Magneto-thermoelectric power in ferrofluids : New thermoelectric energy conversion material

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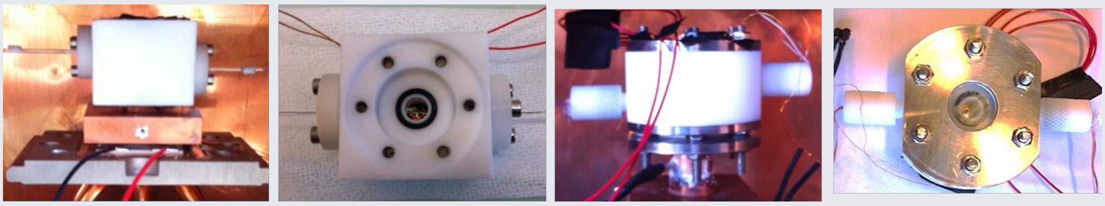
The aim of the project MAGTEP is to explore a hitherto unknown thermoelectric energy conversion mechanism in ferrofluids (suspensions of magnetic nanoparticles in non-magnetic media). Our starting motivation was to demonstrate how the enhanced thermo-diffusion of magnetic nanoparticles under a thermal gradient (and external magnetic field) can lead to a thermoelectric potential across the fluid. The existence of such an effect has been suggested theoretically, but had not been observed prior to the project.

The project advanced generally well according to the initial timetable and we have successfully measured the thermopower (the Seebeck coefficient) in ferrofluids and the results were compared to the thermodiffusion measurements (via Forced Rayleigh scattering technique) performed by the collaborators at the PHENIX/CNRS-UPMC. The obtained data were analyzed using existing theoretical models [1], taking in account the inter-particles interactions [2]. The intricate relation between the thermoelectric and thermodiffusion effects was revealed through the "Eastman entropy of transfer" of nanoparticles, a common parameter that characterizes the particle-solvent interactions. The values of the Eastman entropy of transfer obtained from both experiments are in a quantitative agreement, lending support to the theoretical models. To the best of our knowledge, this is the first experimental observation of thermoelectric effect in any charged colloidal solutions, not limited to ferrofluids.



Two examples of thermocells developed for MAGTEP. From left : the side and the top view of the first model (2012). Inside the A 0.6mL of cylindrical sample space is hollowed out in the Teflon body. Homemade Pt electrodes are inserted from two sides and are separated by 6mm. The cell is heated from the top to avoid the convection within the fluid. Bottom: the side and the top view of the modified model (2014). The assembly of the cell has been simplified and the sealing quality has been improved.

During the course of the project MAGTEP, we have encountered a few difficulties that required certain changes to the original plans set forth in the proposal. The first concerns the thermocell design (see project proposal). The initial model for the thermocells was determined to be inefficient in terms of creating a linear and stable temperature gradient. Furthermore, the design required nearly 5 mL of ferrofluids per measurement, while our sample supply was limited to 2 mL for the most concentrated ferrofluid. The thermocells currently used in MAGTEP resembles closely our previous models [4] with a few modifications in the sample volume and the temperature-control system. The second is the delay in starting the magnetothermopwer measurements. This is due to the fact that we have spent a substantial amount of time in elaborating the existing theoretical models that adequately describe the thermodiffusive and thermoelectric behavior of nanoparticles. However, the results and conclusions stated above, as well as recent measurements on thermodiffusion (the Soret coefficient) by our collaborators at the UPMC suggest that our current working model is on the right track, providing a foundation to tackle more complicated physical conditions; e.g., the presence of magnetic fields. From Equations 2 and 3 one can also identify several experimentally tunable parameters (e.g., the NP surface charge and sign, concentration of NPs and ions, $\hat{S}$ of counter ions) that can be used to test the validity of the model, and furthermore to control the overall thermopower of ferrofluids. We are currently 4 examining the Seebeck coefficient of several ferrofluids (prepared in water, ionic liquids and organic solvents) with various sample parameters. The design and the construction of a thermocell suitable for its use under magnetic field is also underway.

T. J. Salez , B. Tao Huang, M. Rietjens, M. Bonetti, C. Wiertel-Gasquet, M. Roger, C. Lopes Filomeno, E. Dubois, R. Perzynski and S. Nakamae, *Can charged colloidal particles increase the thermoelectric energy conversion efficiency?*, Phys. Chem. Chem. Phys., 19, 9409-9416 (2017)

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