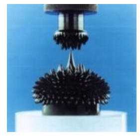
Center for Fundamental and Advanced Technical Research		Research Center for Enginerring of Systems with Complex Fluids

TIMISOARA ACADEMIC DAYS 2015

WORKSHOP

Multifunctional nanoparticles, magnetically controllable fluids, complex flows, engineering and biomedical applications

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Venue: Aula of the Romanian Academy-Timisoara Branch

Chairman: Ladislau Vékás

Abstracts

Keynote lectures

Magnetic particle hyperthermia for cancer therapy: achievements and challenges

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Medics have known of the healing effect of heat for a long time. About 150 years ago it was found that tumours cease to grow for temperature above 42°C whilst healthy tissue is not affected by such temperatures. Magnetic particle hyperthermia (MPH) enables local heating by embedding the heating source (magnetic particles) into the tumour tissue and heating it by using an external alternating magnetic field. This means a clear advantage of MPH therapy compared to other heating techniques with respect to localization of heat.
In this contribution a critical view on the state of the art of magnetic particle hyperthermia as a minimal invasive tumour therapy is presented. On the basis of current knowledge from the literature and own investigations of treating cancer by thermal damaging, this talk elucidates possibilities, prospects, and challenges for establishment of MPH as a standard medical procedure. Magnetic principles of heating mechanisms are discussed with respect to the optimum choice of nanoparticle properties and applied magnetic field. In particular, the relation between superparamagnetic and ferrimagnetic single domain nanoparticles is clarified in order to choose the appropriate particle size and size distribution and the role of particle mobility inside the tissue for the relaxation path is discussed. This knowledge of the effect of particle properties for achieving high specific heating power provides necessary guidelines for development of nanoparticles tailored for tumour therapy.

A need for a harmonized physical, chemical and colloidal characterization of SPIONs

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The growing efforts of researchers have been shown lately to develop newer and newer products of superparamagnetic iron oxide nanoparticles (SPIONs) worldwide. Tremendous amount of promising nanohybrid systems for medical applications has been published. However, the characterization of these hopeful products is not uniform, but rather depending on the tradition and the facilities of the given laboratory. Therefore the characteristic values given for the different products are not always comparable, e.g., due to different experimental conditions such as pH, ionic strength or the use of different buffers, etc. Unfortunately, good protocols have not been available yet.

Based on our previous suggestion for the characterization of carboxylated core-shell products [1] and the need advised by RADIOMAG community (COST - TD1402), we attempt to harmonize physical, chemical and colloidal characterization of SPIONs in order to fulfill the fundamental physico-chemical requirements of biomedical application before implementing expensive in vitro tests, and even more resource-intensive in vivo experiments. In the talk, the governing ideas for methodical harmonization of systematic SPION characterization together with the shortcomings often occurring even in the top articles will be presented. Since the SPIONs for medical use are almost exclusively fabricated with an organic surface coating mainly to improve their biocompatibility, and hence their physicochemical and colloidal properties, both the magnetic (single or multi) core and the stabilizing layer, and the whole nanoparticulate system (water based magnetic fluid) as well have to be characterized. To achieve uniform-characterization of the properties the following procedures are worth harmonizing: i) for magnetic core: crystal structure (XRD pattern), size ((HR)TEM image) magnetic feature (VSM – magnetization curve, hysteresis, saturation magnetization; AC susceptibility, magnetophoretic mobility, chemical stability – oxidation, solubility, corrosion/iron leaching), ii) for stabilizing layer – chemical composition, specific amount (adsorption, TG/DTG), thickness, surface bond formation (FTIR, XPS), charging (pH-dependent charges – protonation/deprotonation equilibria) and iii) for aqueous magnetic fluid: pH-dependent charging (electrophoretic mobility, zeta potential measurement), pH- dependent aggregation (DLS) and ionic strength dependence (salt induced coagulation, salt tolerance – coagulation kinetics to predict colloidal stability). The latter is crucial because of the danger of causing in vivo embolism.

Finally, the harmonized experimental methods have to be validated, and be described in a methodically correct way. The harmonized descriptions should be disseminated widely as recommendation for good characterization practice in order to prevent the failure of promising SPIONs' products in biological in vitro tests due to physicochemical inadequacy.

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Engineering and biomedical applications of magnetic nanofluids

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Invited lectures

Application of Nanotechnology for specific cancer treatment – The SEON-Concept

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Nanotechnology has already revolutionized the energy and electronic sector, and has been deployed successfully on a commercial scale. Nanoparticles form a basis for a huge variety of pharmaceutical and medical applications, including diagnostics, drug delivery, and have especial potential in cancer therapy. The application of nanotechnology for cancer is an interdisciplinary area of research in science engineering and medicine with broad application for imaging, molecular diagnosis and targeted therapy. For diagnosis *in vivo* SPIONs are already in use as contrast agents in magnetic resonance imaging*, in vitro* they are appointed for cell separation. From a drug delivery point of view, targeting of cancer is a most promising area concerning delivery of chemotherapeutics. Highly sophisticated nanoscaled drug delivery systems requiring complex material science and engineering have been raised the past few years. Heading for clinical translation synthesis have to be as complex as necessary but as simple as possible to have a process that can deliver nanoparticles in an amount and quality which is necessary for clinical studies. A very promising approach in this contect is Magnetic Drug Targeting (MDT), which enables a goal oriented local application of cancer therapeutics in the desired region (i.e. tumor). Very successful animal experiences have already been performed on this purpose. SEON (Section of Experimental Oncology and Nanomedicine) is aiming to translate this efficient therapeutic model into clinical trials. To gain this ambitious project, several requirements, such as detailed synthesis and characterization of the nanoparticles, nanotoxicological testings, *ex v*ivo models to simulate *in vivo* conditions for appropriate adjustment for the necessary parameters and pre-clinical animal studies have to be addressed. These results are of pivotal importance to start with respective GMP production and approval, which is essential for clinical trials. Additionally interdisciplinary collaboration with physicists and engineers is necessary to reveal appropriate technical application modes and the possibility for quantitative analysis of particle distribution. SEON addresses these issues with a special focus on specific drug delivery using magnetic nanoparticles in cancer treatment and avoiding the negative side effect of conventional chemotherapy, which will be of medical and economic relevance concerning the increasing number of cancer patients.

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Structural aspects of magnetic fluids stabilization: small-angle scattering studies

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The understanding of stabilization mechanisms for ferrofluids is an important factor in the synthesis of highly stable magnetic colloids with defined properties. The given report reviews the principal results of our works devoted to the detailed investigations of ferrofluid stability regarding the change in the structure under various conditions including the diagnostics and determination of the aggregation regimes in biocompatible ferrofluids for medical applications. The structural features of the ferrofluids and subsidiary solutions were revealed and analyzed basing on the data of small-angle neutron scattering (SANS). Thus, for ferrofluids based on non-polar solvents the study of the effect of free surfactant excess showed a significant increase in the attraction between non-adsorbed acid molecules, which explained the sharp loss in ferrofluid stability at some critical acid concentration as a result of the liquid crystal transition. The later strongly depends on the solvent-acid interaction and is characterized by different critical points in different solvents. For an aqueous ferrofluid (nanomagnetite coated by a double layer of sodium oleate (SO)) used as a precursor for the biocompatible modification with polyethylene glycol (PEG) the fraction of micelles of non-adsorbed surfactant and its change under modification was found by SANS. The comparison with the other kinds of water-based ferrofluids showed the different rate of surfactant adsorption on magnetite surface depending on the surfactant type. The aggregate reorganization and growth in the ferrofluid after PEGylation was observed. To clarify the possible influence of the micelle formation of free surfactant on this process in the presence of polymer the SANS study of the mixed SO/PEG aqueous solutions was carried out, which showed drastic changes in the structure and interaction of micelles under the effect of the PEG addition. In particular, the screening of the micelle interaction was concluded because of the formation of an effective PEG shell around micelles at high (about 10 vol. %) concentration of the polymer.

Magnetoresponsive nanosystems with controlled morphology and surface functionalization

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Magnetic nanoparticles well separated or in clusters, with proper surface functionalization usually dispersed in liquid carriers or embedded/encapsulated in polymeric networks, are the basic building blocks of a large variety of multifunctional carriers. The encapsulation of magnetic nanoparticles into polymeric micro/nanogel systems gives rise to hybrid magnetic carriers that combine the features of a polymeric gel with the interesting properties of magnetic nanoparticles and make them suitable for applications.

Design of magnetoresponsive nanocomposites was achieved using different synthesis procedures that allow controlled clustering of magnetic nanoparticles embedded into polymers/copolymers. High magnetization magnetic microgels have been obtained by the encapsulation of surfacted clusters of magnetite nanoparticles from organic carrier magnetic nanofluid into crosslinked polymers (poly(N-isopropylacrylamide), polyacrylic acid, poly(3-acrylamidopropyl)-trimethylammonium chloride).

TEM investigations show the close packing of magnetite nanoparticles into well defined sherical microgel particles with sizes in the range 50-300 nm. X-ray Photoelectron Spectroscopy investigation of surface chemical composition of the magnetic microgels confirms the nanocomposites formation and the attachment of specific functionalities. The magnetic nanocomposites show superparamagnetic behaviour at room temperature and relatively high saturation magnetization values (40-69 emu/g).

Our results show that polymer encapsulation of magnetic nanoparticles allows tailoring the properties of the magnetic nanocomposites in a highly modular fashion by control of the polymer structure and composition.

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Magnetically induced structuring in magnetic colloids

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Magnetic colloids are stable, homogeneous and isotropic colloidal dispersions of magnetic nanoparticles or nanocomposites. Magnetically induced structuring in magnetic colloids is the result of the synergy between magnetic dipole-dipole and dipole-field interactions. The external magnetic field triggers local order in magnetic colloids that can span through the entire nano - micro - macro scale range. This may have unwanted consequences on the applicability of the magnetic colloids but may also enhance their potential use for the synthesis of taylored magnetic composites as well as for magnetic separation. We present optical methods for *in-situ* investigation of the magnetically induced structuring in magnetic colloids.

Hyperthermia of magnetosome samples

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Bacterial magnetosomes were isolated from Magnetotacticum Spirillum-AMB1 bacteria. In this contribution will be compared hyperthermic results from magnetosome samples obtained by changing of cultivation conditions during biomineralization process and magnetosomes normally prepared with “standard” length and magnetosome of a short length prepared by mechanical cleavage by means of centrifugation and sonication treatment after isolation. It was shown that adding a higher amount of Wolfe’s vitamin solution (WVS) or ferric quinate (FQ) to cultivation solution cause increase of the mean diameter from 47 nm (normal condition) up to 52 nm and 58 nm, respectively. As a consequence of this change the preparation conditions coercivity and Specific Absorption Rate (SAR) increased up to 20 Oe and 949 W/g for sample FQ, respectively. The increase of coercivity for sample WVS and FQ is connected with higher shape anisotropy for samples with higher mean size diameter. As coercive force increases for samples FQ and WVS, higher values for SAR are obtained as a consequence to the higher release of thermal energy which is result of the additional loss caused by the hysteresis.

The effect of the sonication was analyzed using transmission and electron microscopy, atomic force microscopy, and dynamic light scattering. Scanning imaging reveals three types of shortening effect in sonicated sample, namely, membrane collapse, membrane destruction, and magnetosomes cleavage along its length with a comparable contribution of these effects in the sample. Dynamic light scattering showed a reduction of hydrodynamic diameter in SM sample. Magnetic properties of magnetosome were analyzed in DC and AC magnetic field based on evaluation of quasistatic hysteresis loops (energy losses) and calorimetric hyperthermia measurements (specific absorption rate), respectively. The sonicated sample magnetically behaves in a different meaner, showing that energy loss and specific absorption rate are noticeable reduced, and thereby indicates variation in the relaxation process and heat distribution. This showed that this type of magnetosomes can be auspicious material for application in hyperthermia, primarily in cancer treatment, as the short chain magnetosomes demonstrates good distribution and penetration properties providing a uniform heating in the tumor tissue.

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Oral presentations

Comparative structure analysis of magnetic fluids at interfaces by neutron and x-ray reflectometry

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For the moment, synthesis of stable biocompatible ferrofluids (FF) with pre-defined properties is quite big problem. Therefore, the study of biocompatible FF is of great interest. At the same time behavior of magnetic nanoparticles in the bulk and at interfaces can be very different due to specific adsorption properties, which should be considered in a variety of applications. It also remains an open question regarding to the possible differences in the stability of magnetic fluids in bulk and at interfaces.

The main aim of this work was to obtain structural parameters of biocompatible ferrofluids and to study of FF stability in the bulk and at the interface. Information about the structure of FF in bulk was obtained from small-angle neutron scattering experiments. Neutron reflectometry experiments were done to investigate behavior of magnetic fluids with different methods of preparation and concentration at the interface with silicon. Influence of gravity on the adsorption properties of magnetic particles was also checked. It was shown that only single magnetic nanoparticles, coated by surfactant molecules, are adsorbed to the surface of the silicon from bulk of ferrofluids. X-ray reflectometry makes it possible to study free liquid surfaces or interfaces air/FF. It was found additional structural organization of the nanoparticles at this interface. Influence of magnetic field with horizontal and vertical to surface direction was shown.

Multidisciplinary approach in bypass surgery planning

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Bypass graft failure is mainly caused by intimal hyperplasia (IH) that occurs at the graft anastomis after surgery. It has been shown that local hemodynamics influences the process of IH initiation and progress. A main concern at this type of surgery is to increase the graft patency. For this reason there have been developed different anastomosis techniques and, nowadays,

different graft geometrical configurations. Recent tendencies are focused on developing helical grafts that induce at the anastomosis region a swirl flow pattern, associated to positive local hemodynamics change.

A multidisciplinary approach is necessary in order to understand the phenomena that appear in bypass and to plan an efficient bypass surgery. The use of computational and experimental fluid dynamics tools permitted to investigate in vitro the fluid flow in different conditions, with different graft configurations. By using magnetic particles, we succeded to put in evidence the effects of local hemodynamics at the graft anastomosis in terms of particle depositions in magnetic field. The process is similar to IH development. Experiments showed that in case of bypass with helical grafts, the quantity of magnetic particles deposited at the anastomosis region is significantly lower than in case of straight graft.

In order to have a succesful bypass surgery it is very important to take into consideration the conditions that could increase the graft patency.

Keywords: bypass surgery, magnetic particles, magnetic field, helical graft, intimal hyperplasia

Particles deposition induced by the magnetic field in the coronary bypass graft model

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Bypass graft failures is a complex process starting with intimal hyperplasia development which involve many hemodynamic and biological factors. This work presents experimental results regarding the possibility to use magnetic drug delivery to prevent the development of the intimal hyperplasia using a simplified but intuitive model. The primary goal is to understand the magnetic particle deposition in the anastomosis region of the bypass graft taking into account the complex flow field created in this area which involves recirculation region, flow mixing and presence of particles with high residence time. The three-dimensional geometry model was used to simulate the motion and accumulation of the particles under the magnetic field influence in anastomotic region of the coronary bypass graft. The flow patterns are evaluated both numerically and experimentally and show a good correlation in term of flow parameters like vortex length and flow stagnation point positions. Particle depositions are strongly dependent on the magnet position and consequently of the magnetic field intensity and field gradient. Increased magnetic field controlled by the magnet position induces increased particle depositions in the bypass graft anastomosis. The result shows that particle depositions depend on the bypass graft angle, and the deposition shape and particle accumulation respectively, depend by the flow pattern in the anastomosis region.

Keywords: bypass graft, recirculation, flow dynamics, magnetic particle targeting, particle deposition

Magnetic hyperthermia of single and multicore magnetite nanoparticles

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The on-going research for the therapeutic use of magnetic hyperthermia (MH) to treat cancer substantiates the need for biocompatible magnetic fluids (MF) that exhibit good heating efficiency. Recently published research involving physico-chemical and magnetic characterization of nanoparticles with different size, morphology and state indicate that multicore magnetite nanoparticles (MNP) show greater potential in MH when compared to single core particles or clusters of MNPs [1,2]. Our goal was to test and compare the MH efficiency of MFs containing single and multicore superparamagnetic iron oxide nanoparticles (SPION).
The MFs were synthesized by co-precipitation of iron(II)- and iron(III)-chloride salts with sodium hydroxide, no surface modification was carried out. Variation in the synthesis method yielded two different MF products. One of them (SC) bearing characteristics similar to single core MNP systems and the other behaving as it contained larger aggregates (SC+MC). The crystallographic analysis of the MFs by an X-ray diffractometer (XRD) showed that both contained magnetite NPs. The results of the size analysis by transmission electronmicroscope (TEM) and dynamic light scattering (DLS) proved that SC contained single core particles of about 10 nm in size, and that in the SC+MC sample multicore MNPs were also present along with the observed single core particles resulting in a higher degree of polydispersity. The SC+MC sample was fractionated by magnetic and centrifugal separation yielding MFs with different size distribution (TEM, DLS). The MH efficiency of all the products (SC, SC+MC and the fractions) was assessed using a MagneTherm™ MH system. The effect of the MNP concentration (0-60 g/L), frequency of the AC magnetic field (100-900 kHz) and field strength (4-25 mT) on the MH efficiency was investigated in a series of experiments for all of the MF samples in a given sample volume (4 mL). The dependence of the specific absorption rate (SAR) with concentration showed that at low concentrations (<5 g/L) the values were unrealistically high, but at concentrations higher than ~5 g/L the SAR values did not change substantially, so the concentration of 10 g/L was chosen for further tests. By increasing the resonant frequency and magnetic field the calculated SAR values increased in a near-linear fashion. The SAR values calculated for the different MFs and frequency/field settings (2-40 W/g) were compared.

The future in-vivo application of these MFs is planned but the surface modification of these MNPs is yet needed to provide biocompatibility [3].

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Speed Control with Magneto-Rheological Fluids in Hydraulic Machinery

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The basic property of magneto-rheological (MR) fluids is the ability to change viscosity in the presence of a magnetic field. The fast response makes them advantageous in interfacing electric signals and fluid power without the need of mechanical moving parts. The MR fluids are designed to work in a high range of temperature (-40°C ÷ 150°C) being used in a wide variety of applications as dampers, shock absorbers, torque clutches or brakes. Typically MR fluids are suspension of micron sized magnetic particles (iron) in a non magnetic carrier fluid (hydrocarbon oil, silicone oil, water). When a magnetic field is applied the particles forms a chain like structures aligned parallel to the applied magnetic field, [1].

A MR device was developed to the Hydraulic Machinery Laboratory from Politehnica University of Timişoara in order to slow down the runner speed. As a result, an extended range of hydrodynamic regimes is investigated using this control technique [2, 3]. For this purpose a preliminary test rig was designed, developed and built in order to analyze different brake models for other applications. Several MR fluids developed and characterized in our laboratory were compared with different MR fluids available on the market [3, 4, 5]. This method was chosen taking into account the mechanical properties of the MR brake. The test rig consists in a variable speed electric motor (0-1500 rpm), a torque detector (0-20 Nm, 0-2500 rpm), the MR brake and the control and acquisition system. The control and acquisition system set the nominal speed of the electric motor and records the following data: (i) the torque value, (ii) electric motor speed, (iii) the voltage and current from the coil of brake or clutch and (iv) the brake temperature, respectively. The temperature is acquired on the outside wall of the brake with ±1.5°C accuracy.

The aim of this study is to provide an evaluation of the MR brake operated in air and water. First is presented the design of the MR brake. The mechanical design takes into account the geometrical, magnetic and electrical constraints and also the temperature generated by the MR fluid. The second part of the presentation shows the experimental investigations for a market MR fluid and a MR fluid developed in our laboratory, tested in air as well in water on the test rig presented above. The third part presents the implementation of the MR brake on test rig for hydraulic machinery. The speed was reduced from 900 rpm up to 300 rpm, obtaining operating regimes from part load to full load [2]. The conclusions are drawn in the last section.

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Ferronematics - way to have liquid crystalline sensors of magnetic field

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Liquid crystals (LCs), due to their large dielectric anisotropy, respond very sensitively to application of an external electric field, whereas they are only weakly sensitive to the magnetic field. A possible way of improving that sensitivity is doping liquid crystals with magnetic nanoparticles. As a result, stable colloidal suspensions of liquid crystals with relatively low concentrations of magnetic nanoparticles, called ferronematics, can be produced. These stable suspensions are considered to be extremely promising materials, in which the properties of LCs are modified by doping. We demonstrated such possibility in several experiments. As a representative example, the presence of the magnetic admixture enhances the magnetic susceptibility of ferronematics in comparison to that of the undoped nematic LCs and allows to control their orientation with much lower magnetic fields [1]. We have demonstrated that even very low magnetic fields ($B < 0.1$ T) may induce a significant magnetic response in ferronematics. We have also shown the possibility to alter the nematic-isotropic transition temperature with an external field in the thermotropic calamitic doped with rodlike magnetic particles [2]. Our results have proven that ferronematics can be just as effective in demonstrating the magnetic field induced isotropic-nematic phase transition as pure bent-core nematics [3]. Recently a consistent mean-field model was developed for the field-induced shift of the temperature of isotropic–nematic phase transition in ferronematics [4]. It was shown that depending on the anchoring conditions on the particle surface, the particles might either enhance or decrease the clearing temperature of the suspension. Our experimental results have confirmed the magnetic field induced negative shift of the isotropic-nematic phase transition temperature in the mixture of bent-core and calamitic liquid crystal doped with spherical magnetic particles [5].

An important feature of lyotropic liquid crystals is the self-assembly of the amphiphilic molecules as supermolecular structures. We have studied the formation of nematic liquid crystal phase in solutions containing lysozyme amyloid fibrils and magnetic nanoparticles using oscilloscopic method. Interaction of fibrils with magnetic nanoparticles under the external magnetic field resulted in fibril re-arrangement.

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The structure of water-based ferrocolloids with agarose synthesized by different methods according to neutron and synchrotron investigations

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Investigation of colloidal systems of magnetic nanoparticles dispersed into a liquid medium constitutes a specific trend in condensed matter science by enabling the use of magnetic particles in a wide range of technical applications and especially in medicine [1,2]. For medical purposes the particles have to meet special requirements, like being nanosized, nontoxic and having stability to aggregation, etc. Prospects of using magnetic NPs in particular hyperthermia treatment of cancer impose an additional requirement: the ensemble of particles has to demonstrate high heating efficiency under alternating magnetic field.

Manufacturing of new ferrofluids with the specified properties for biomedical purposes involves the development of new methods of synthesis of magnetic nanoparticles. The first basic requirement to ferrocolloid in this case is biocompatibility of the liquid medium.

Water based agarose gel due to haptic behaviour compared to biological material [3] is often used as a model of biological tissue in biomedical experiments with magnetic nanoparticles [4-6]. For this reason, a mixture of agarose (polysaccharide, $C_{12}H_{18}O_9$) in a water is selected as liquid carrier of magnitite contained ferrofluids.

Samples of the magnetic liquids prepared by three different methods of magnetite nanoparticles synthesis [7,8] were studied by Small-Angle Neutron (SANS) and Synchrotron Scattering methods. Obtained experimental data allowed to make some conclusions about the structure of considered ferrofluids. All samples demonstrated the separation of liquids on a precipitate and a supernatant fractions. Small-angle scattering experiments were performed on the corresponding supernatant fractions.

It is shown that two kinds of ferrofluids have a similar microstructure: monomers of magnetite with Guinier radius of 2.8-2.9 nm and big aggregates with 2.6-2.8 fractal dimension are presented in the systems. The magnetic liquid prepared using microemulsion method (3rd synthesis method) differs from previous ones by its complex aggregation.

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Nano-micro composite magnetic fluids: magnetic and magnetorheological evaluation for rotating seal and vibration damper applications

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Abstract In this paper, static magnetic properties and magnetorheological behavior of a set of 12 nano-micro composite magnetic fluids (CMFs) were studied. The samples, with a ferromagnetic particle volume fraction ranging in a large interval $\varphi_{Fe} = (0 \div 44)\,\%$, were prepared by adding carbonyl iron powder, with saturation magnetization of $M_s = 210\,A \cdot m^2 / kg$, in a highly concentrated transformer oil-based ferrofluid having the magnetite volume fraction of $\varphi_{Fe_3O_4} = 22.90\%$ and saturation magnetization of $M_s = 78\,kA/m$ (980 Gs). No further additives were used in order to prevent sedimentation. It was noticed an increase of the static yield stress, of about 3 orders of magnitude, with the increase of the total solid volume fraction of samples and with the increase of the applied magnetic field, which varied between 0 kA/m and 950 kA/m. The dynamic yield stress of the samples strongly increases with the increasing applied magnetic field, and shows a slight tendency of saturation for higher intensities of the magnetic field. There is a less pronounced increase of the τ_{HB}, about an order of magnitude, with the increasing volume fraction of the iron particles. The relative viscosity increase induced by the applied magnetic field reaches a maximum for both considered shear rates: $\dot{\gamma} = 7.85\,s^{-1}$ and $\dot{\gamma} = 88.41\,s^{-1}$, and it was revealed an optimal volume fraction of Fe particles, $\varphi_{Fe} = 20\%$, corresponding to a total volume fraction of $\varphi_{tot} \approx 38\%$, at which the magnetoviscous effect has its maximum value. The results obtained by applying the demagnetizing field correction on magnetization data of CMFs are consistent with rheological and magnetorheological ones. The magnetization, the magnetorheological and the magnetoviscous behavior of highly concentrated ferrofluid based CMFs can be controlled by the addition of iron microparticles, in order to attain the right concentration for each envisaged engineering application, rotating seals and magnetorheological vibration dampers.

Posters

Uptake of albumine coated iron oxide nanoparticles into tumor cells

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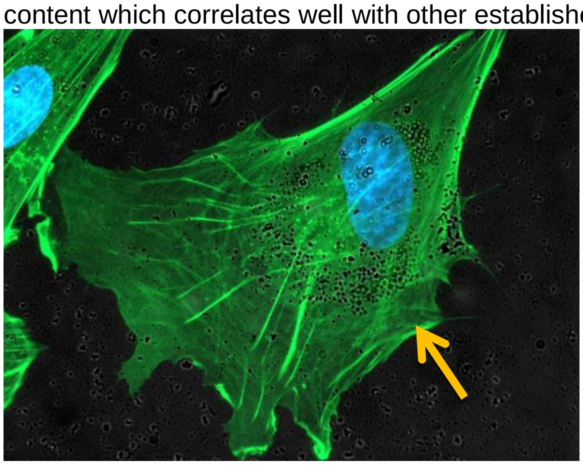
The uptake of nanoparticles into cancer cells is an important issue for the therapeutic outcome of nanoparticle based tumor therapy. The size of the particles their surface charge and chemical composition are commonly regarded to influence the internalization significantly. Nevertheless the exact mechanism has not been elucidated, so far.

Our workgroup has frequently used fatty acid/albumin hybrid coatings on SPIONs before, as these coatings provide very useful properties for magnetic drug targeting [1]. However, for clinical translation of this particle system, it is necessary to use human serum albumin which is free of viruses and pyrogens. The protein structure critically affects particle uptake and, consequently, their biocompatibility. This arises the question whether cellular uptake and biocompatibility of human serum albumin coated particles are different from bovine serum albumin coated ones.

We compared uptake and biocompatibility of lauric acid/bovine serum albumin and lauric acid/human serum albumin coated SPIONs into human T-lymphoma cells. We therefore used an established flow cytometry method [2] to investigate the uptake of nanoparticles into cells. We used microwave plasma assisted atomic emission spectroscopy (MP-AES) to quantify the iron uptake after washing and lysis of the cells as a highly sophisticated, complimentary method.

Conclusively, we showed that MP-AES is a useful method for the determination of cellular iron content which correlates well with other established methods.



Internalized iron oxide nanoparticles (yellow arrow). Nucleus appears blue (DAPI-staining). Light green fibers: Cytoskeleton (Alexa 488 staining)

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Studies regarding magnetic nanoparticles size variation

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Magnetic fluids (MF) represent a category of smart fluids, which are rather attractive for a large variety of biological and medical applications, due to the magnetically controllable property. The agglomerative stability of colloidal suspensions with magnetic particles is achieved by coating each particle with adsorbed surface layers that hinder the particles approach to each other at distances at which the attraction energy is larger than the disordering energy of the thermal motion. Samples of magnetic fluid based on isooctane, containing magnetite (Fe_3O_4) coated with oleic acid were prepared by coprecipitation method. It was tested the influence of stirring speed and the precursors concentrations on the magnetic nanoparticles (MNPs) size. Also, MF based on pentanol, was obtain by coating oleic acid (OA) monolayer coated MNPs, with dodecylbenzenesulfonic acid (DBSA). Dispersion efficiency and MNPs size was compared with the OA monolayer coated MNPs from isooctane based MF, as the same precursor MF was used to obtain both MF based on pentanol, respectively MF based on isooctane. The obtained samples were characterized by transmission electron microscopy (TEM), magnetization measurements (VSM) and dynamic light scattering (DLS) measurements, in order to determine the magnetic (Dm), physical (Dp) and hydrodynamic diameter (Dh) of the MNPs.

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High concentration water based magnetic fluids: synthesis and characterization

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The aim of this paper is to present the methods applied to obtain and to investigate the properties of concentrated water based magnetic fluids. The high degree of colloidal stability of these biocompatible magnetic fluids is achieved through double-layer sterical stabilization of Fe_3O_4 nanoparticles dispersed in the carrier liquid. Ensuring the efficient adsorption of the surfactant (oleic acid) used and solvability of the coated nanoparticles are key features in the preparation process of high-quality magnetic fluids. The samples were investigated using a vibrating-sample magnetometer, a rheo/magnetorheometer, and by dynamic light scattering. The results reveal the dependence of the colloidal stability on the pH and volumic concentration of the magnetic fluid samples, as well as the dimension of the dispersed nanoparticles.