

TP2 "Experimental characterization of magneto-electric coupling-type composites"

In this project, the class of "smart materials" is examined by various characterization methods. For this purpose, a number of set-ups is constructed or modified allowing to simultaneously apply electric, magnetic and mechanical fields in different modes. The project investigates the interaction of the composite material with each physical field quantity mediated by material strain. The main aspect is to achieve a detailed description of the mechanical, electromechanical and magneto-mechanical behavior yielding the complete coupled constitutive relations at the macroscopic level. Highest precision strain measurement

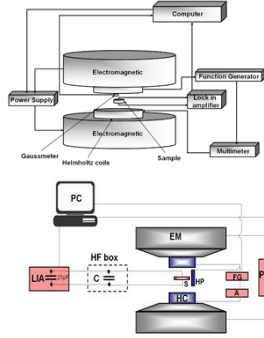
is a crucial ingredient of the major measurement device coupling all fields in one go. The magneto-electric specification of the materials is probed in field dependent mode by a variety of techniques as displayed below. At the nano-scale local scanning probe methods and spectroscopic methods yield a local understanding of material response and coupling. Direct and converse coupling are contrasted in experiment without reference to dielectric constant or magnetic permeability so far not undertaken in literature.

Direct magneto-electric measurement set-up



$$\frac{\partial E}{\partial H}$$

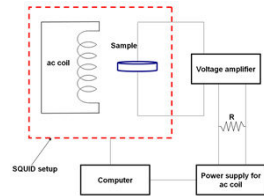
$$\frac{\partial D}{\partial H}$$



Converse magneto-electric method @ AG-Wende



$$\left. \frac{\partial M}{\partial E} \right|_T$$



Custom designed set-ups for integral and differential parameters



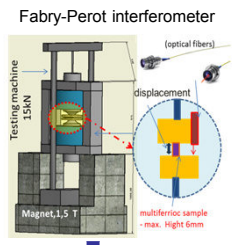
$$\left. \frac{\partial \epsilon}{\partial H} \right|_{\sigma, E}$$

$$\left. \frac{\partial \epsilon}{\partial E} \right|_{H, \sigma}$$

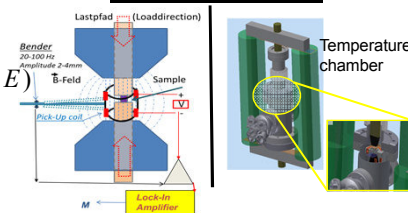
$$\left. \frac{\partial M}{\partial E} \right|_{H, \sigma}$$

$$\epsilon(H, \sigma, E)$$

(→ absolute values soon
→ temperature in „Verlängerung“)



Extensions

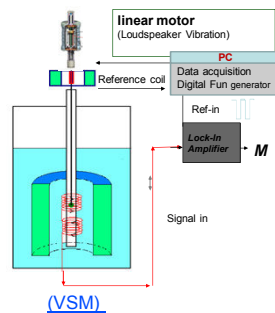


MPMS SQUID VSM (recently) @ CENIDE (NETZ-Building)

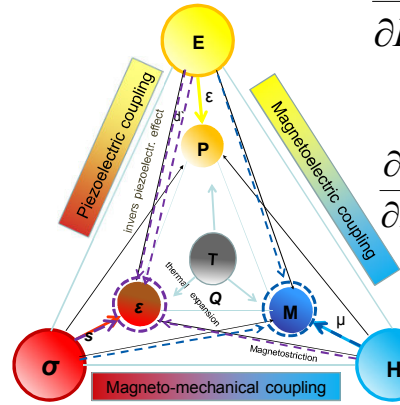


$$\left. \frac{\partial M}{\partial E} \right|_{H, T}$$

and
 $M(E, \sigma, H, T)$
absolute values



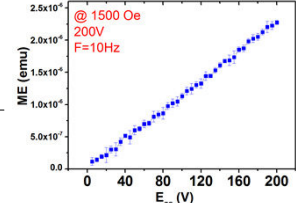
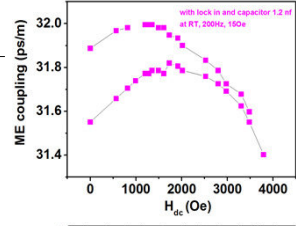
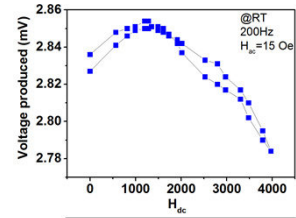
sensitivity of 10^{-8} emu



$$\frac{\partial E}{\partial H}$$

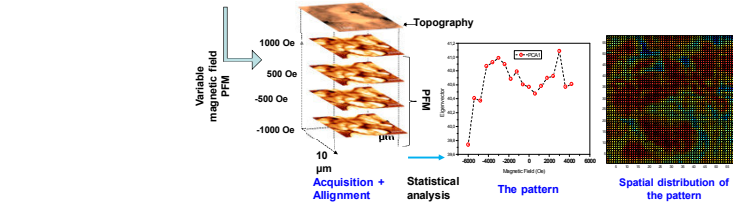
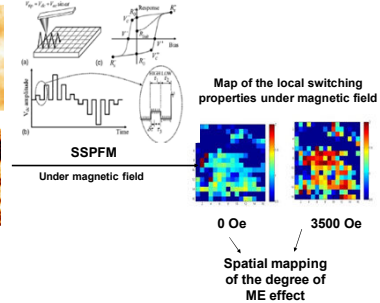
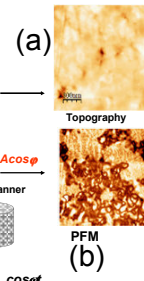
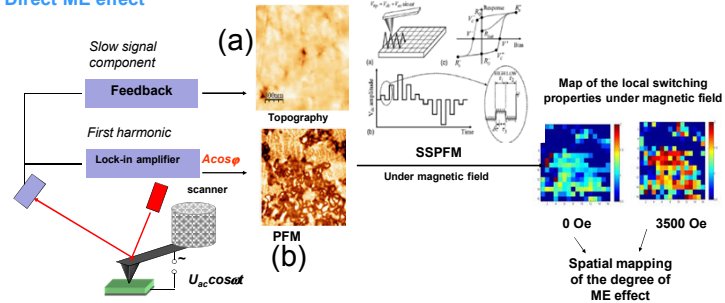
$$\frac{\partial D}{\partial H}$$

$$\frac{\partial M}{\partial E}$$

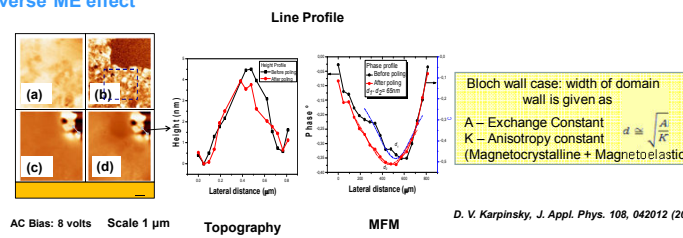


Scanning Probe Microscopy & Local magnetoelectric coupling

Direct ME effect



Converse ME effect



D. V. Karpinsky, J. Appl. Phys. 108, 042012 (2010)

Topography (a), lateral PFM (b), MFM phase images before (c) and after (d) electrical poling (40 volts). The marked area (blue) represent the poled region.