



Study of the Optical Properties of Cobalt Ferrite Magnetic Liquids

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Authors' contributions

This work was carried out in collaboration among all authors. Author NL designed the study, wrote the protocol and performed the experiments. Authors AMN, DB and BD performed the data analysis and wrote the first draft of the manuscript. Authors DB, TJ and BD managed the literature searches and revised the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

In this study, we discussed the optical properties (Faraday rotation, transmittance and Merit factor) of two samples of magnetic liquids synthesized by co-precipitation and an additional hydrothermal synthesis of cobalt ferrite (CoFe₂O₄) developed according to the protocol developed by R. Massart at the PHENIX laboratory at Pierre and Marie Curie University in the form of ferrofluids. The measurements were carried out using the spectral polarimetric bench (400-1600 nm). The materials did not meet the standard and did not allow a good Faraday rotation due to their preparation conditions. Cobalt ferrite is a hard ferrimagnetic material, having many important applications in the field of magnetic storage and spintronics. The results show a very high spectral Faraday rotation in the Telecom range (1550 nm) with good transparency in the infrared of the transmittance spectra and a strong merit factor around 1550 nm, with a value of the order of 11°. For a cobalt ferrite magnetic liquid obtained hydrothermally.

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1. INTRODUCTION

The aim of our study is to study the optical properties, of cobalt ferrites (CoFe₂O₄) obtained by the method of R. Massart [1-3] which are diluted in water by reducing their initial volume concentration at $\phi = 0.1\%$ [4] as a function of the wavelength in the range 400-1600 nm. The materials did not meet the standard and did not allow a good Faraday rotation due to their preparation conditions. The Faraday rotation improves the merit factor which is very important in the resolution of the insulator. The use of ferromagnetic materials is a technique which makes it possible to address this problem mentioned above. The interest is to compare the curves giving the Faraday rotations, the transmittance and the merit factor [4] of these different original ferrofluids based on CoFe₂O₄ according to their size and their treatment.

2. MATERIALS AND METHODS

2.1 Materials

The samples used during this work were developed [2] at the PHENIX Laboratory by the team of Mrs. S. Neveu [5] whom we would like to thank in passing. These Ferrofluids were obtained by coprecipitation and hydrothermal synthesis [5] and have diameters of 15 and 20 nm as shown in Table 1.

2.2 Methods

The measurements were carried out using the spectral polarimetric bench (400-1600 nm) illustrated in the following Fig. 1 making it possible to characterize the optical properties. Bench too sensitive because we measure hundredths of a degree.

Table 1. Characteristics of ferrofluids

Magnetic liquids of cobalt ferrite	$\frac{[C_o]}{[F_e]}$	Φ (%)	Diameter \approx nm	Treatment
S487			20	Coprecipitation
S489A	0,39	1,7	15	Hydrothermal

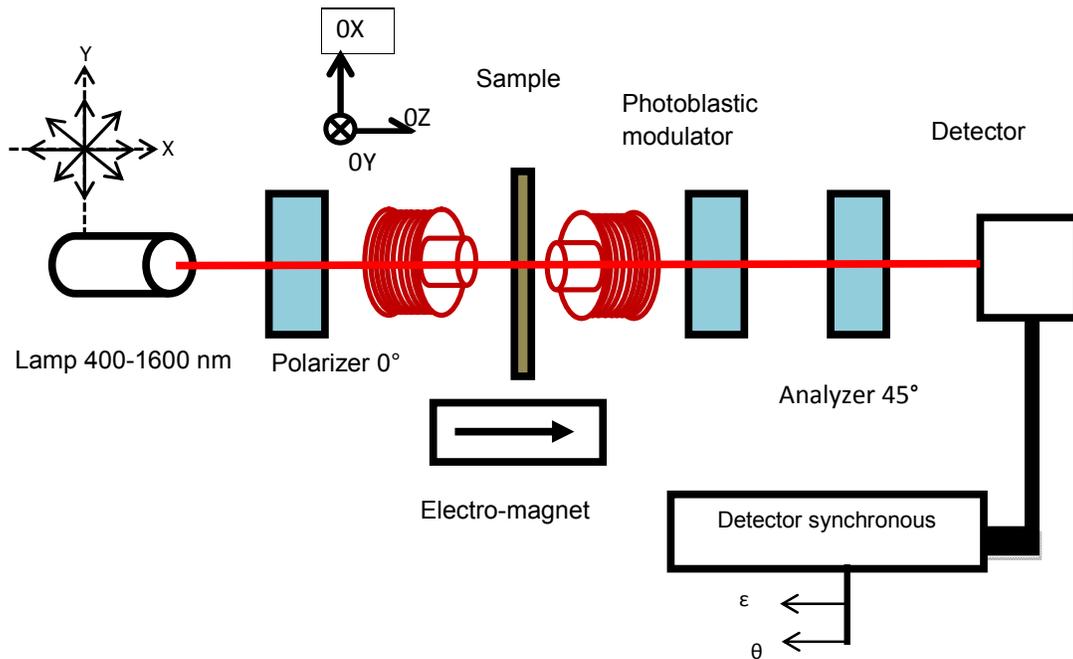


Fig. 1. Installation using the spectral polarimetric photo elastic modulator

His bench is made up of a lamp which sends a random light source which crosses the polarizer. After the polarizer, the light is polarized rectilinearly and after having crossed the sample, it undergoes a Faraday rotation. It should be noted here that the polarizer and the analyzer each rotate in a rotator controlled by a computer; and for each position of the two, the detector takes an intensity measurement: although measuring intensities, the purpose of the bench is to determine the phase shift produced by the sample [6].

3. RESULTS AND DISCUSSION

3.1 Faraday Rotation

A study of Faraday rotation (RF:(°/cm)) as a function of wavelength was made by the spectrophotometer in the wavelength range from 400 to 1600 nm. The measurements were made at room temperature. The spectra show a sign change from positive to negative of the RF producing two peaks around 750 nm and 1550 nm. The Faraday rotation spectra of the different ferrofluids follow the same behavior but it is different depending on the type of ferrofluids (coprecipitation or hydrothermal) when they are superimposed. Faraday rotation reaches a

minimum value at 750 nm and a maximum value at 1550 nm, which improves rotation (Fig. 2). This improvement is due to the type of materials and the conditions of sample preparation and experimentation.

3.2 Transmittance

Optical transmittance measurements ($T(\%) = f(\lambda)$) were carried out with a spectrometer in the wavelength range from 400 to 1600 nm of these different ferrofluids to allow the optical quality of the ferrofluids to be determined. For transmittance, the spectra also exhibit differences in behavior with good transparency in the telecom range. It can be seen (Fig. 3) for these different ferrofluids of CoFe_2O_4 that the more the size increases, the more the transmittance decreases for similar volume concentrations: which leads us to say that the transmittance depends on the size of the particles; and it is very important for the ferrofluids obtained by hydrothermal route than for the ferrofluids obtained by coprecipitation. Our results are consistent with the various works in the literature [7-9]. This improvement is due to the type of materials and the conditions of sample preparation and experimentation.

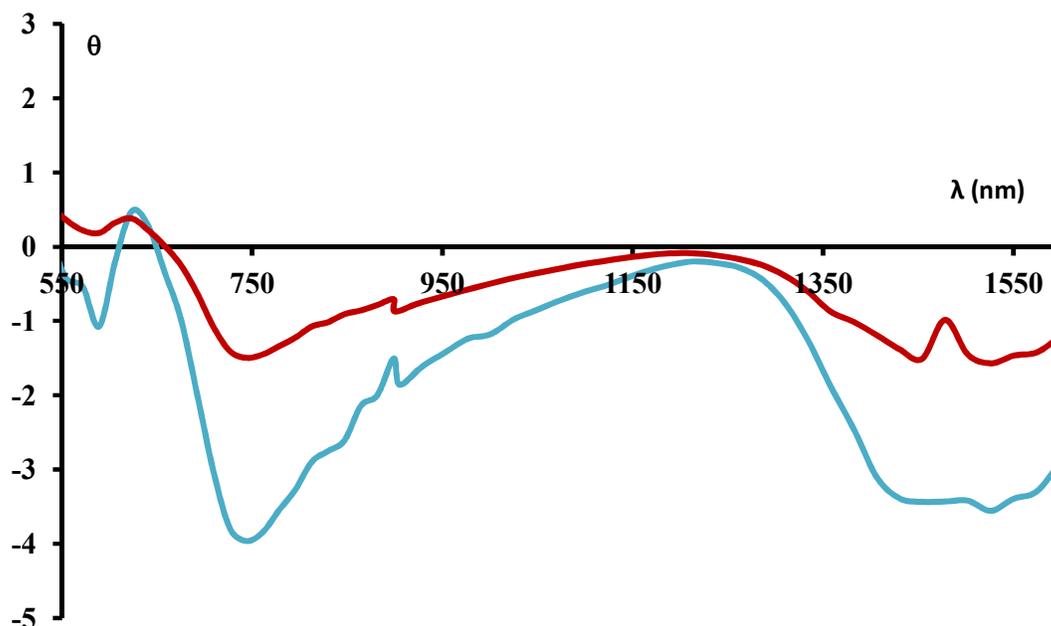


Fig. 2. Spectral evolution of the Faraday rotation saturation of 2 samples. The measurement is made with a 1 mm cell at a concentration of 0.1%

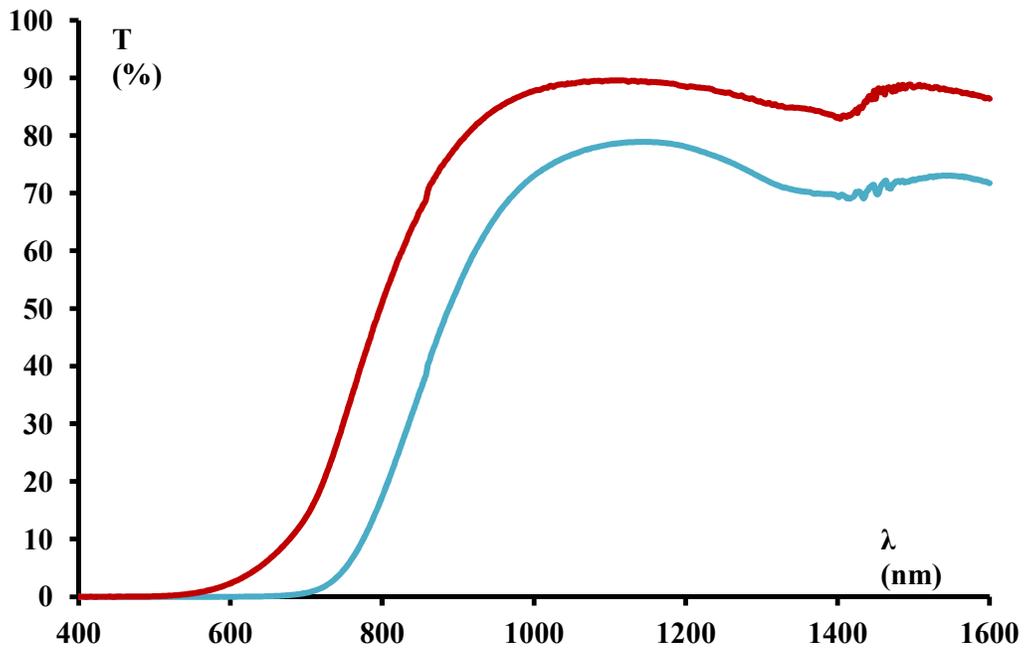


Fig. 3. Evolution of the spectral transmittance of 2 samples. Theme asurement is made with a 1 mm cell at a concentration of 0.1% [10]

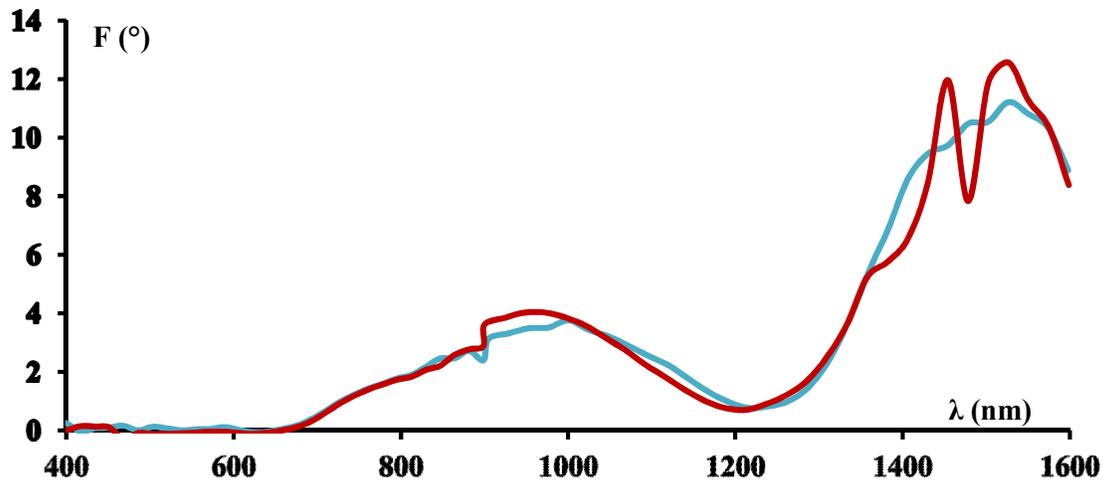


Fig. 4. Spectral evolution of the 2 samples of merit factor

3.3 Merit Factor

A merit factor was also determined. It is the ratio between the specific Faraday rotation at saturation and the absorption coefficient deduced from the transmittance curve $((\theta_F \text{ (}^\circ/\text{cm)}) / \alpha \text{ (}^\circ/\text{cm)}) = F$, $\alpha = -\ln(T / 100)$ [11]. The spectra have an expected shape with a peak around

1000 nm and another around 1550 nm. Here we find the difference in spectral behavior of the R.F and the transmittance. We find very interesting values (Fig. 4). The merit factor curves are plotted relative to the Faraday rotation specific to saturation. The merit factor of the two liquids is the same and is high due to the improvement of the Faraday rotation.

4. CONCLUSION

RF measurements have shown resonances at two main levels: the first at 750 nm is attributed to the Co²⁺ ion, which is mainly located at the site of tetrahedral coordination [1], and the second at 1550 nm is attributed to Co²⁺ ions, which are in octahedral coordination [1]. The different transmittance spectra all have good transparency in the infrared, with a difference around 1400-1600 nm which is probably due to the treatment of the different ferrofluids (this is the only explanation we can give because there is no record of this in current literature). To give a precise account of the importance of the use of particles, we have also drawn the merit factor curves relating to the Faraday rotation specific to saturation: the merit factor of the two liquids is the same and high; which opens up an interesting avenue for scientific research. There is a significant improvement in the optimal properties of the materials used in terms of Faraday rotation, transmittance and merit factor allowing a good solution of the insulator.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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