic precursors, assisted sonochemical, electrochemical methods and sol-gel process. It is important for biomedical applications, to know the synthesis process of the nanomaterial – which needs to be dispersed in water – and also, the study of biocompatibility and toxicity that must possess adequate characteristics for such applications. In the case of iron oxide nanoparticle coated with biocompatible material determining the crystal phase, the average diameter and the magnetic property are important, which can be measured using several techniques.

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Recently there has been considerable interest in magneto optic devices which combines magnetic and optical phenomena [10, 11]. The magnetic field and wavelength dependence of the optical transmittance for some magnetic fluids have been reported [12-15]. Investigation of magneto optical characteristics of ferrofluids is an important task aimed at the development of novel optoelectronic systems. In this paper, the variation of the transmission of light through $Fe_3O_4$ magnetic fluid film has been investigated as a function of external magnetic field and incident optical wavelength.

## 2. Experimental

The synthesis of magnetite nanoparticles has been prepared by chemical co-precipitation. The mean particle size is monitored by varying pH value. The mean size is strongly dependent on the acidity, and clearly decreases with increasing pH. The magnetic fluids are dispersion of synthesized nanoparticles of $Fe_3O_4$ with oleic acid coating in kerosene. The crystal structure of the particles was analyzed by x-ray diffraction. The particles are exhibits pure $Fe_3O_4$ structure. The average particle size, shape and morphology were examined using Transmission electron microscope (TEM). The TEM images revealed a uniform spherical shape of the particles with very different mean sizes not shown here. A drop of magnetic fluid is injected into a 10 μm thick glass cells to form a magnetic fluid film, which is placed between the poles of an electromagnet and is normal to the axis of light. The intensity of transmitted light can be measured as a function of incident wave lengths between 450 and 750 nm and applied magnetic fields upto 40 Oe for all the films.

## 3. Results and discussion

The variation of the transmittance as a function of wavelength with a various applied magnetic fields for the magnetic fluid film of $Fe_3O_4$ particles are shown in figures 1 as the magnetic field is perpendicular to the film. In general, the transmission threshold shifts to lower energy side and a reduction of the average transmission are observed with increasing magnetic fluid film thickness. This may be due to the elongation of the traveling path as the light passes the films. The variation of transmittance as a function of the wavelength between 450 to 750 nm is quite high, under zero magnetic field near 450 nm is almost 45% and it increases monotonically with increasing wavelength and saturates at 57 % near 750 nm in 10 μm depth film. The variation of transmittance due to magnetic field is quite different compare to that of the zero magnetic field for 10 μm depth film. However the transmittance value is increases with increasing magnetic field. In figure 2 shows the variation of transmittance as a function of the magnetic field for fixed wavelength between 450 to 750 nm. Under zero magnetic field near 500 nm is roughly 47 % and it increases monotonically with increasing magnetic field upto 10 Oe and saturates above 10 Oe in 10 μm depth films. We also found that under a given magnetic field, the transmittance decreases exponentially with the increasing film thickness for all the samples. The variation of transmittance due to magnetic field is increased with increasing magnetic field. Similarly, the variation of the transmittance as a function of wavelength with a various applied magnetic fields for the magnetic fluid film of $Fe_3O_4$ particles are shown in figure 3 as the magnetic field is parallel to the film. The variation of transmittance as a function of the wavelength between 450 to 750 nm is quite high, under zero magnetic field near 450

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nm is almost 82% and it increases monotonically with increasing wavelength and saturates at 87 % near 750 nm in 10 μm depth film. The variation of transmittance due to magnetic field is quite different compare to that of the zero magnetic field for 10 μm depth film as the magnetic field is parallel to the film. However the transmittance value is increases with increasing magnetic field, the value of transmittance is high compare to that of the perpendicular magnetic field. In figure 4 shows the variation of transmittance as a function of the magnetic field for fixed wavelength between 450 to 750 nm as the magnetic field is parallel to the film. Under zero magnetic field near 500 nm is roughly 83 % and it increases monotonically with increasing magnetic field upto 10 Oe and saturates above 10 Oe in 10 μm depth films as the magnetic field is parallel to the film. We also found that under a given magnetic field, the transmittance decreases exponentially with the increasing film thickness for all the samples. The variation of transmittance due to magnetic field is increased with increasing magnetic field. This indicates that under an applied magnetic filed, the variation of the transmittance is mainly dependent on the area covered by the droplets of the emulsions in the magnetic fluid thin films. To clarify the mechanism of these different behaviors, we studied their microscopic pictures as shown in figure 5 and 6. Under perpendicular magnetic fields, originally dispersed magnetic particles agglomerate to form ordered structures (figure 5). It shows that the size of the droplet in the emulsions decreases with increasing particle size. We found that the lower particle size samples aggregated to form an ordered structure under an applied magnetic field and the number of the droplets per unit area decreases. The number of droplets per unit area is increases with increasing magnetic field. The transmittance value is an indicator of the structures formed in the fluid. It reveals that the ferrofluid structures appear to be very sensitive to particle size. The variation of the transmittance is mainly dependent on the amount of light being scattered by the sample, which is determined by the size, shape, and number of scatterers in the magnetic fluid films under an applied magnetic field. To clarify the mechanism of these different behaviors, we studied their microscopic pictures. Figure 6 show the typical microscope photographs of the ferrofluid under parallel magnetic fields for the 10 μm films. At zero magnetic field, one can see the separate droplets, randomly distributed in the films. This different aggregation ability of the magnetic fluid films of different particle is responsible for the variation of the optical transmittance under magnetic field.

## 4. Conclusions

$Fe_3O_4$ nanoparticles have been prepared by chemical co-precipitation method. The transmission of light through magnetic fluid has been investigated as a function of particles and thickness of the films with wavelength in between 450 and 750 nm, and parallel as well as perpendicular applied magnetic fields. It was found that the transmittance increased with the increasing applied magnetic field for both parallel and perpendicular directions. The onset of transmittance shifts to higher wavelength with increasing film thickness. For a given film thickness, the transmittance increases with increasing magnetic field. The ordered structures of the magnetic columns were formed in the magnetic fluid films under the influence of the external magnetic field are responsible for significant field dependent transmittance observed.

**Acknowledgements**

The Authors greatly thankful for the support from the management of Koneru Lakshmaiah Education Foundation (KLEF), Principal and Management of Marri Laxman Reddy Institute of Technology and Management (MLRITM) for providing facilities.

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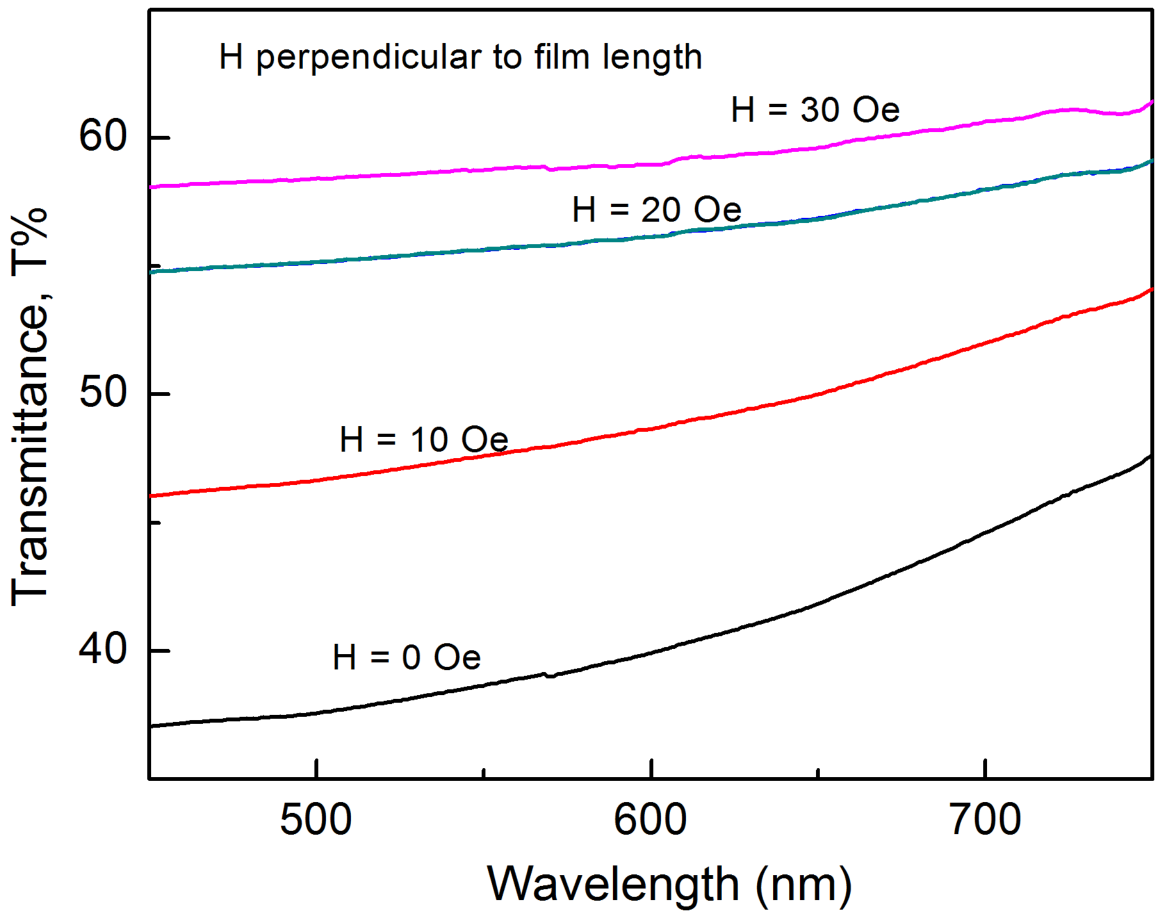


**Figure 1. The variation of the transmittance as a function of wavelength with a various applied magnetic fields for $Fe_3O_4$ particles with 10 μm film in perpendicular magnetic field.**

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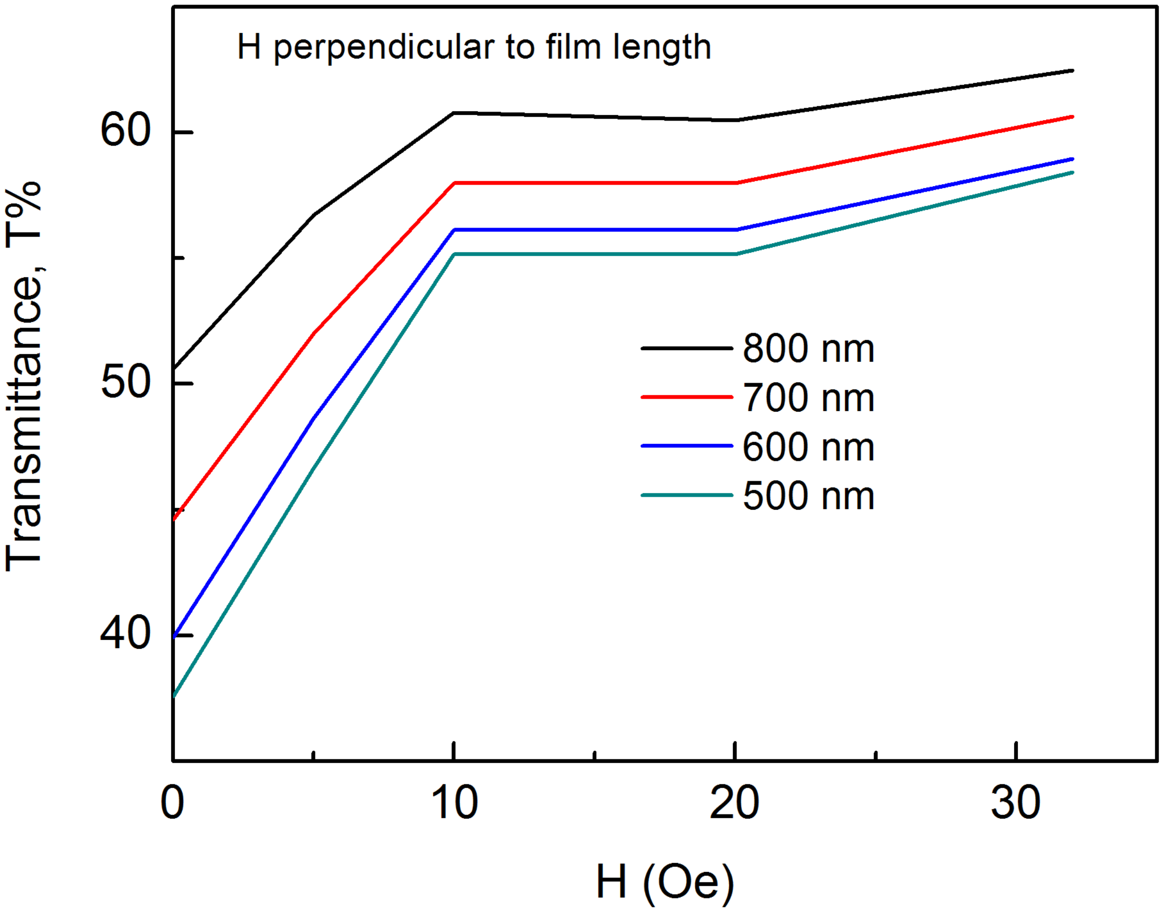


**Figure 2. The variation of the transmittance as a function of magnetic field with fixed wavelengths for $Fe_3O_4$ particles with 10 μm film in perpendicular magnetic field.**

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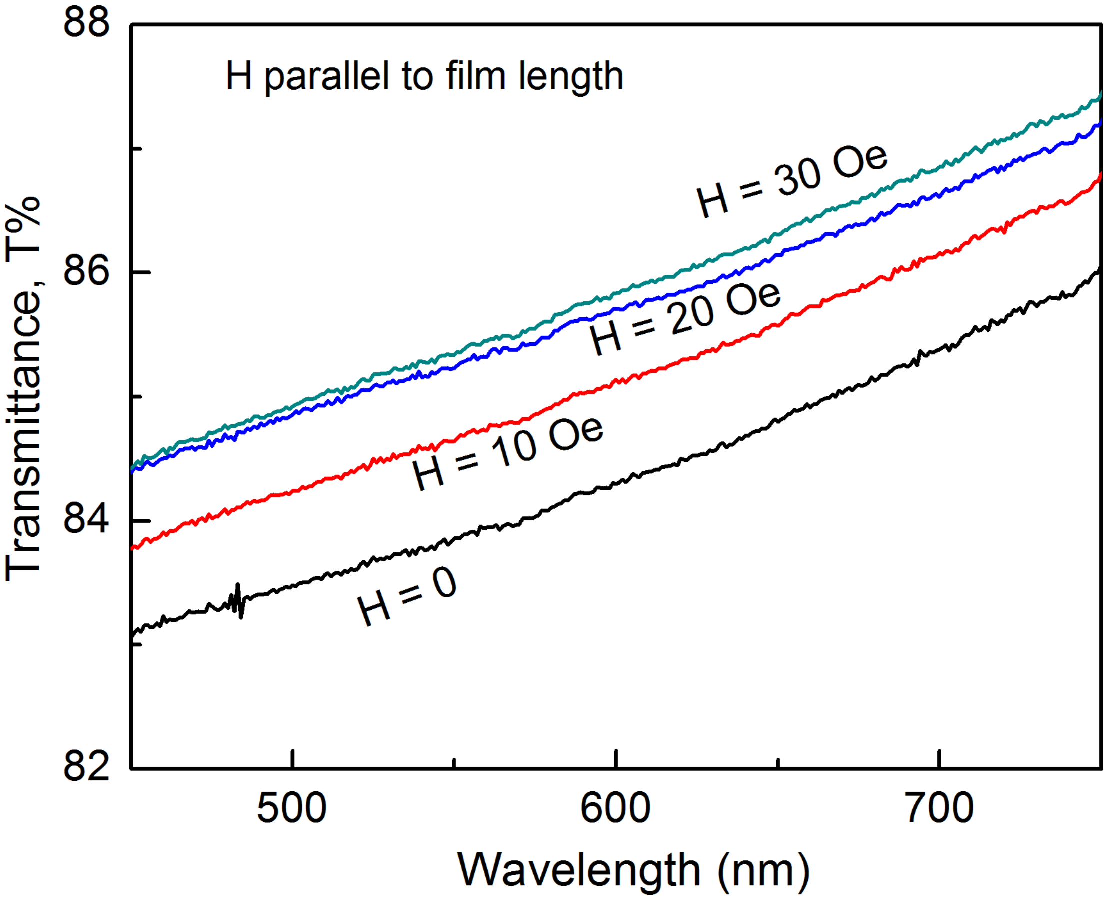


**Figure 3. The variation of the transmittance as a function of wavelength with a various applied magnetic fields for $Fe_3O_4$ particles with 10 μm film in parallel magnetic field.**

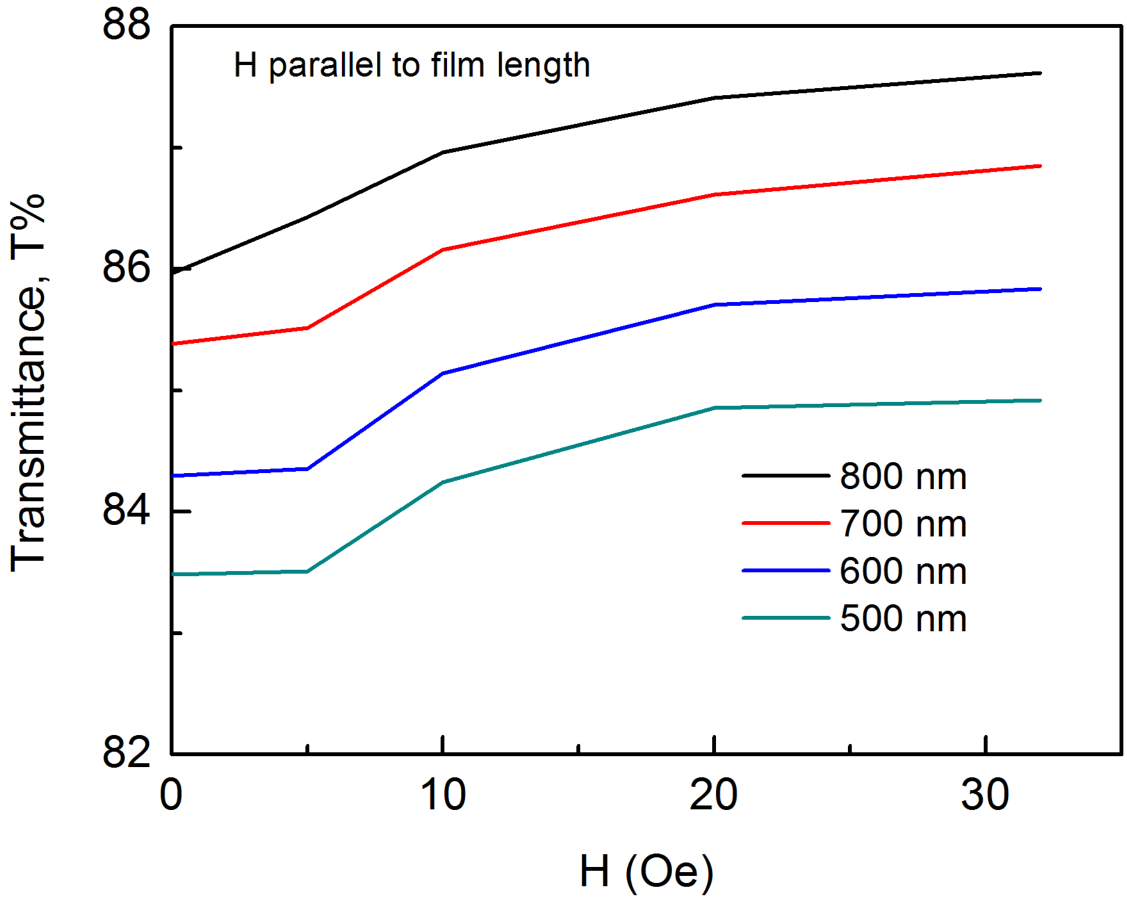


**Figure 4. The variation of the transmittance as a function of magnetic field with fixed wavelengths for $Fe_3O_4$ particles with 10 μm film in parallel magnetic field.**

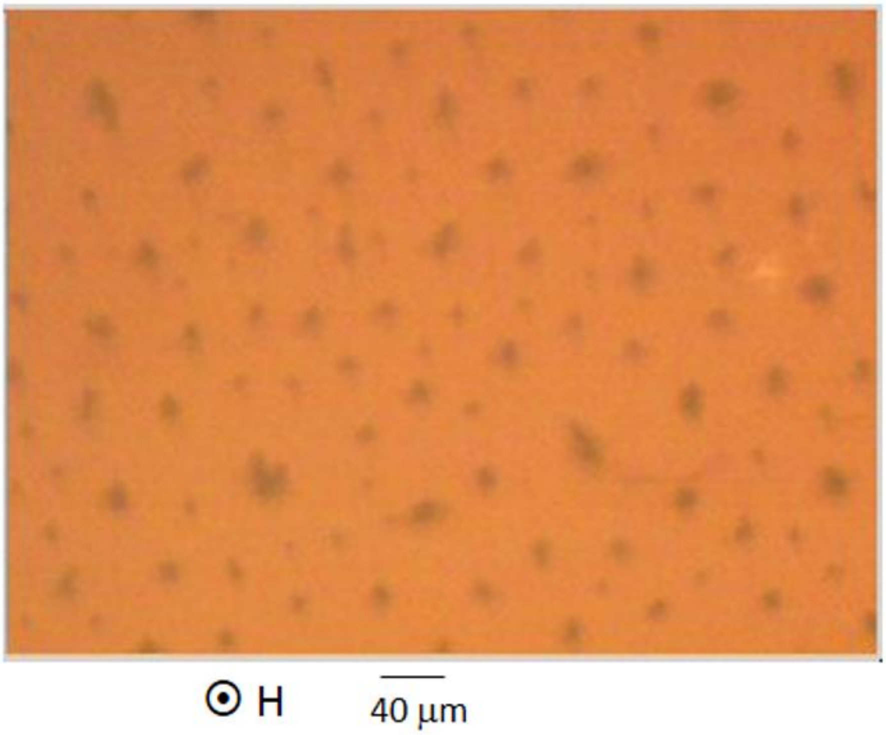


**Figure 5. Optical micrographs of magnetic fluid at perpendicular magnetic field of H = 25 Oe.**

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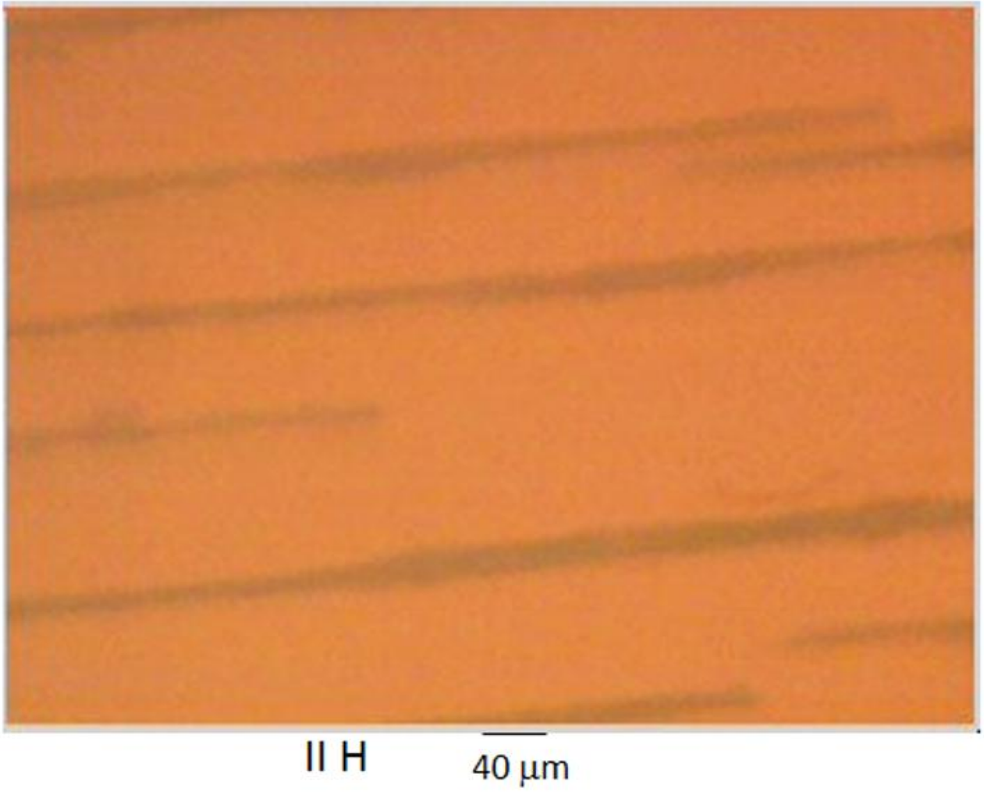


**Figure 6. Optical micrographs of magnetic fluid at parallel magnetic field of H = 25 Oe.**