
Preface

The fascination of ferrofluids – suspensions of nanosized magnetic particles in appropriate carrier liquids – arises from the fact that their flow and properties can be significantly altered by the influence of moderate magnetic fields. The possibility to exert an externally controllable force to a fluid opens obviously a wide spectrum of possibilities as well in basic fluid dynamics research as for applications in nearly every field adapting fluids. In the past 40 years since the first synthesis of a ferrofluid has been reported the attraction of these fluids and the challenging possibilities to control them by means of magnetic fields generated by normal permanent magnets or simple coil arrangements has driven intense research activities and brought up a number of technical applications. Some of these applications gained importance in every day life and represent a significant commercial value meanwhile. Reviewing the proposed applications one finds that those which have been successful on the market are characterized by two basic traits. First they employ the magnetic field only to exert a force which positions the fluid somewhere inside a certain device. Moreover, and that is the second common aspect of these applications, they are all technical applications mainly in the field of mechanical engineering.

In contrast to this clear restriction of the successful applications to a single technical field and a comparably simple use of the action of the magnetic influence the perspectives of ferrofluid research are much broader. First of all the magnetic action can not only be used to provide a force positioning the fluid. The force enters directly into the Navier–Stokes equation and can thus be utilized to control and drive flows in the fluid. Taking into account that strength and direction of magnetic fields and field gradients can be tailored for a specific need one can imagine the variety of arising possibilities. Furthermore not only the flow of magnetic suspensions can be changed by magnetic fields but also their thermophysical properties – in particular the rheological behavior – change significantly in the presence of magnetic fields. Moreover literature reports since many years about approaches to use magnetic fluids in biomedical applications namely for such important questions like cancer treatment. The significant discrepancy between successful applications on the one hand and principle potential

and scientific activities on the other hand emerges mainly from the complexity of the fluids as well as of the description of their behavior in a magnetic field.

The fluids – mentioned above to be suspensions of nanoparticles in a carrier liquid – have a microscopic make-up, which is not as simple as it may seem in the first view. Basically the particles have to be stabilized against agglomeration – especially due to v. d. Waals attraction – to achieve colloidal stability. This is usually obtained by a sterical stabilization provided by long chained molecules attached to the particle surface. The stabilization of the suspension as well as the variation of compositional aspects like the size and material of the magnetic particles requires a deep knowledge in – colloidal – chemistry. The mentioned changes in the fluids composition lead on the other hand to sometimes dramatic alterations in their properties. As an example a slight change in the size of the magnetic particles can give rise to significant changes in the interparticle interaction leading to fundamental variations of the fluid’s rheological properties. The latter can be used for technical applications, but this requires as well new measuring techniques to characterize the fluids as new models to describe their behavior. On the other hand the models may be used to identify influence parameters, which can be used to optimize the fluid’s behavior for a certain application. This example sheds a light on the most important needs in ferrofluid research. Interdisciplinary interaction is the key to success and the development of innovative ideas.

Interdisciplinarity means in this context an intense interaction between chemists synthesizing the fluids, theoretical physicists describing their behavior, experimentalists characterizing the fluids and their flow and engineers employing them for applications and providing the application-based needs as guideline for the preparation of new fluids. Moreover the approach toward biomedical applications widens the interaction field to specialists from medicine and pharmacology.

An approach including scientists from numerous different research fields requires a highly coordinated background structure to be successful. In the years 2000–2006 such a structure has been provided by the priority program “Colloidal Magnetic Fluids: Basics, Development and Application of New Ferrofluids” founded by the Deutsche Forschungsgemeinschaft (DFG-SPP 1104). Within this coordinated research program 30 groups and about 90 scientists from all mentioned fields have contributed to the development and understanding of new ferrofluids and related innovative applications. About 400 publications in refereed journals resulted from these efforts; a third of them authored by an interdisciplinary group of scientists.

This book summarizes now the major results of SPP 1104 in six chapters focussing on the different main research areas. The first chapter is devoted to the synthesis of ferrofluids and their experimental characterization as a basis for all research on such colloids. As a highlight in this context one could mention the preparation of ferrofluids containing cobalt particles providing an immense magnetic response.

In chapter two the theoretical foundation for the description of flows in magnetically controlled fluids is given with the deduction and explanation of Ferrofluid–Dynamics.

The third part of the book is a combined theoretical and experimental work, on one of the most fascinating phenomena arising in ferrofluids – the spike-like surface instabilities being even a kind of icon for the research field “Ferrofluids”.

Another combination of theory and experiments is given in Chap. “Ferrofluid Structure and Rheology” reviewing the measurement and modeling of the rheological behavior of ferrofluids, ending with a comparison, which provides a real approach for a microscopic understanding of the observed phenomena.

The two last chapters are finally devoted to the applications of ferrofluids. Chap. “Biomedical Applications of Magnetic Nanoparticles” reviews the biomedical use of magnetic nanoparticles with a special focus on magnetically aided cancer therapies.

The last chapter summarizes a wide variety of approaches to new and innovative technical applications going far beyond those which are known on the market.

Altogether we hope that the book will provide as well a look on the state of the art in ferrofluid research as a glance on the fascination of this research field.

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