superconducting YBCO layers,
biomagnetic field shields

Andrzej KWATERA, Agata SAWKA, Paweł ANDREASIK*

SUPERCONDUCTING LAYER SHIELDS FOR MEASUREMENT OF BIOMAGNETIC FIELDS

Interest of the biomagnetic fields results from necessity of the using of non-invasive methods of early diagnosis of many diseases like heart attack, cerebral stroke, tumours. The magnitude of the induction of the biomagnetic fields values are in the range of 10 fT- 50 pT. SQUIDs can register the magnetic field of the induction as low as even 0,1 fT. The fundamental condition of the practical application of SQUIDs is preparation of the shields, which would protect a subject against the electromagnetic smog (the average magnitude of the magnetic induction - about 50 μT). Theoretically, magnetic field oughtn't to penetrate into superconducting materials only. Because this material must be continuous (without cracks), so it seems that only superconducting layer shields can fulfil this condition. This paper shows preliminary results of investigation on synthesis of superconducting YBCO layers by the MOCVD method on dielectric substrates.

1. INDRODUCTION

Biomagnetic field is produced by human body. The value of its magnetic induction is in the range of 10 fT - 50 pT [7]. This field is a consequence of flow an electric current across the neurones [6]. Very small magnetic fields are also created in metal corrosion process [5].

Average magnetic induction of the Earth magnetic field and electromagnetic impulses resulting from electric devices (so called electromagnetic smog) is about 50 μT [2]. For this reason, shielding of electromagnetic smog is necessary if we want to measure very small magnetic fields.

The first time when an idea of a device for the measurement of magnetic field produced by brain would use many SQUIDs was presented in 1989 by Hari and Lounasmaa [2]. This method was named magnetoencephalography (MEG).

MEG method as opposite to the other classical methods: e.g. electroencephalography (EEG), X-ray computer assisted tomography (CT), magnetic resonance imaging (MRI), regional cerebral blood flow measurement (RCBF), positron emission tomography (PET) is considerably less susceptible to impulses originating from other sources being found in organism (magnitude of pulse, movement of eyeballs, electric field of heart and so on). It's predicted that in this method one can register impulse originating from source in cerebral cortex at the distance not greater than 1-2 mm from surface of the brain.

* University of Mining and Metallurgy, Faculty of Materials Science and Ceramics, Department of Advanced Ceramics, Av. Mickiewicza 30, 30-059 Cracow

Measurement of biomagnetic field doesn't require contact of a indicator with surface of human body. Due to this unique feature, test of the other parts of human body could be quickly pushing this sound from one part to the next [11].

Examples of possible future applications of MEG [10]:

- establishment of preoperative diagnostic of epilepsy and explanation of its pathogeneses,
- localisation of the local brain damage and functional disturbances of the brain,
- localisation of the local brain damage and functional disturbances of the brain assessment of the ascultatory, optical, olfactory and gustatory track,
- localisation of the ischaemic focuses in the brain,
- assessment of the brain oedema.

Magnetocardiography (MKG) in **cardiology** may be useful in the following investigations [10]:

- non-invasive localisation of physiological and pathological additive conducting atrial ventricular tracks and preexcitation syndrome,
- early diagnosis of acute heart graft registration,
- cardiomiopathy estimation.

Magnetoenterography (MENG) in **gastroenterology** may be use to recognise gastroparesis in diabetes mellitus or uraemia [9].

This method in **gynaecology** may serve for localisation and estimation of utheral tumours (myomas) [1].

This method in **orthopaedics** would be useful for estimation of corrosion resistance of metallic endoprostheses before introduction them to organism and for non-invasive monitoring of their behaviour after implantation.

Testing of the above mentioned diseases can be carried out by shielding object and human body from external magnetic field.

Nowadays there have been elaborated the shields for small magnetic fields made of high-temperature superconducting ceramics [3, 8] . The method involves the sintering of ceramic powder of YBCO ($YBa_2Cu_3O_{7-x}$) or BSCCO ($Bi_2Sr_2CaCu_2O_{8-y}$). Such shields can be applied for shielding of magnetic fields to about 1,2 mT for YBCO and to 6 mT for BSCCO [8].

Idea of using shields from high-temperature superconducting ceramics for shielding e.g. biomagnetic fields from activities of electromagnetic smog has been resulted from the Meissner effect. Penetration of magnetic field into materials depends on their electrical conductivity. The better conductivity of materials the smaller depth of penetration of these materials by magnetic fields. In the case of superconductors, which probably could have continuous microstructure, penetration would not be proceed.

Received shields by sintering of powders of YBCO or BSCCO are porous and there are microcracks in them, what causes penetration of magnetic field through these shields. Microcracks of shields were due to difference in thermal expansibility of coefficients in different crystallographic direction of these materials and low mechanical strength.

Taking the above statement into consideration the following suggestion have been proposed:

- sealing of the surface of YBCO sintered magnetic shields by coating them by thin continuous YBCO layers obtained by MOCVD method,
- obtaining superconducting magnetic shields by synthesis of superconducting layers of YBCO or other superconducting materials by MOCVD method on dielectric substrate.

This work shows results of preliminary research on synthesis of YBCO layers by MOCVD method on dielectric substrates.

2. MATERIALS AND METODS

Superconducting YBCO layers were deposited on the inner surfaces of quartz glass tubes with or without layer of Al_2O_3 by the MOCVD (Metal Organic Chemical Vapour Deposition) method. The Al_2O_3 layers were synthesized using aluminium acetyloacetonate ($Al(acac)_3$) at 800 and 1000^0C. The YBCO layers were deposited using $Y(tmhd)_3$, $Ba(tmhd)_2$ and $Cu(tmhd)_2$ (Sigma Aldrich) as basic reagents. Argon and air were carrier gases. The molar ratios of the reagents used were following: 1:2,2:2,3; 1:2:3; 1:1,75:2,25; 1:2,35:1,65. Diagram of the equipment used for Al_2O_3 as well as YBCO layers synthesis is presented in work [4]. Summary conditions of the YBCO layers synthesis shows the table 1.

Parametr	Synthesis conditions
Substrate temperature	800 - 870^0C
Air flow	600 - 800 Nl/h
Synthesis time	15 - 120 min.
Cooling time after synthesis process	about 5 min.
Evaporator temperature	270 - 300^0C

Tab.1. Summary conditions for the YBCO layer synthesis on dielectric substrates.

3. RESULTS AND DISCUSSION

Colour of the layers obtained were changed from light brown to golden. The sample covered with a such layer heated at 800^0C in air during 30 min. grew dark. Longer its heating caused decay of the sample colour and caused that the layers obtained became transparent. A reason of the layer transparency was probably Cu evaporation Analysis of chemical composition performed by RBS (Rutheford Backscattering Spectrometry) method indicates that the layer composition is quite different than the reagents composition. The sample shown in fig. 1 doesn't contain Ba and contents of Y is very small in it. Fig. 2 shows the sample with presence of Y, Cu and small amounts of Ba. This analysis also indicates that microstructure of the layers obtained isn't continuous. The above results are confirmation of earlier scanning microscopy observations (fig. 3 and 4) and examination by EDS of the samples obtained. Discontinuity of the layers obtained was a reason of lack of superconducting properties. It seems that decrease of the synthesis temperature should increase barium contents in the layer and be favourable obtaining continuous and thin layers, because of much higher density of crystal nucleation of the layers at lower temperatures.

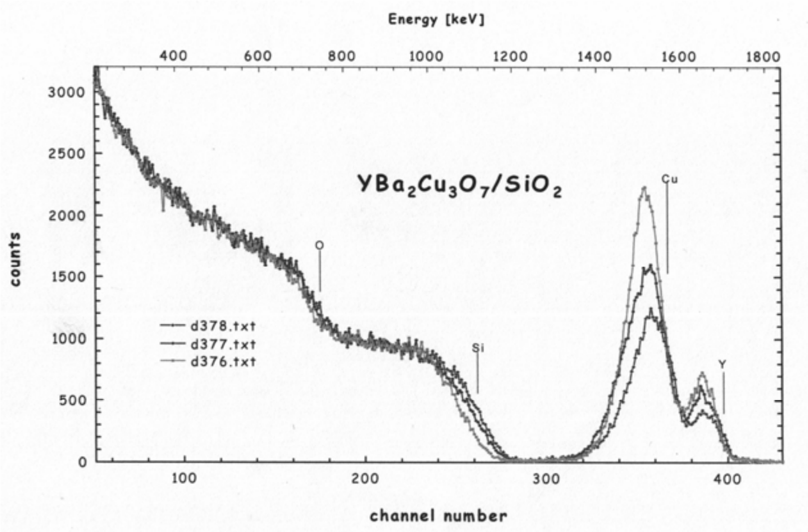

Fig.1. Experimental curves obtained by the RBS method for sample: SiO_2 - YBCO layer. Temperature of the layer synthesis: about 840^0C, ratio $Y(tmhd)_3$: $Ba(tmhd)_2$: $Cu(tmhd)_2$ = 1 : 2 : 3, synthesis time: 30 min.

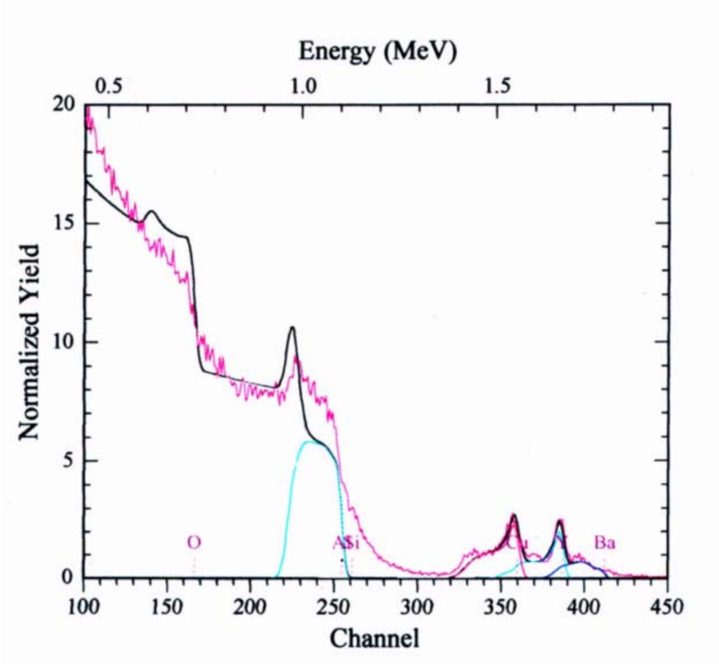

Fig.2. Experimental curves obtained by the RBS method for sample: SiO_2 - Al_2O_3 layer (1000^0C) - YBCO layer. Temperature of the YBCO layer synthesis: about 800^0C; ratio $Y(tmhd)_3$: $Ba(tmhd)_2$: $Cu(tmhd)_2$ = 1 : 1,75 : 2,25; synthesis time: 30 min.

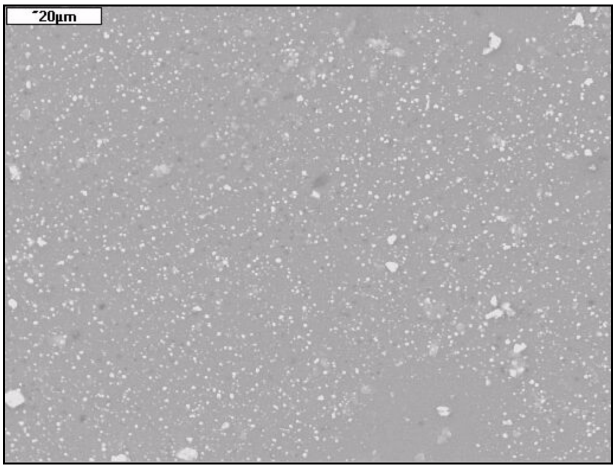

Fig.3. Surface of the YBCO layer synthesized at 870^0C on quartz glass. Molar ratio $Y(tmhd)_3 : Ba(tmhd)_2 : Cu(tmhd)_2$ = 1 : 2,2 : 2,3. Synthesis time: 30 min.

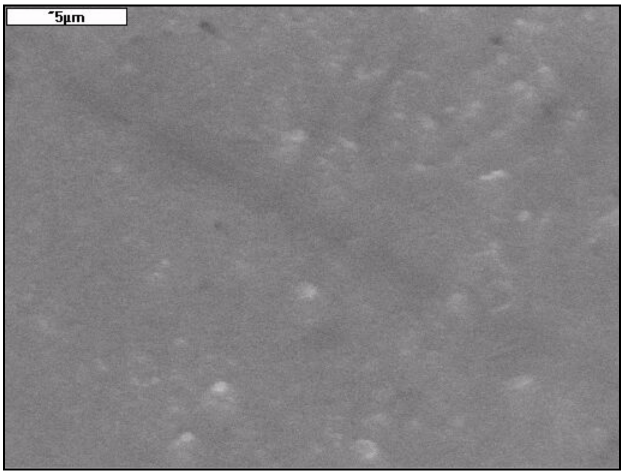

Fig.4. Surface of the YBCO layer synthesized at 800^0C on quartz glass covered with Al_2O_3 (1000^0C). Molar ratio $Y(tmhd)_3 : Ba(tmhd)_2 : Cu(tmhd)_2$ = 1 : 2,25 : 2,36. Synthesis time: 15 min.

4. CONCLUSIONS

1. Preliminary research on obtaining of superconducting YBCO layers on dielectric substrates confirms the literature data - the molar ratio Y:Ba:Cu in the layers is quite different than ratio of these elements in the reagents used.
2. The YBCO layers should be synthesized at lower temperatures than it's also suggested by other authors. It should be favourable obtaining of higher contains of barium in the layers and also let obtain continuous and contemporary thin layers.
3. Using of separate evaporators for reagents is recommended, especially in the case of barium compounds.
4. These investigations should be continued.

BIBLIOGRAPHY

[1] ANASTASIADIS P.G., ANNINOS P.A., KOUTSOUGERAS G.C. et al., Biomagnetic measurements in uterine leiomyomas using a superconducting quantum interference device (SQUID), Int. J. Gynaecol. Obstet., 1989 May, 29(1): 47-49

[2] HARI R., LOUNASMAA O.V., Recording and interpretation of cerebral magnetic fields, Science, 144(1989)432

[3] KWATERA A., CHRUŚCIEL B., STASZKÓW E., KWATERA D., SAWKA A., Application of ceramic materials for measurement of biomagnetic fields and magnetic fields created in corrosion process of metals, Ceramics 66(2001)740

[4] KWATERA A., SAWKA A., Synteza przeźroczystych warstw Al_2O_3 z $Al(O_2C_5H_7)_3$ metodą CVD na szkle kwarcowym, Proc. of Conf. „Nowe Materiały - Nowe Technologie Materiałowe w Przemyśle Okrętowym i Maszynowym" - „INŻYNIERIA MATERIAŁOWA", Szczecin-Świnoujście 10-13.09.1998, p. 351

[5] LI D. MA Y., FLANAGAN W. F., LICHTER B.D., WIKSO J. P., Corrosion Science 52(1996)219

[6] MOJKOWSKI J, Clinical Electroencephalography, PWN, W-wa 1989, p. 107

[7] NOWAK H., GIESSLER F., HUONKER R., Multichannel magnetography in unshielded environments, Clin Physphysical Meas 1991; 12 Suppl B: 5-11

[8] PLEWA J., JASZCZUK W., SEEGA C., MAGERKURTH C., KIEFER E., ALTENBURG H., Liquid phase sintered YBCO hollow cylinders for magnetic shielding, 3 rd European Conference on Superconductivity, EUCAS'97, June 30 - July 3, Eindhoven 1997

[9] RICHARDS W.O., BRADSHAW L.A., STATON D.J. et al., Magnetoenterography (MENG): non-invasive measurement of bioelectric activity in human small intestine, Dig. Dis. Sci., 1996 Dec.; 41(12): 2293-2301

[10] SCHNEIDER S., ABRAHAM-FUCKS K., REINCHENBERGER H., Experience with a multichannel system for biomagnetic study, Phys. Meas 1993 Nov. 14 Suppl 4A: A55-A60

[11] TAKANASHI Y., Magnetoencephalography: it's principles and clinical application, Rinsho Byori 1993 Nov.; 41(11):1191-1197

This work was supported by the Polish State Committee for Scientific Research (project nr7 T08D 036 19)