THE DEVELOPMENT OF MAGNETIC SUBSTRATES WITH DETERMINED 3D GEOMETRY OF MAGNETIC FIELD FOR THE BIOTECHNOLOGY APPLICATIONS

T.A.Ignatyeva[1], V.N.Voevodin[1], P.A.Kutsenko[1], **V.V.Kalynovskyi[1]**, Y.I.Dzhezherya[2], V.O.Golub[2], V.V.Kiroshka[3]

[1]National Scientific Center "Kharkov Institute of Physics and Technology, 1 Akademicheskaya str. 61108 Kharkov, Ukraine

[2]Institute of Magnetism NASU and MESYSU, 36-B Vernadsky blvd., 03142 Kiev, Ukraine

[3]Institute for Problems of Cryobiology and Cryomedicine NASU, Pereyaslovkaya str., 61015 Kharkov, Ukraine

taignatieva@mail.ru

A future progress in science and technology is connected with the implementations of nanomaterials. Nanotechnology will allow the creation of new materials and devices with a vast range of applications, such as in electronics, medicine, biomaterials and energy production.

One of the most promising applications of the nanotechnology is tissue engineering, i.e. repair or replacement of portions of or whole tissues. The development of this direction will open new opportunities for the creation of effective biomedicine techniques for neogenesis and therapy of a bunch of severe metabolic diseases. On of the main tasks here is to create favorable conditions for 3d tissue growing for substitution of damages or pathologies.

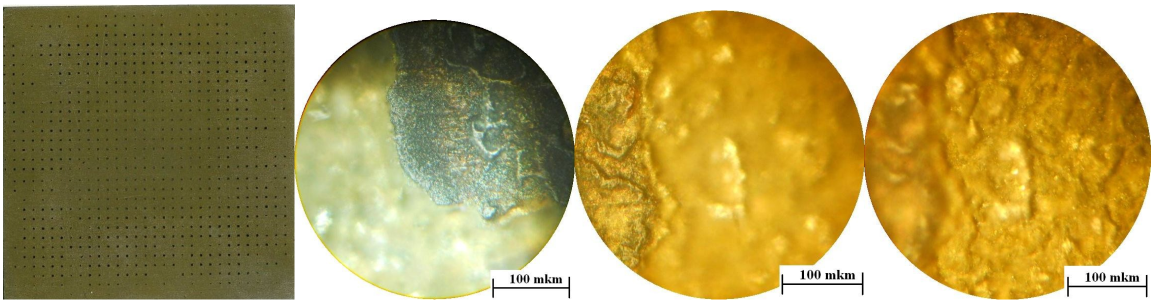
The goal of tissue engineering is a construction and growing of live and functional tissues and organs outside an organism for a following transplantation to a patient. Polymer biocompatible materials with pores of definite sizes are widely investigated now as materials which could provide spatial cells growth and formation of 3d tissue structure. In this case the tissue could not only replace a damaged area but fulfill biological (metabolic) functions. It should be noted that usual implants produced from inert materials can improve only physical and mechanical defects of damaged tissues.

New approaches based on tissue engineering should be developed to improve the techniques of reconstructive medicine to create bioimplants with characteristics of live tissues:

- regeneration ability;
- blood supply maintenance ability;
- ability to change structure and functions in response to environmental factors.

Our goal is the manipulation of spatial cell growth using magnetic fields and this work is devoted to the development of magnetic field concentrators (substrates) that could produce high gradient magnetic fields of required configuration over large area.

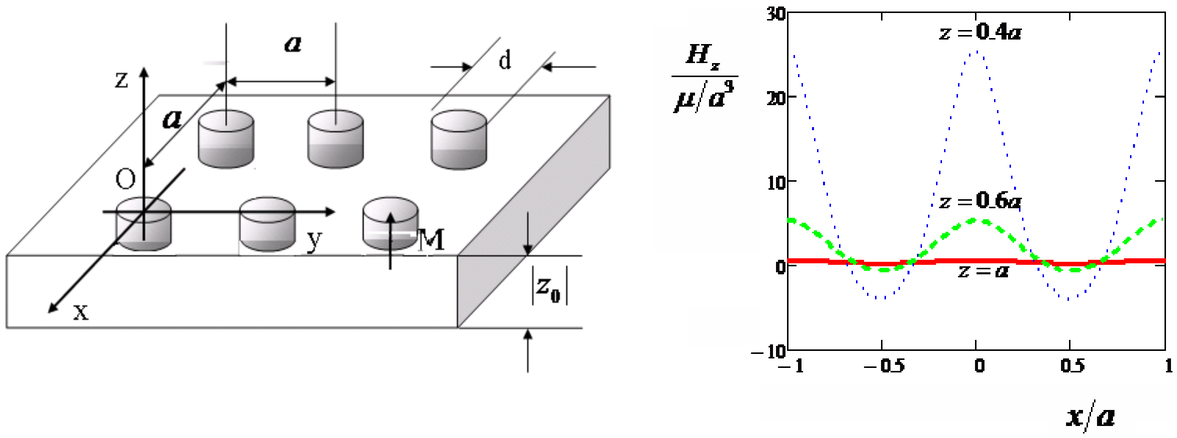
The image of proposed substrate-magnetic conductor obtained with optical microscope is shown in Fig.1. The magnetic field is produced by permanent magnet while the substrate determines magnetic field lines distribution.



a b c d

Figure.1 *Optical image of magnetic conductor-substrate (a). The distance between centers of squares is 1.65 mm. The side of square is 0.35-0.40 mm. A step height is 20 μm. (b) View of a dot. (c) Focus on the top of the step. (d) Focus on bottom of the step.*

The distribution of magnetic fields formed over such substrates can be understood from a simple theoretical model [1]. A fragment of periodical structure which is quite simple to be produced technologically and that can produce high gradient magnetic fields is shown in Fig. 2. The system is a 2d array of magnetic rods. The interrod distance is a, the rod height and width are z_0 and d correspondingly. The saturation magnetization of the dots is M_s. The rods are supposed to be saturated along z-direction.



a b

Figure.2. *Model magnetic system (a) and the distribution of z-component of magnetic fields as a function of x for different heights (b).*

To calculate the distribution of magnetic fields the approach of effective magnetic charges was used. If ferromagnetic rods have a small base radius the top of the rod can be considered as a point magnetic charge $q_M = M_s \pi d^2/4$ and the bottom of the rod as $-q_M$.

In this case the magnetic potential takes the form

$$\psi(\mathbf{r}) = q_M \sum_{n=-\infty}^{\infty} \sum_{m=-\infty}^{\infty} \left\{ \left((x-a\cdot n)^2 + (y-a\cdot m)^2 + z^2 \right)^{1/2} - \left((x-a\cdot n)^2 + (y-a\cdot m)^2 + (z+|z_0|)^2 \right)^{1/2} \right\} \quad (1)$$

If $z >> |z_0|$

$$\psi(\mathbf{r}) = \sum_{n=-\infty}^{\infty} \sum_{m=-\infty}^{\infty} \frac{z \cdot q_M z_0}{\left((x-a\cdot n)^2 + (y-a\cdot m)^2 + z^2 \right)^{3/2}} \quad (2)$$

Here $q_M |z|_0$ is just the magnetic moment of the dot *μ*. Thus only one scale parameter (lattice period) remains in the system. Substituting $\xi = x/a,\ \eta = y/a,\ \zeta = z/a$ the expression (2) can be rewritten as

$$\psi(\mathbf{r}) = \frac{\mu}{a^2} \sum_{n=-\infty}^{\infty} \sum_{m=-\infty}^{\infty} \frac{\zeta}{\left((\xi - n)^2 + (\eta - m)^2 + \zeta^2 \right)^{3/2}} \quad (3)$$

This expression allows to obtain the magnetic field in any point of the space where $z >> |z_0|$. The field is inhomogeneous and high gradient only for heights below $z \sim a$ see Fig.2. So if the lattice period is 1 mm the field will be inhomogeneous only if the height above the substrate does not exceed several millimeters.

To increase the heights of the gradient magnetic field created by such substrate the period of modulation of the magnetization inside the substrate should be optimized. The heights will increase with the modulation period but this will decrease gradients of the field. So we need to provide additional steos to increase the magnetic field inhomogeneity. The shape of the magnetic elements should be more complicated (bars, stars, etc.) like in substrates proposed here.

[1] L.D. Landau & E.M. Lifshitz. The Classical Theory of Fields (Volume 2 of A Course of Theoretical Physics) Pergamon Press 1971.