The Collaborative Research Center "Magnetoelectric Composites - Future Biomagnetic Interfaces" at the Christian-Albrechts-University in Kiel

H. FÖLL
Institute for Materials Science, Christian-Albrechts-University of Kiel
hf@tf.uni-kiel.de

I. ABSTRACT

In Jan. 2010 the "Deutsche Forschungsgemeinschaft" (DFG) established a so-called "Sonderforschungsbereich" (Collaborative Research Center) for Research into magnetoelectric composites for future biomagnetic interfaces at the Christian-Albrechts-University (CAU) in Kiel / Germany; the project is funded with more than then 10 Mio €. The Institute of Materials Science with it's background in functional materials and nanotechnology background was instrumental in writing the proposal and in getting together ... primary researchers from Electrical Engineering, Physics, and Medicine besides almost all groups of Materials Science and Engineering. The speaker is Prof. E. Quandt from Materials Science.

The project is scheduled for 4 (+ another 4) years. Its primary goal is the development of extremely sensitive (vector) sensor for magnetic fields. These sensors are to be used in dense arrays (about 1 sensor /cm^2) primarily for medical purposes. A sensor-studded "cap", for example, put around the head of patients suffering from various neural disorder syndromes, should be able to pick up the magnetic fields from neuronal firing deep in the brain and tallow to localize malfunctioning brain areas with far higher precision than present techniques; similar potential uses are seen in cardiography. The necessary sensitivity for magnetic field must rival those of SQUIDs; the project thus is fairly ambitious because present technology is many orders of magnitude less sensitive than SQUIDs.

The project has 4 major partial projects an a central project: Partial Project A develops the magnetoelectric composites and is thus the core project for the undertaking; it will be discussed in some detail in the presentation. Partial Project B investigates the detailed structural. magnetic and electric properties of the interfaces between the magnetostrictive and piezoelectric materials used. Partial Project C develops the sensor systems including theory and simulation tools, and partial project D introduces the medical component. The central Project provides analytical services like electron microscopy or a room heavily shielded against magnetic fields for sensitive measurement (including patients).

The project depends on the exploitation of magnetoelectric composites, meaning mechanically coupled structures of magnetostrictive and piezoelectric materials. The working principle is very simple. A magnetic field causes dimensional changes of a magnetostrictive material. The mechanical coupling to a piezoelectric material then puts elastic stress on the piezoelectric material, resulting in a voltage that is a measure of the magnetic field strength. In reality, magnetoelectric composites are rather complex systems. An input vector (magnetic field) produces an output scalar (voltage), and the coupling between the input and the output relies on several vector / tensor relations (stress / strain induced in the magnetostrictive material, transfer to the (tensor) piezomaterial, position of contacts). In addition, noise and time constants (e.g. for mechanical resonance and damping) need to be considered since the sensors are to be used for low-frequency (< 100 Hz) signals.

Advanced technologies, usually derived from micro- or nanotechnology including MEMS and implemented in the "Kiel Nanolab", are used to make magnetoelectric composites. In addition, some novel concepts are pursued. For example, layered structures of alternating piezo- and magnetostrictive materials clamped a only on end (and thus able to oscillate in one direction) have already proved sensitivities able to measure magnetic fields smaller 1 nT. A novel approach that will be presented elsewhere in the workshop intend to use porous III-V semiconductors, in particular InP, as the piezoelectric component. The piezoelectric properties of III-V semiconductors are well known but useless so far since the charges produced by mechanical stress are quickly short-circuited by the conductivity of the material. Porous membranes, however, can be made to be semi-insulating and thus can be used as a new single-crystalline piezoelectric materials, as will be shown. Filling the pores with a magnetostrictive material then will produce a sensor with properties that could be advantageous for certain applications.

The presentation will give a general overview of the project but then will focus on the material aspects.