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The Droplet Epitaxy as an Efficient Tool for Thin Film Magnetic Field Sensor Manufacturing

V.F. Shkar'[a], V.N. Spiridonov[a], I.G. Salkov[b,*] and V.V. Morenko[b]
[a]Donetsk Physicotechnical Institute, National Academy of Science of Ukraine, Donetsk, 83114, Ukraine
[b]Donetsk National University, Donetsk, 83000, Ukraine

The modified liquid-phase epitaxy method have been used to obtain submicron iron-yttrium garnet ferrite films in vortex state. There is shown a possibility to use these films for creating sensors, which are very sensitive to zero magnetic field.

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1. Introduction

A variety of devices has been developed based on iron-yttrium garnet (YIG) films. Among them are delay lines, generators, circulators etc. These devices use YIG films in saturated state so the presence of magnetic bias system is required. If it is absent, domain structure appears in the film, and dynamic characteristics of corresponding device become worse.

Recently [1] it has been shown that if YIG films have thickness less than certain critical value, the domain structure is absent. Nevertheless, the film is still not in saturated single-domain state. More detailed studies revealed that the state of the film could be characterized, as the state with magnetic vortices structure [1]. If compared to domain structure, the above mentioned state does not prevent an excitation of magnetic oscillations similar to those in saturated state [2]. Also there has been shown narrow line of absorption (0.05 Oe) of high frequency energy exists in a zero planar magnetic field. The nature of this line is being studied. Nonetheless, there is a correlation between the width of this absorption line and the width of the magnetization loop of the film, taking into account its thickness.

2. Construction and results

The presence of absorption in a zero value magnetic field makes it possible to prepare a probe sensitive to magnetic inhomogeneities that are comparable to the width of absorption line (0.05 Oe), and geometrically comparable with the film thickness (0.12 μm).

The construction of the probe, taking into account the geometry of spin wave excitation, is depicted in Fig. 1. The main element of the probe is a thin magnetic stripe on a substrate. The stripe was obtained by chemical etching of the thin film. The film was prepared by droplet epitaxy on the (111)-oriented gadolinium-gallium garnet (GGG). It is evident that the stripe size should be similar to the magnetic inhomogeneity, which must be investigated. The strip of film is located in homogeneous high-frequency magnetic field of an oscillatory circuit of generator. It is also exposed to modulating low-frequency field. The entire construction is copper shielded. Modulation method of registration signal allows to increase the sensitivity of the device and to determine the sign (direction) of magnetic inhomogeneity.

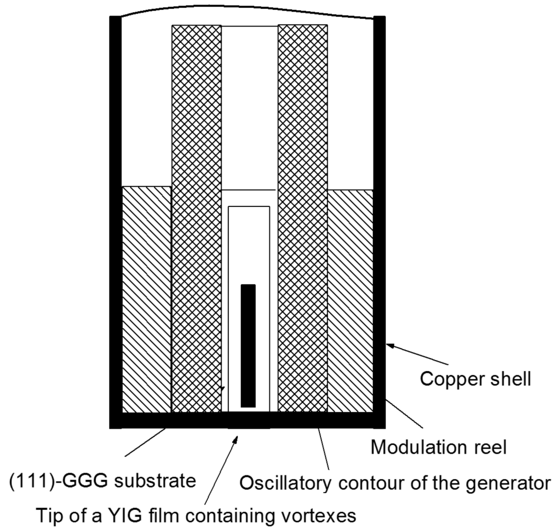

Fig. 1. The construction of the probe adjusted to the excitation geometry of the absorption in a zero value magnetic field.

This probe was used in a magnetic inhomogeneity scanner, and its schematic representation is shown in Fig. 2. It consists of autodyne generator, whose coil is placed in the probe, modulator that is loaded on the coil also inside the probe, amplitude detector that extracts the modulation signal (bearing an information about the absorption of high-frequency power), the modulation signal amplifier, synchronous detector (to determine the direction of magnetic inhomogeneity), and a registration device.

This scanner is capable to register the change of imaginary part of magnetic susceptibility of the film, i.e. change in a Q-switched oscillator circuit.

To verify the workability of the concept in a laboratory, the model of the scanner has been built and it was used to

* corresponding author; e-mail: i.salkov@a.donnu.edu.ua

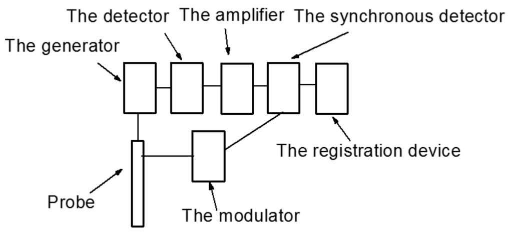

Fig. 2. Scheme of the electronic part of the magnetic inhomogeneity scanner.

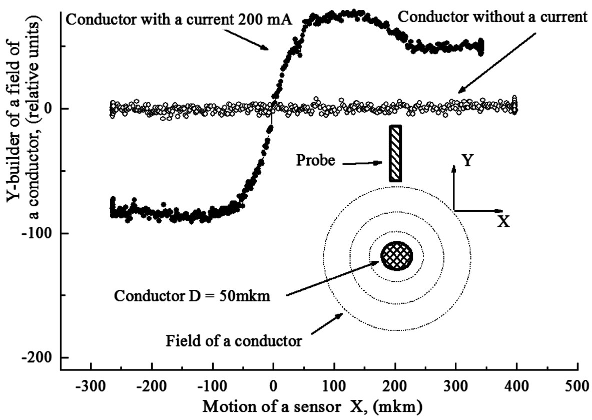

Fig. 3. Function of the Y-component of magnetic field around a conductor with current at scanning along X-axis.

determine the distribution of magnetic field around the conductor with current. The result is presented in Fig. 3.

From Fig. 3 one can see that the scanner is sensitive to the value and the direction of the field created by the current. The probe is sensitive only on Y-component of magnetic field (when scanned along X-axis).

3. Growth of the films

To obtain YIG films a modified method of dripping epitaxy was used. The procedure was as follows. First, wetting solution-melt of YIG is prepared, using a procedure described in [3]. From this solution-melt a checking film was grown by usual epitaxy method. Then overheated solution-melt of YIG quickly is quenched by pouring into metal bath, which is cooled by water. Thus, a homogeneously black glass is obtained with no evidence of spontaneous crystallization of YIG.

Then a piece of the obtained glass was melted by a gas torch and a 0.5 mm platinum wire folded twice and having a small loop at the end was covered by the melt. The small loop filled with a glassy material serves as a glass drop holder and is mounted onto the moving mechanism similar to the one used in optical microscopy. So, the glass drop can be delivered to the hot zone of the vertically placed cylindrical oven. To the same zone the GGG substrate, fixed on the alundum rod, can be delivered from the opposite side of the oven. The size of the oven and platinum holder on the end of the rod are designed for rectangular substrates up to 6 mm, and 0.5 mm thick. Using a servo-system the rod can be rotated in both directions with variable angle velocity.

The growth of the film can be described as follows. The substrate is inserted into hot zone of the oven from the bottom side and then annealed for several minutes. The rotation device is turned on and the substrate is rotated in each direction in 1–2 s interval. Then from the top side of the oven the drop of glass is inserted and placed 2–3 mm from the rotating substrate. The temperature in the oven is held close to the temperature of liquid-phase epitaxy. At this temperature the drop melts, drops and spreads on the rotating substrate. The substrate and the drop are held in the hot zone during several seconds, and then slowly withdrawn with simultaneous increase in rotation speed (one direction only). The rotation speed is adjusted so that the drop is evenly spread on the substrate by centrifugal force. The temperature difference between hot zone and withdrawal zone is *ca.* 100 °C. Finally, the sample is slowly taken out of the oven, and the residues of glass are removed by rinsing with hot diluted nitric acid.

4. Conclusion

Thus, method of dripping epitaxy has been developed for the growth of the films in the vortex state. With using an experiment of detection of magnetic field distribution in a microconductor there was shown a possibility of the use of these films to create sensors very sensitive to magnetic fields.

Acknowledgments

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