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THE INFLUENCE OF CONCENTRATION OF Nd-Fe-B POWDER IN COMPOSITE COATING OF OPTICAL FIBER TO THE SENSIBILITY TO EXTERNAL MAGNETIC FIELD

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Abstract

Multi-mode optical fiber with magnetic composite coating was investigated as an optical fiber sensor element (OFMSE) for magnetic field sensing The composite coating was formed with dispersions of permanent magnet powder of Nd-Fe-B in poly (ethylene-co-vinyl acetate)-EVA solutions in toluene.

The influence of the applied external magnetic field on the change of intensity of the light signal propagate trough developed optical fibers sensor element was investigated. In this paper the influence of the content of magnetic powder in the composite coating on the optical propagation characteristics of optical fiber were particularly investigated.

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1. Introduction

The introduction of optical fibers has changed the way of

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telecommunications and related fields. The optical fibers provides a large band width, low cost in mass production and low transmission loss in communication channels. The measurements of magnetic field have been critical part in various technical areas. Optical fiber coated with a composite polymer-magnetic powder coating can be used as an optical fiber magnetic sensor [1-3]. Fiber optic sensors can be used in areas that are too harsh to measure with conventional sensor systems, since the optical fiber is usually made of dielectric materials that have high resistance to vibration, electromagnetic interference, thermal shock and corrosion. The optical fiber magnet sensor element (OFMSE) presented in this paper was constructed on the base of intensity-based optical fiber vibration sensors (OFVS) [4]. OFMSE in this study consists of two optical fibers held in close proximity to each other, and are based on the principle of intensity modulation. One of them (coated with magnetic composite) is cantilevered on the plastic plate. The cantilevered section moves in the opposite direction to the rest of the sensor in response to an applied magnetic field, and the amount of light coupled between the two fibers is modulated. The composite coating can be made by adapting the existing process of manufacturing optical fibers in stage in which polymer coating is applied to the drawn fiber [5-7]. Instead of a solely polymer coating, a coating with particles of magnetic powder can be used. Appropriate composite coatings should be homogenous and thus enable reliable magnetic detection, while minimizing the side effects. A copolymer of ethylene and vinyl-acetate (EVA) was chosen for the polymer component of the composite coating, because of its good adhesive properties. Using EVA it is possible to produce coating without the application of UV or thermal curing process, and hence the number of process parameters was reduced. The magnetic component of the composite coating can be selected from a variety of permanent ferromagnetic powders (hard ferrite, Sm-Co, Nd-Fe-B). Nd-Fe-B magnetic powder have shown better result than $SmCo_5$ [8-10], and it was chosen for presented investigation. In this paper, dependence of concentration of magnetic powder in composite coating will be investigated.

2. Experimental

In order to avoid positioning and connecting optical fibers in the capillary tube, plate for simulation has been constructed. Simulation plate consisted of one plastic plate with incision and round hole in the middle. Diameter of the hole is two centimeters and diameter of incision was one millimeter. Optical fiber which received signal had bigger diameter in order to avoid problems with cantilevering fibers.

Original coating of optical fiber was removed and polymer – magnetic composite coating was applied instead of it. Polymer – magnetic composite coating consisted of mixture of permanent magnetic powder and poly(ethylene-co-vinyl acetate) produced by DuPont under the commercial name ELVAX 265. Polymer was used Amount of magnetic powder in different samples is presented in table1.

The light from the light emitting diode (λ = 849 nm) is launched to an optical fiber with deposited composite coating which had particles of permanent magnet. Intensity and wave length of light emitted trough optical fiber was constant during experiment. The optical signal is received by the optical fiber that is fixed at the other end of plate. The intensity of the light from this fiber is detected by a photo detector. The amplified output signal from the photo detector is connected to the data acquisition system based on the A/D card, personal computer and the specially developed software in Pascal. If the OFMSE is not in a magnetic field the ends of optical fibers on the plate and collinear and the intensity of the propagated light is maximum. If the permanent magnet is approached to the sensing element, the light intensity decreases.

Samples with different amount of magnetic powder were prepared for measurement, as it is shown in table 1.

Table 1. Mass percent of Nd-Fe-B powder in different samples

Sample number	Mass % of Nd-Fe-B powder
1	50
2	40
3	30
4	20

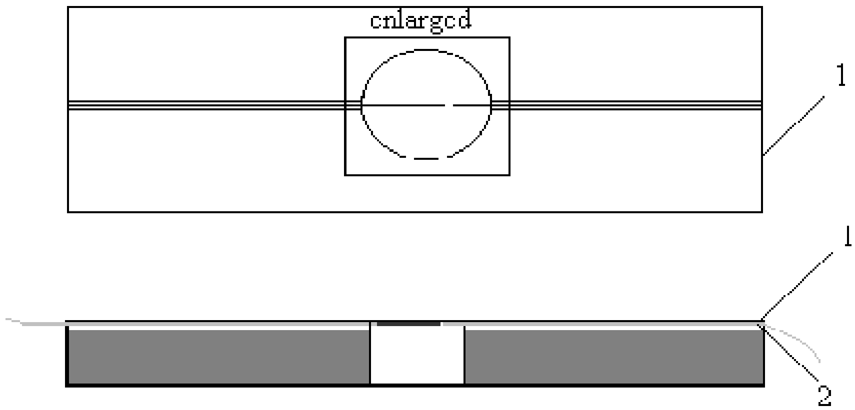

Fig. 1. Plate for measuring of optical fibers with composite magnetic coating: 1 – plastic plate; 2 – optical fiber

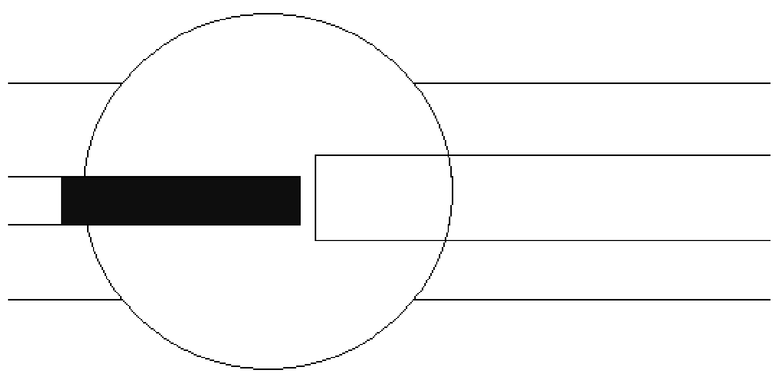

Fig. 2. Enlarged detail from the plate

3. Results and discussion

In this paper, dependence of response of OFMSE made with different concentration of magnetic powder to the external magnetic field has been investigated and the results are presented on the figures 3-6. It is obvious that every sample reacts in the external magnetic field. Presented parts of recorded response have been measured with approximately equal maximal strength of magnetic field (around 200 mT). Depending on the concentration of magnetic powder signal attenuation is different for different samples. The highest signal attenuation has been observed at the sample number 1, which has the highest amount of magnetic powder. If amount of Nd-Fe-B magnetic powder in composite coating is decreased, signal attenuation decreases in the external magnetic field. Sample number four (20 mass % of Nd-Fe-B powder) has shown good sensibility, but in the opposite direction (with increased magnetic field strength, the intensity of signal increases too).

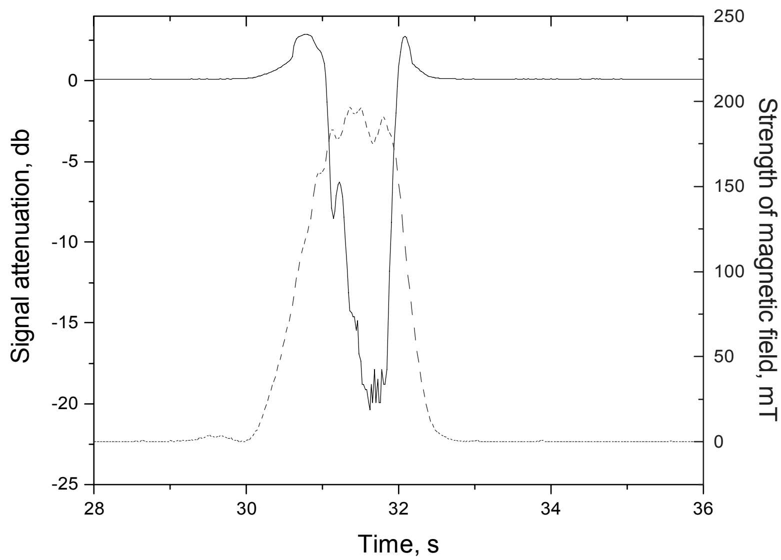

Fig. 3. Response of OFMSE sample no. 1

Receiving optical fiber with bigger diameter made receiving of signal easier, but interpretation of results is much harder. All samples have slight increase in the intensity of signal at the beginning of measurement. It is supposed that the reason for that is that optical fibers are not completely collinear, and that small difference in the angle of their axes exists. When external magnetic field is applied, axis of optical fiber with composite coating passes through the axis of the receiving fiber, and at that point, maximum in signal intensity is reached. After that, angle between axis's increases and signal decreases. In the case of sample number four, that has not occurred – the maximum of signal remained. So, in this configuration of OFMSE, this content of Nd-Fe-B was too low for magnetostrictive reaction of composite coating.

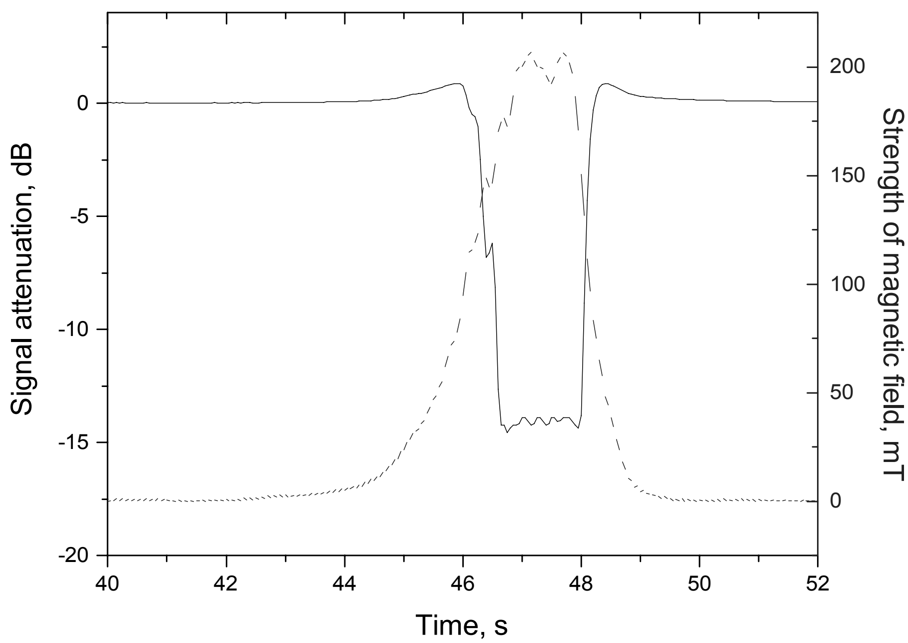

Fig. 4. Response of OFMSE sample no. 2

As it was mentioned before, signal attenuation decreases with decreasing of Nd-Fe-B content in composite coating. Table 2 shows values of signal attenuation for different samples (taken from pictures 3-6)

Table 2: Signal attenuation and strength of magnetic field

Mass % of Nd-Fe-B powder	Signal attenuation, dB	Magnetic field strength, mT
50	19.92	194,3
40	14.37	206.6
30	12.41	251,7
20	-2.29	223,4

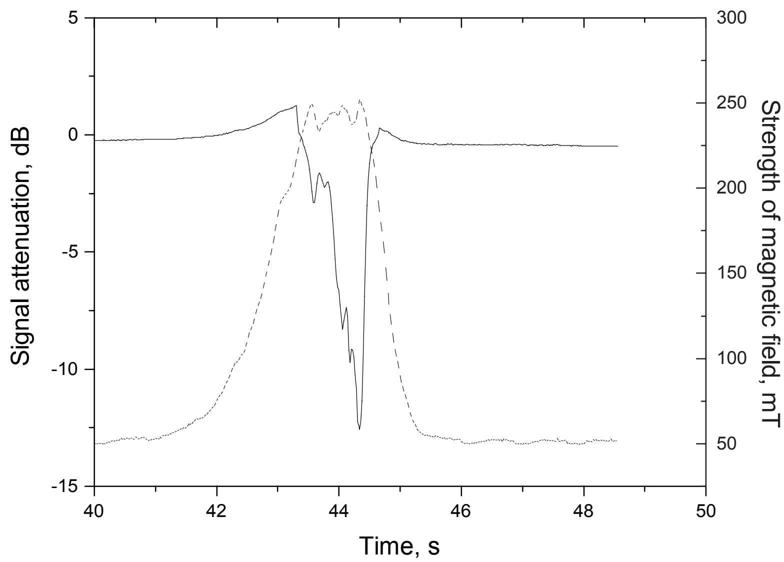

Fig. 5. Response of OFMSE sample no. 3

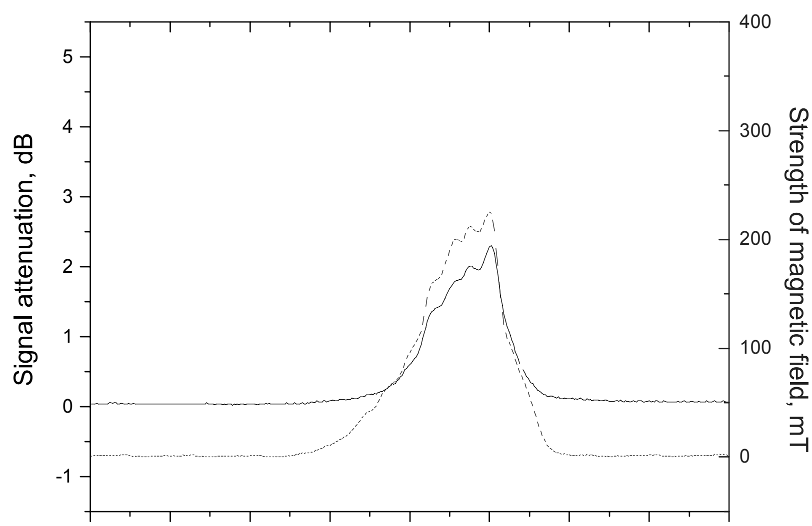

Fig 6: Response of OFMSE sample no. 4

4. Conclusion

OFMSE with optical fiber coated with composite coating has already been introduced in magnetic field sensing. In this paper the influence of content of Nd-Fe-B powder in composite coating of optical fiber to the sensibility to external magnetic field was investigated. Samples with different amount of magnetic powder were prepared and measurements of signal attenuation in applied external magnetic field were done. The samples of OFMSE shew good sensibility and reversibility of signal. If the content of Nd-Fe-B magnetic powder in composite coating is decreased, signal attenuation decreases in the external magnetic field. In experimental configuration of OFMSE, content of 20 mass % of Nd-Fe-B was too low for magnetostrictive reaction of composite coating.

Acknowledgement

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