

Nanofluide magnetice si fluide magnetoreologice

- sinteza, caracterizare si aplicatii -

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&

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Universitatea "Politehnica" din Timisoara

Cuprins

- Scurt istoric
- Fluide controlabile magnetic
- Nanoparticule magnetice si fluide magnetice, procedee de sinteza
- Stabilitate coloidala si procese structurale
- Proprietati magnetice si de curgere
- Fluide magnetoreologice, tipuri principale, compozitie
- Procese structurale, efect magnetoreologic
- Producere de fluide controlabile magnetic la nivel industrial
- Exemple de aplicatii

Inceputul...

FLUIDITATE + PROPRIETATI MAGNETICE = ??



Noi tipuri de materiale, noi fenomene

Ferrofluid / Fluid magnetic

- T.L. O'Connor, Belgian Patent 613,716 (1962)
- **S. Papell (NASA), US Patent 3,215,572 (1965)**

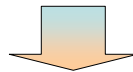
Fluid magnetoreologic

- National Bureau of Standards Technical News Bulletin 1948; 32(4): 54-60
- **J. Rabinow Proceedings of the AIEE Trans., 1948, 67, 1308-1315**

Ferofluide

- primele publicatii -

- **G. Knight (1779) (Fe/water) F. Bitter (1932) (Fe₃O₄/water) W. C. Elmore (1938) (Fe₃O₄/water)...**
- **J.L. Neuringer, R.E. Rosensweig, Ferrohydrodynamics, Phys. Fluids, 7 (1964) 1927**
- **R.E. Rosensweig, Fluidmagnetic buoyancy, AIAA J., 4 (1966) 1751**
- **R.E. Rosensweig, Buoyancy and stable levitation of a magnetic body immersed in a magnetizable liquid, Nature (London), 210 (1966) 613**
- **R.E. Rosensweig, The fascinating magnetic fluids, New Scientist, 20th January, 1966**
- **R.E. Rosensweig, Magnetic fluids, Int.Sci. Tech.48-56 (1966)**
- **E.L.Resler, R.E. Rosensweig, Magnetocaloric power, AIAA J. 2 (8)1418 (1964)**



... un ciclu termodinamic magnetocaloric destinat conversiei eficiente a caldurii in electricitate fara a avea componente mecanice in miscare, pentru utilizare pe vehicule spatiale ...

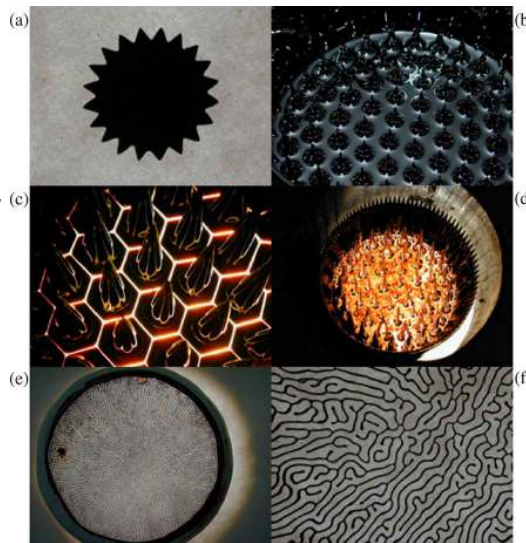
Ferofluide

- instabilitate interfaciala statica indusa de camp magnetic -

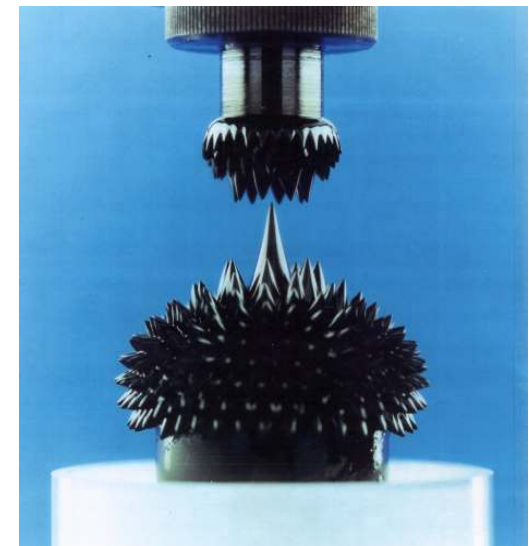
M.D. Cowley, R.E. Rosensweig,
The interfacial stability of a ferromagnetic fluid,
J. Fluid Mechanics, 30 (1967) 671-688

Sesiune jubiliara **Dynamics Days Europe 2007**, Loughborough, Anglia despre fenomenele de instabilitate cu ocazia a 40-a aniversare a publicarii lucrarii. **Fenomenul constituie un exemplu singular de formatiune fluidica in absenta unui proces disipativ.**

C. Rinaldi,..., M.Zahn/
Current Opinion in
Colloid & Interface
Science,
10 (2005) 141– 157



Lab. Lichide
Magnetice
Timisoara



Ferofluide

- instabilitate interfaciala dinamica indusa de camp magnetic -



Exponat realizat cu ocazia aniversarii a 100 de ani de existenta a Laboratorului Van't Hoff, Univ Utrecht
Prof. A.P. Philipse (Utrecht), Dr. Doina Bica (Timisoara) (2001)

Ferofluid

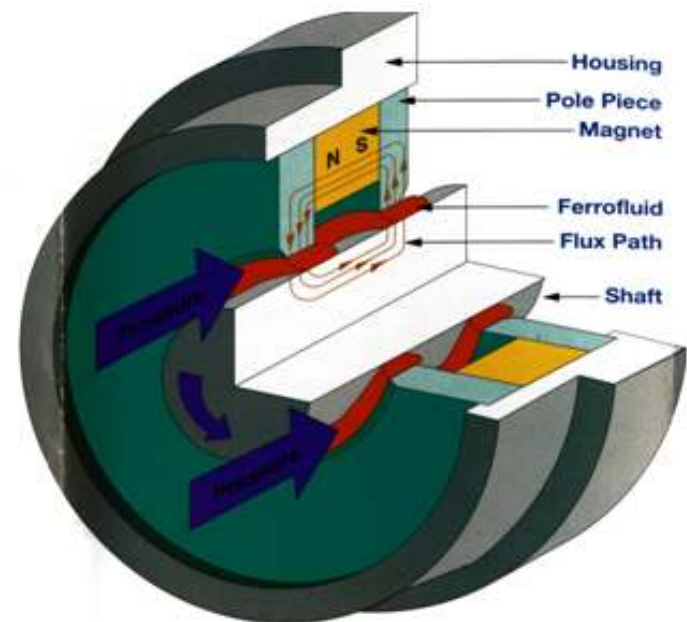
- productie si comercializare-inceputul -

Infiintarea primei firme comerciale:

Ferofluidics Corporation (USA), Massachusetts, **1968** - R. E. Rosensweig si R. Moskowitz

R. E. Rosensweig, *Magnetic fluid seals*
US Patent 3,260,584 (**1971**)

❖ inventia se refera la un nou tip de etansare rotitoare fara scapari, care are drept etaje de etansare inele "O" de lichid magnetic



Ferofluide in Romania

❖ Prepararea primelor ferofluide

Centrul de Fizica Tehnica, Iasi
... anii 1970-1975 ...

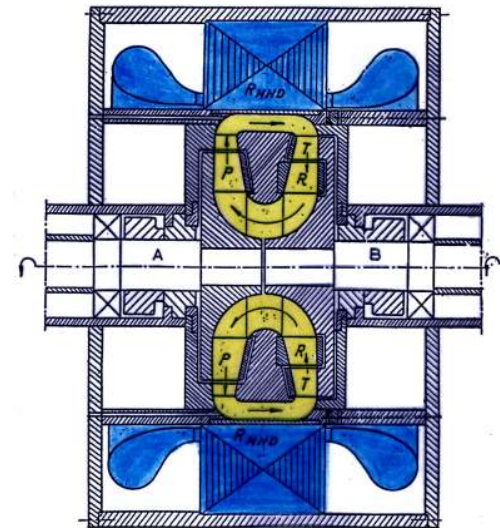
❖ Prima carte publicata despre ferofluide

E. Luca, G. Calugaru, R. Badescu, C. Cotae, V. Badescu, Ferofluidele si aplicatiile lor in industrie, Editura Tehnica, Bucuresti, **1978**
(336 pagini)

❖ Primul laborator

Laboratorului de Lichide Magnetice de la Timisoara
Catedra de Masini Hidraulice-Univ. Politehnica Timisoara
Acad. Ioan Anton, 1975

Turbotransformatorul MHD



Brevet RO Nr.57574
Acad. Ioan Anton 1971

Fluide controlabile magnetic

➤ **Ferrofluide (FF), nanofluide magnetice (NFM)**

- Suspensii coloidale ultrastabile de **nanoparticule magnetice** (NPM) intr-un lichid de baza (LB) – **sedimentare zero**, inclusiv in camp magnetic
- Fluide magnetizabile **quasiomogene**
- Comportare magnetica de tip **Langevin**
- Comportare aprox. **newtoniana**, inclusiv in camp magnetic; efect magnetovascos redus

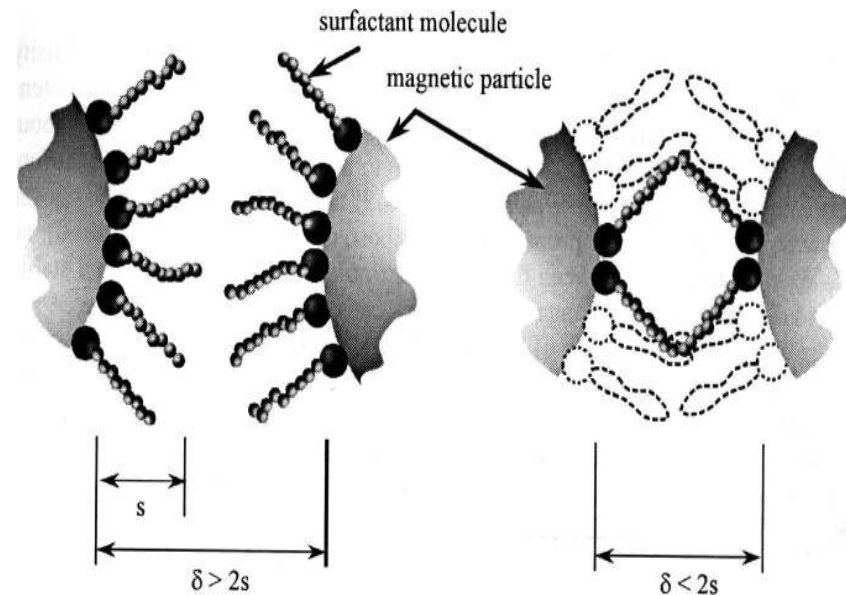
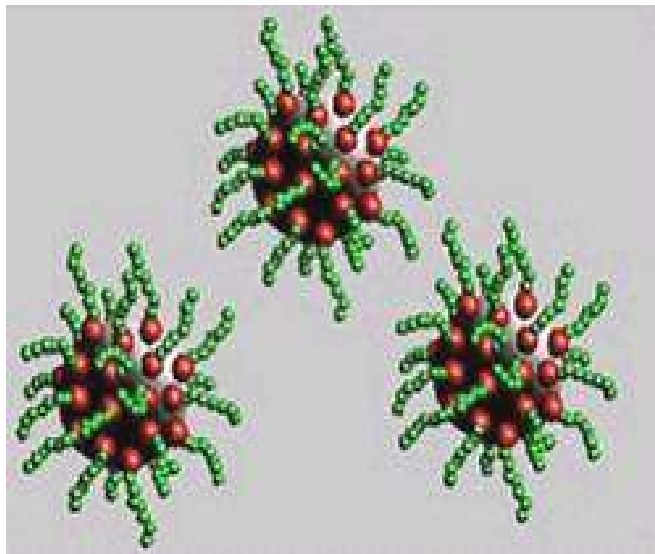
➤ **Fluide magnetoreologice (FMR)**

- Suspensii de **particule feromagnetice micrometrice** intr-un lichid de baza- **sedimentare gravitacionala semnificativa**
- Comportare reologica **ne-newtoniana**, tensiune remanenta si vascozitate efectiva puternic dependente de campul aplicat, **efect magnetoreologic intens** ($\sim 10^3$)

Ce este un nanofluid magnetic (Ferofluid)?

- definitie & compozitie -

Mediu quasi-omogen susceptibil magnetic: coloid ultrastabil de nanoparticule magnetice



- nanoparticule magnetice (NMP) acoperite cu mono- sau dublu strat de surfactant dispersate într-un lichid de baza (LB)
- stratul de stabilizant (S) are rolul de a impiedica aglomerarea NPM
- **compozitie:** NPM - magnetita, maghemita, ferita de cobalt, fier, cobalt
LB - solventi organici nepolari si polari, apa S- acizi carboxilici, acizi sulfonici, polimeri

Nanofluid magnetic

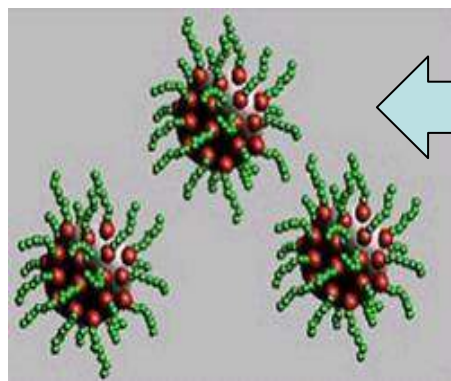
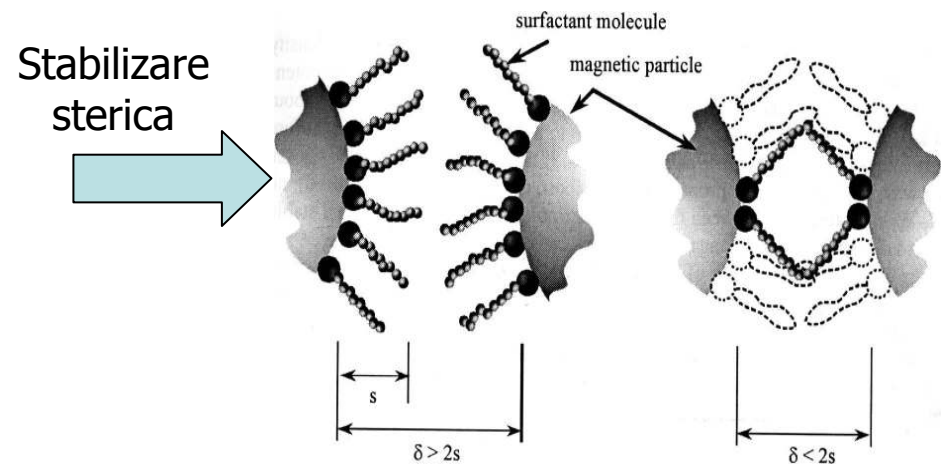
- dimensiunea NPM & stabilizare-dispersare -

NPM-magnetita

Energia de interactiune magnetica adimensionala

$$\lambda_{int} = \mu_0 m^2 / (2\pi k_B T d_m^3)$$

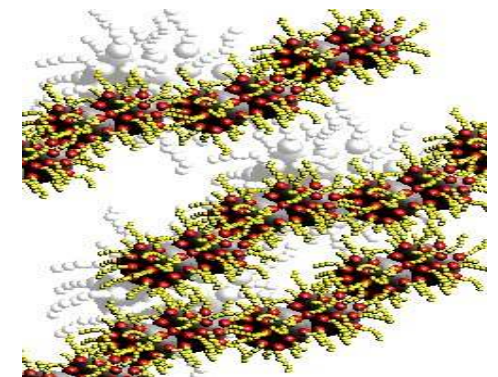
Conditia de stabilitate: $\lambda_{int} < 1$



NFM stabil

$$\lambda_{int} < 1 \Leftrightarrow d \leq 10 \text{ nm}$$

$$d > 10 \text{ nm} \Leftrightarrow \lambda_{int} > 1$$



Formare de aglomerate

Procedee de sinteza

Etape principale:

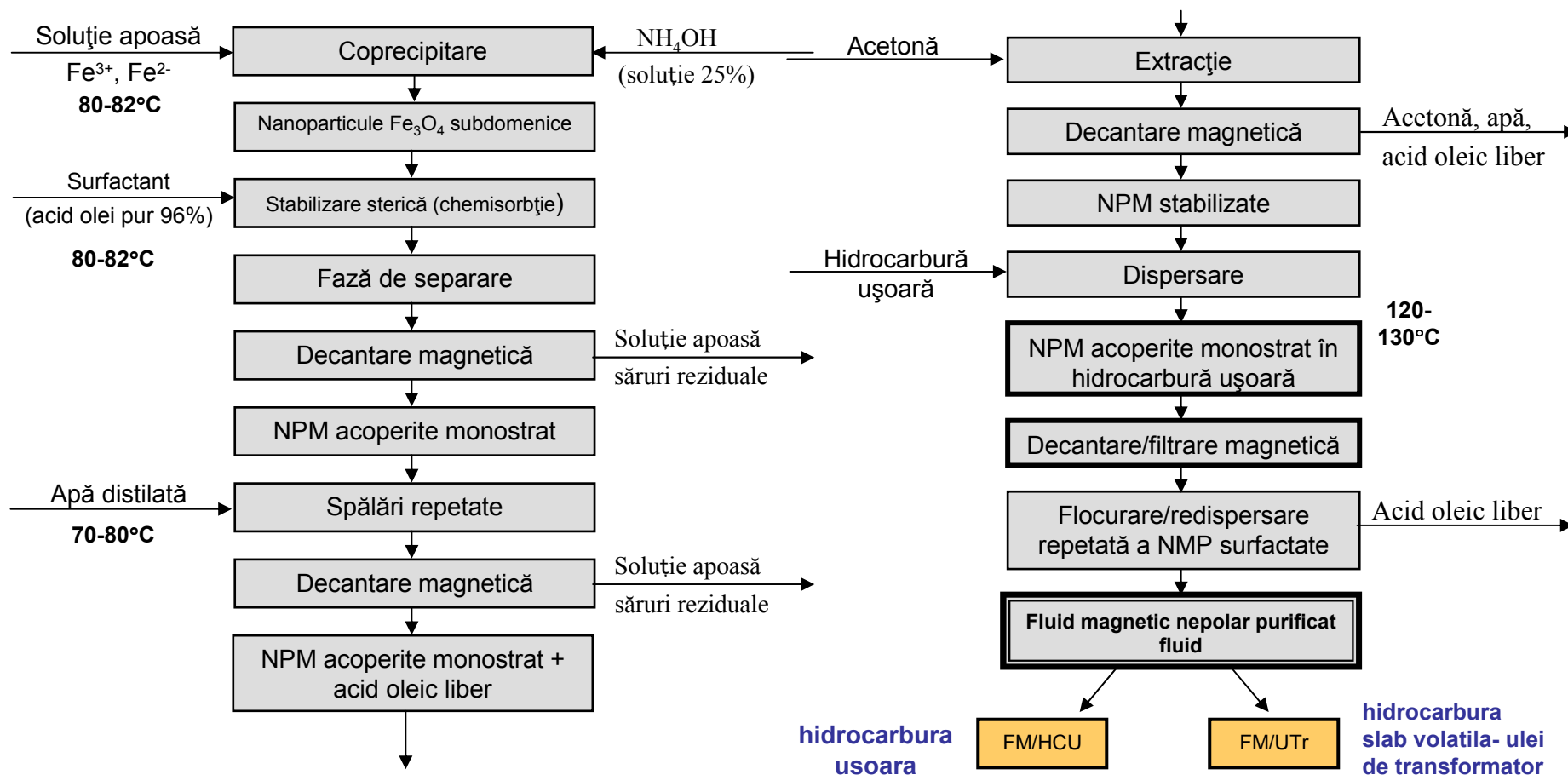
- **Sinteza nanoparticulelor magnetice**
 - co-precipitare chimica
 - descompunere termica a componentelor organo-metalice

- **Stabilizare/dispersare in lichid de baza non-polar sau polar**
 - stabilizare electrostatica (apa)
 - stabilizare sterica sau electro-sterica (lichid de baza organic sau apa)

Nanofluid magnetic

- solvenți organici nepolari -

Procedeu elaborat de Dr. D. Bica

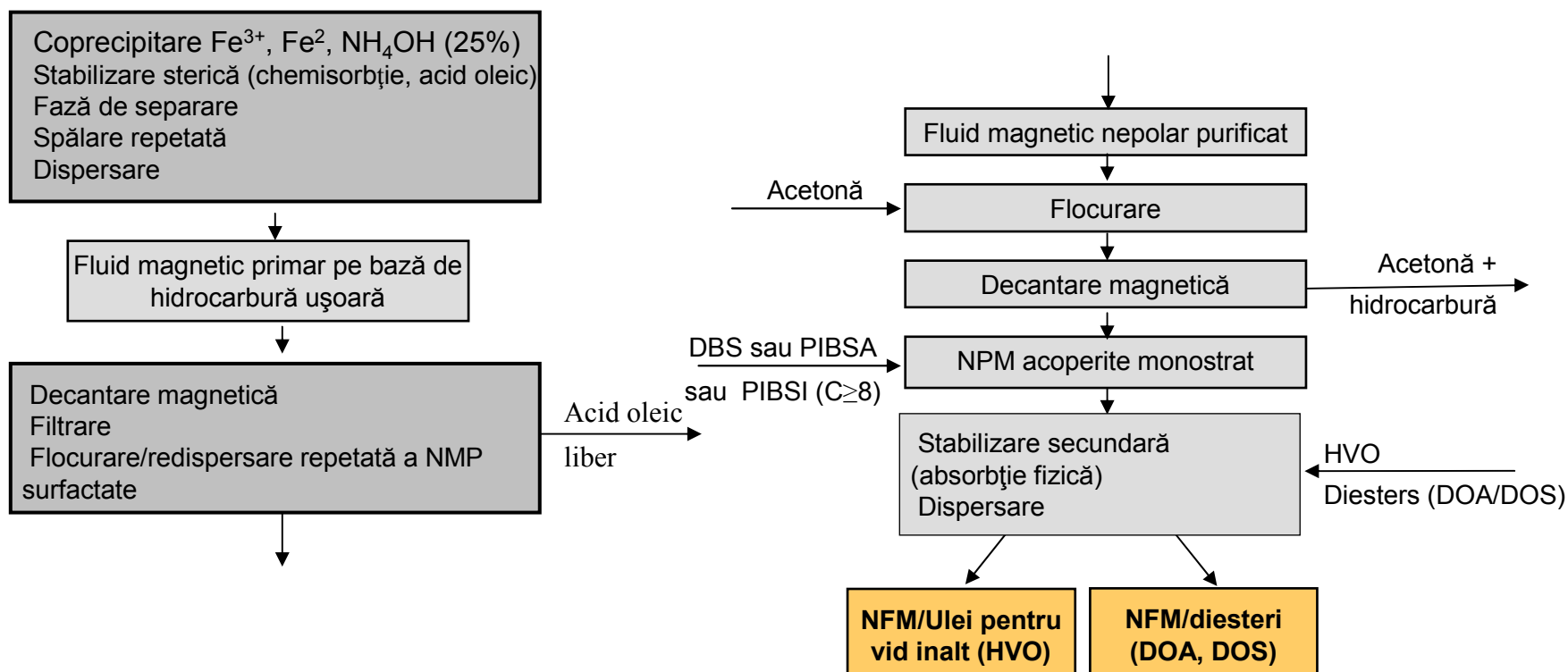


MF/H/OA: D. Bica, R.Minea, Patent RO 97556(1989); D. Bica, Rom. Rep. Phys. 47(1995)
MF/H/LA; MA : L. Vekas et al. Rom. Rep. Phys. 58(2006); M.V. Avdeev, D. Bica et al. JMMM, 311 (2007)

Nanofluid magnetic

- solventi organici polari -

Procedeu elaborat de Dr. D. Bica



D. Bica et al. Patents RO 93107 (1987), 93162 (1987), 97224 (1989), 97599 (1989), 105048 (1992), 115533 (2000)

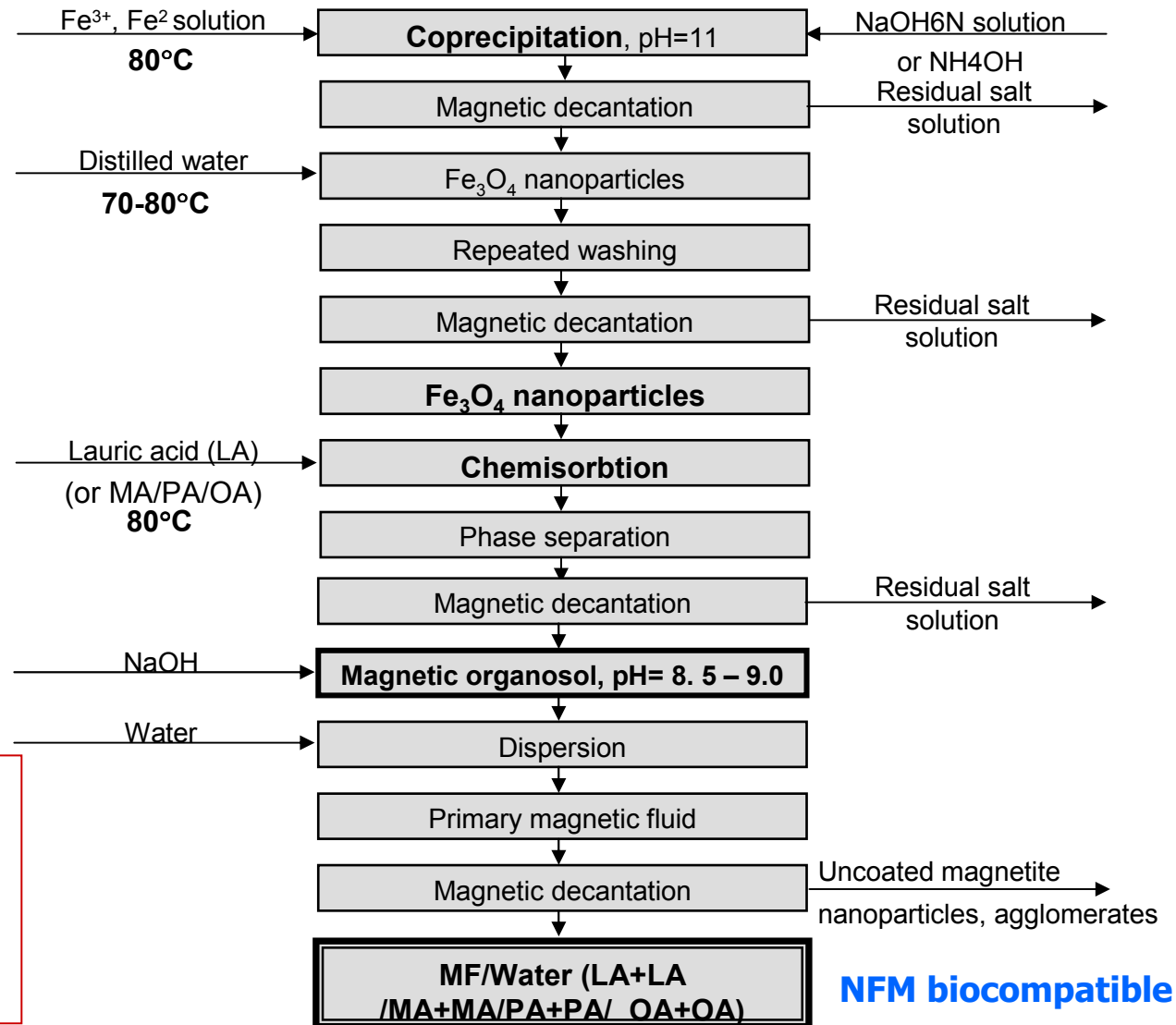
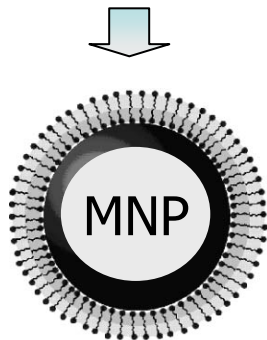
D. Bica, Rom. Rep. Phys. 47 (1995)

D. Bica, L. Vekas, M. Rasa, J. Magn. Magn. Mater. 252 (2002)

Nanofluid magnetic

- solvent anorganic polar: apa -

FF/apa
LA+LA, MA+MA,
OA+OA, LA+DBS,
MA+DBS, OA+DBS
stabilizare sterica
dublu-strat



NFM biocompatible

D.Bica, Patent RO 90078 (1985); Rom. Rep. Phys., 47(1995)

D. Bica, L. Vékás, M. Rasa, J. Magn. Magn. Mater., 252(2002)

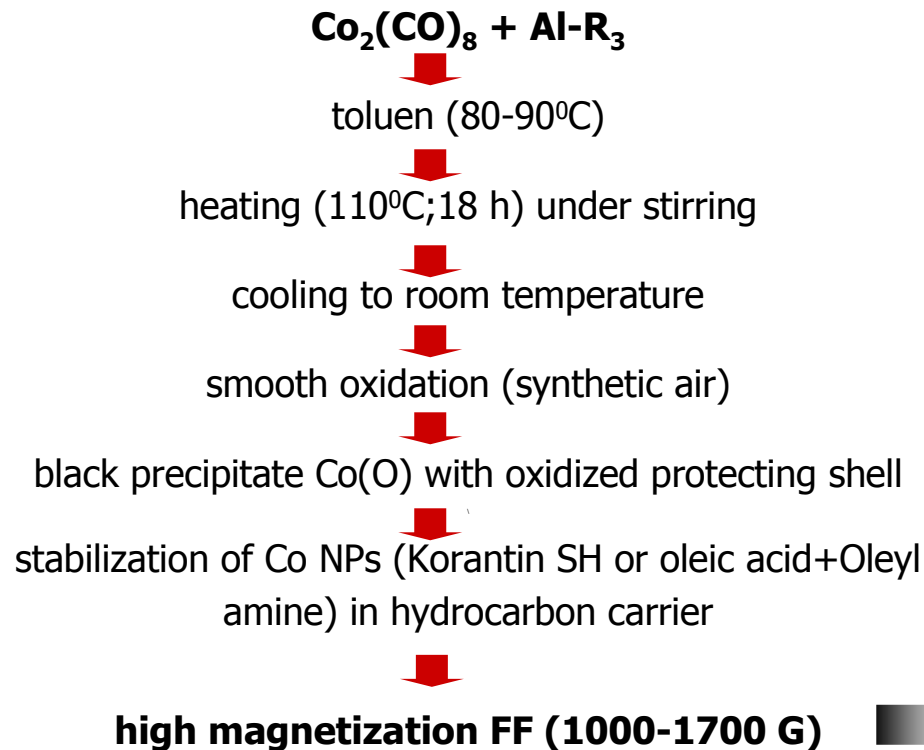
D.Bica, L. Vekas, M.V.Avdeev, O. Marinica, V. Socoliuc, M. Balasoiu, V.M.Garamus, J.Magn. Magn. Mater. 311 (2007)

Procedee de sinteza

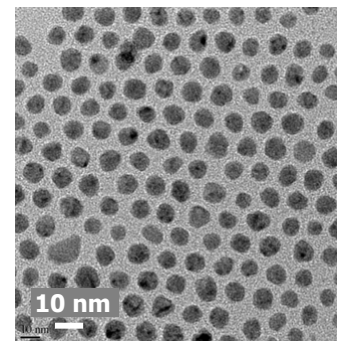
Proiect DFG: ferrofluide si aplicatii

FF cu magnetizatie ridicata cu nanoparticule de Co

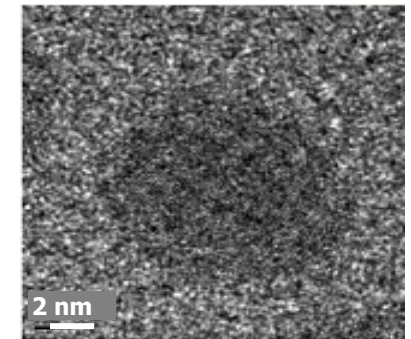
- sinteza in faza lichida a NP de Co prin descompunere chimica a $\text{Co}_2(\text{CO})_8$ -



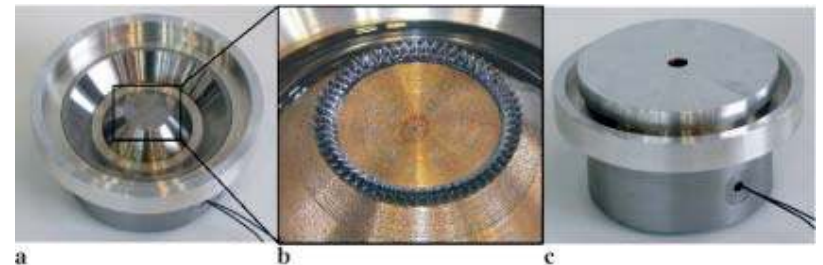
S. Behrens et al Z. Phys. Chem. 2006
S. Behrens et al., J Phys: Condens. Matter, 2006



a. imagine TEM a FF cu nanoparticule Co



b. imagine HRTEM a unei singure nanoparticule de Co, aratand structura policristalina

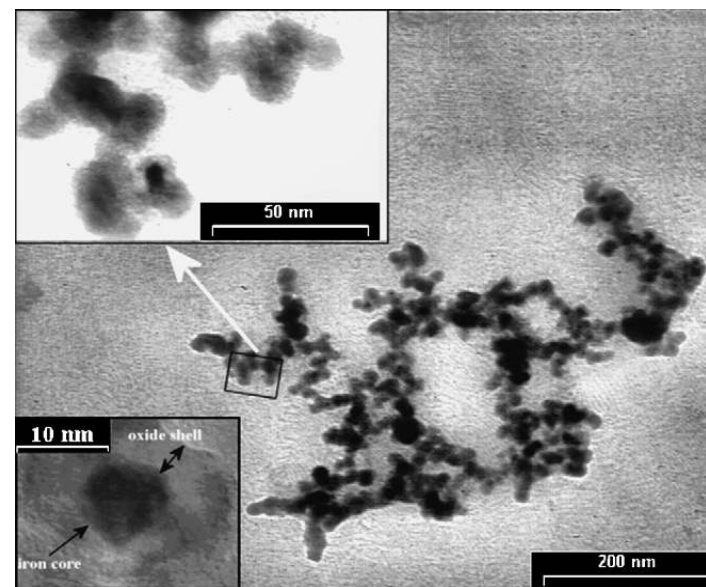
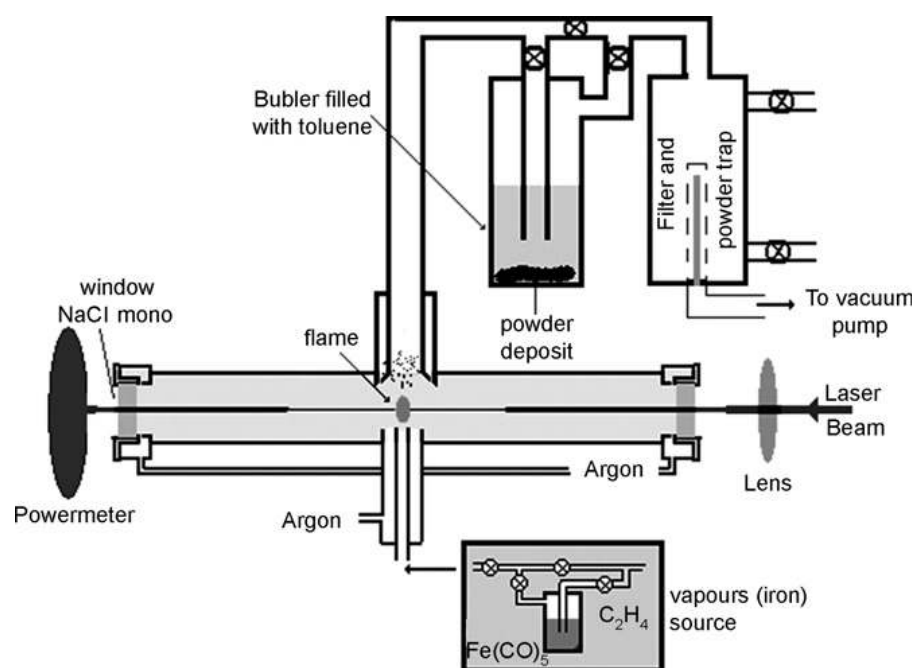


Lagar axial magnetohidrostatic

a) Stator b) Sectiune marita a statorului cu ferrofluid
c) Vedere generala a lagar

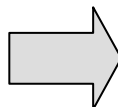
Proiect CEEEX: FeMANANOF

Sinteza in faza gazoasa a NP fier/oxid de fier prin piroliza laser



TEM/HRTEM: fier/oxid de Fe core-shell NPM

Instalatia experimentală:
sinteza NPM prin piroliza laser



- **Laser CW CO₂** ($\lambda = 10.6 \text{ mm}$, power 35 W)
- **Amestec de reactie:** vapori de $\text{Fe}(\text{CO})_5$ + gaz purtator de C_2H_4 .
- **Parametrii de sinteza:**
 - 3000 Pa pentru reactorul de presiune si
 - 100 sccm pentru debitul de etilena

E. Popovici, I. Morjan et al., Appl.Surf.Sci. 2007

Nanofluid magnetic cu particule de Fe/oxid Fe dispersate in solvent organic

Iron/iron oxide core-shell MNPs – laser pyrolysis

Sterical stabilization - oleic acid (OA) (heating up to 353 K; pH 8.5; continuous stirring; chemisorption of OA

Monolayer coated MNPs

Elimination of free OA - magnetic decantation

Stabilized MNPs

Addition of carrier - hydrocarbon, e.g. petroleum

Heating up to 110–120 8C - elimination of water + acetone

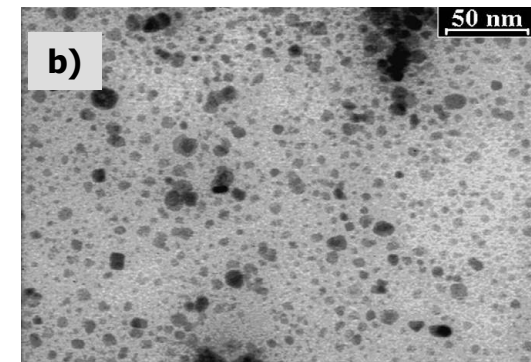
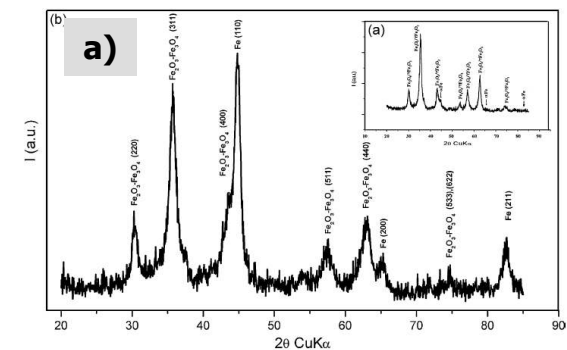
Primary hydrocarbon-based ferrofluid –

Magnetic decantation; repeated flocculation/re-dispersion of MNPs (elimination of free oleic acid)

Sterically stabilized, **highly purified FF** with surface protected MNPs

E. Popovici et al., Appl. Surf. Sci. 2007

E. Popovici et al. / Applied Surface Science 254 (2007) 1048–1052



- a) **Diagrama XRD** : Fe bine definit in amestec cu Fe₂O₃ cu Fe₃O₄
b) **Imagine TEM** : NFM pe baza de hidrocarbura; se evidentiaza preponderenta particulelor individuale fata de aglomerate

Evaluarea performantelor nanofluidelor magnetice

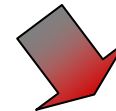
- caracterizare complexa -

- Analiza distributiei dimensionale a NPM: TEM, HRTEM
- Compozitie, procese structurale induse de camp magnetic, stabilizare sterica, stabilitate coloidala de lunga durata: SANS, SANSPOL ($B = 0 - 2.5 \text{ T}$)
- Mecanisme de stabilizare si selectia "chimica" a NPM dispersate
- Stabilitate la dilutie si fenomene de tranzitie de faza: investigatii magneto-optice, DLS
- Proprietati magnetice vs. concentratia volumica NPM: masuratori VSM
- Proprietati de curgere sub influenta campului magnetic aplicat: investigatii MR
- **Evaluarea si selectarea nanofluidelor magnetice pentru diferite aplicatii**



NFM pentru etansari rotitoare, lagare, traductoare

- magnetizatie ridicata
- solvent organic
- stabilitate ridicata in camp magnetic intens si neuniform



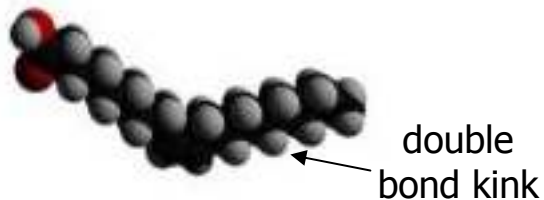
NFM pentru aplicatii biomedicale

- componente biocompatibile
- solvent: apa
- stabilitate coloidala in conditii fiziologice

Stabilizare sterica

- eficienta lungimii catenei surfactantilor -

Acid carboxilic nesaturat



oleic acid (OA)
 $C_{18}H_{34}O_2$



Excelent stabilizant datorita solvabilitatii ridicate

Acid carboxilic saturat



stearic acid (SA)
 $C_{18}H_{36}O_2$

Stabilizant neeficient datorita solvabilitatii reduse



palmitic acid (PA)
 $C_{16}H_{32}O_2$



myristic acid (MA)
 $C_{14}H_{28}O_2$



lauric acid (LA)
 $C_{12}H_{24}O_2$



Stabilizanti cu eficienta redusa

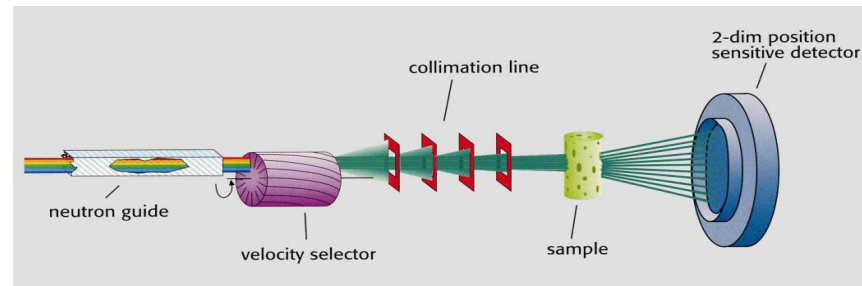
- solvabilitate redusa?
- lanturi scurte?

R. Tadmor, R. E. Rosensweig, J. Frey, J. Klein,
Resolving the Puzzle of Ferrofluid Dispersants, *Langmuir* 16 (2000)

Investigatii structurale

- imprastiere de neutroni la unghiuri mici – SANS -

**Componente principale
si
Principiul de masurare**



**GKSS Geesthacht:
facilitatile SANS 1 si SANS 2**



**Budapest Neutron Center-SANS-
Yellow Submarin**

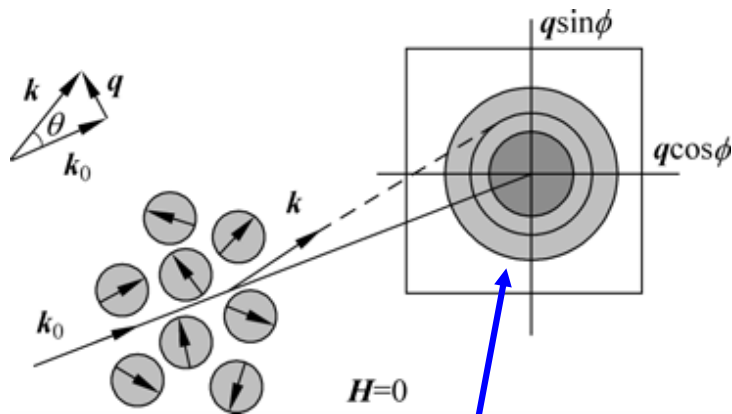


Investigatii SANS

- procese structurale in NFM -

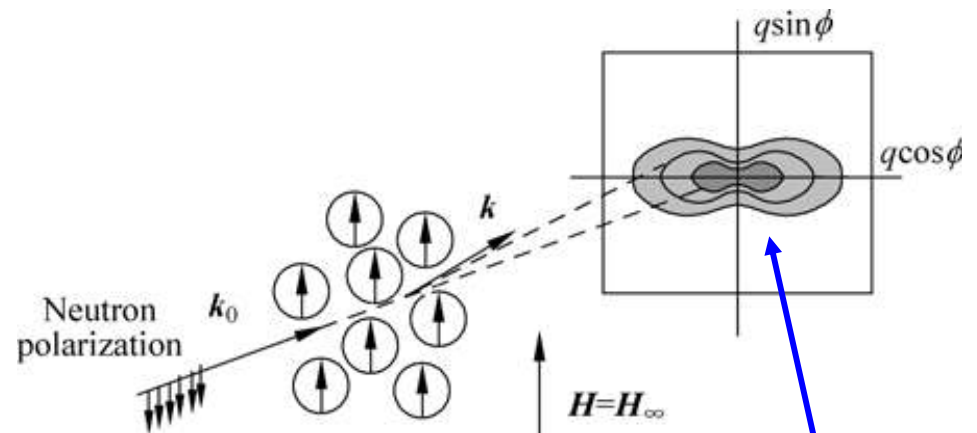
Schema experimentului SANS pentru un sistem de nanoparticule magnetice

In absenta campului magnetic ($B=0$)



Imprastierea este **izotropa** in functie de unghiul radial ϕ in planul detectorului

In prezenta campului magnetic ($B>0$)



Imprastierea este **anizotropa** dupa unghiul radial ϕ , rezultat al magnetizarii sistemului

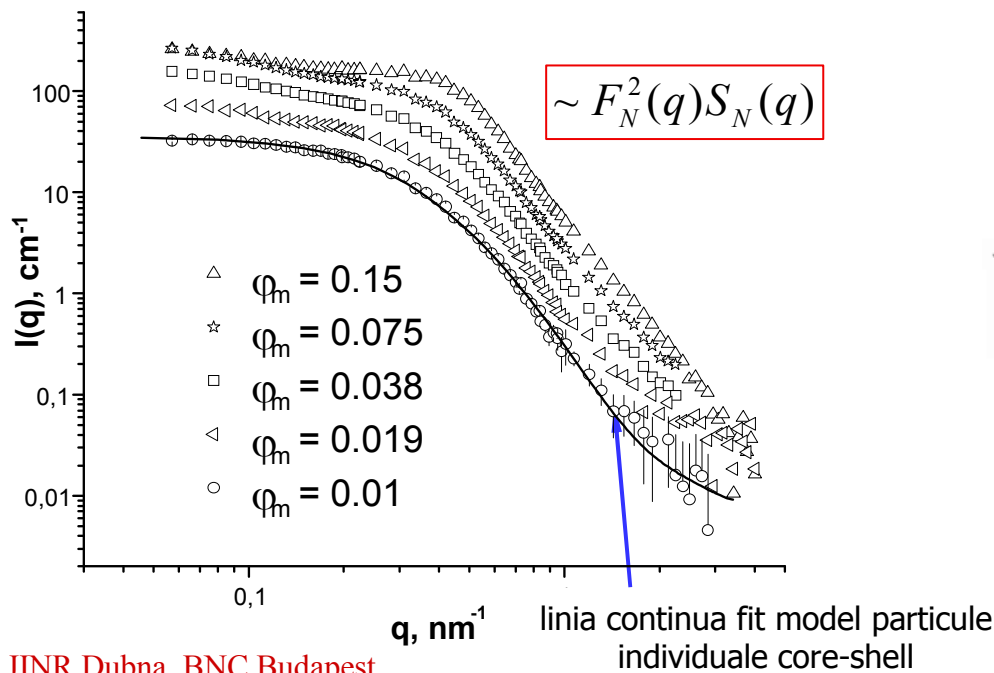
Intervalul: 1-100 nm

Investigatii SANS

- interactiunea dintre particule la $B = 0$ -

NFM cu stabilitate ridicata

magnetita/ acid oleic/H-benzen

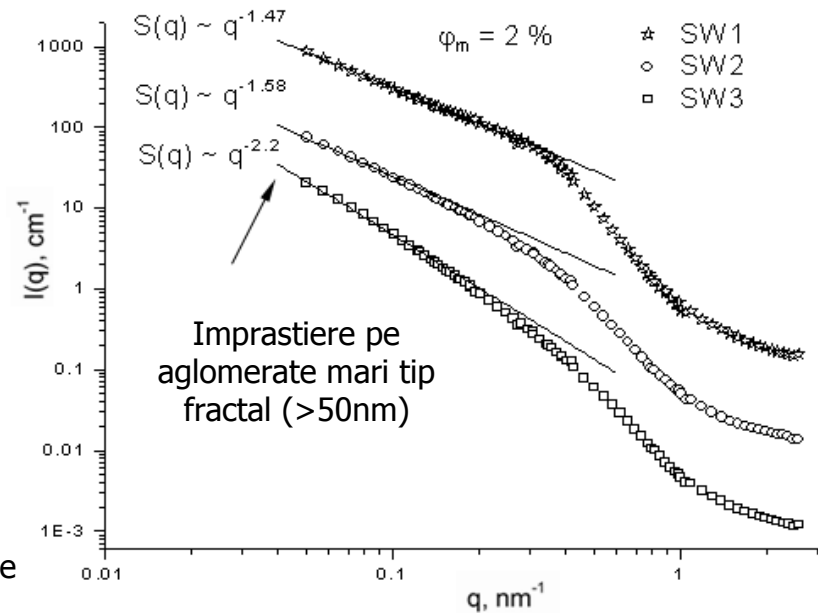


JINR Dubna, BNC Budapest

Tip factor structura: atractie la distante mari, repulsie la distante mici

NFM cu stabilitate scazuta

magnetita/apa: OA+DBS, DBS+DBS, OA+OA



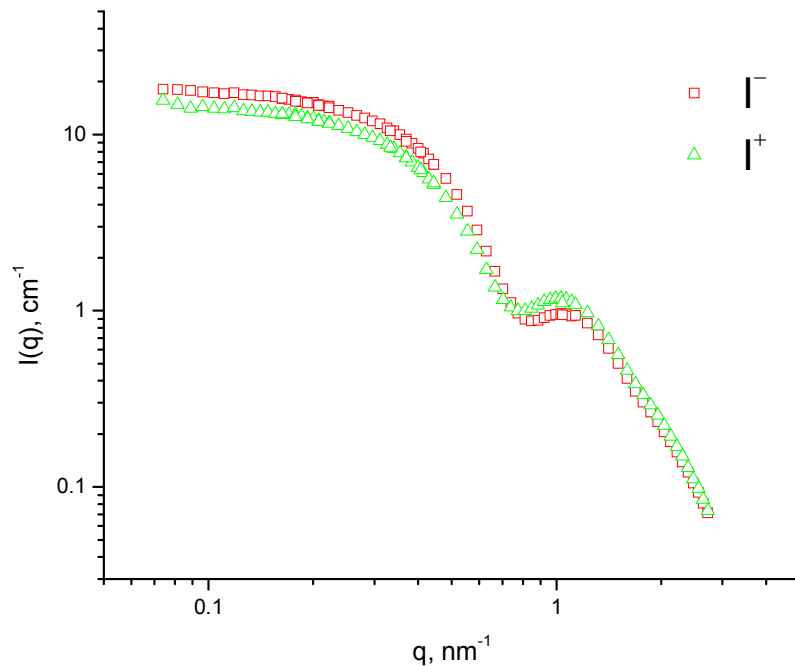
Dimensiune aglomerate tip fractal: $D \sim 1,5 - 2,5$
Raza medie a aglomeratelor: $R \sim 10$ nm

M.V. Avdeev, V.L Aksenov, M. Balasoiu et al. J. Coll. Interface Sci, 2006
L. Vekas, M.V. Avdeev, D. Bica, Magnetic fluids: Synthesis and Structure (Springer V, to appear)

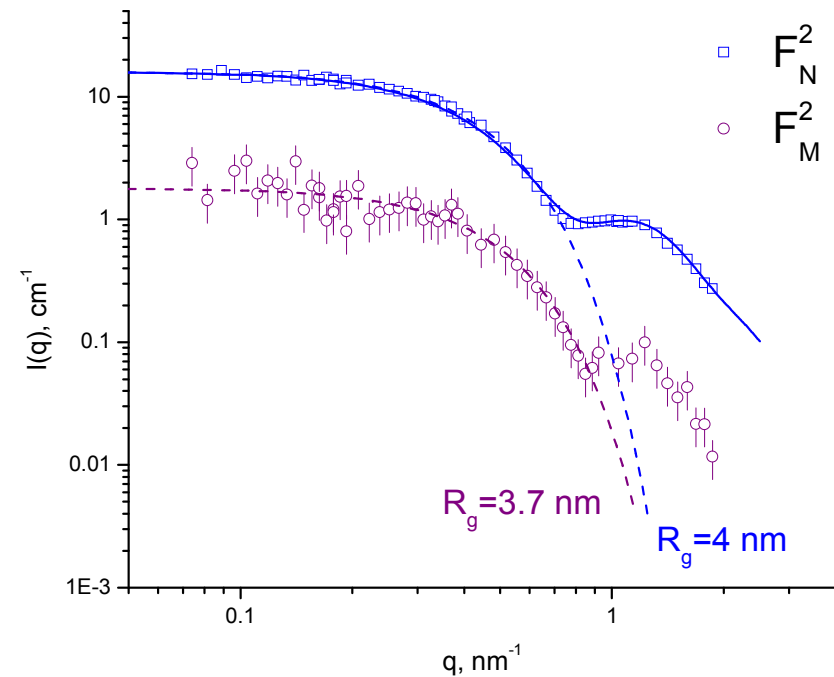
Investigatii SANS

- interactiunea dintre particule la $B = 2.5 \text{ T}$ -

NFM: d-cyclohexane + Fe_3O_4 + MA, $\varphi_m = 2.8 \%$
stabilitate ridicata in camp magnetic intens, max $\varphi_m \sim 10 \%$.



Averaged (over radial angle φ) intensities of the scattering for two spin orientations of polarized neutrons



Blue solid line – **fit of the core-shell model.**

Final parameters are

$R_0 = 2.3 \text{ nm}$; $S = 0.28$; $\delta = 1.35 \text{ nm}$.

Dashed lines are Guinier approximations.

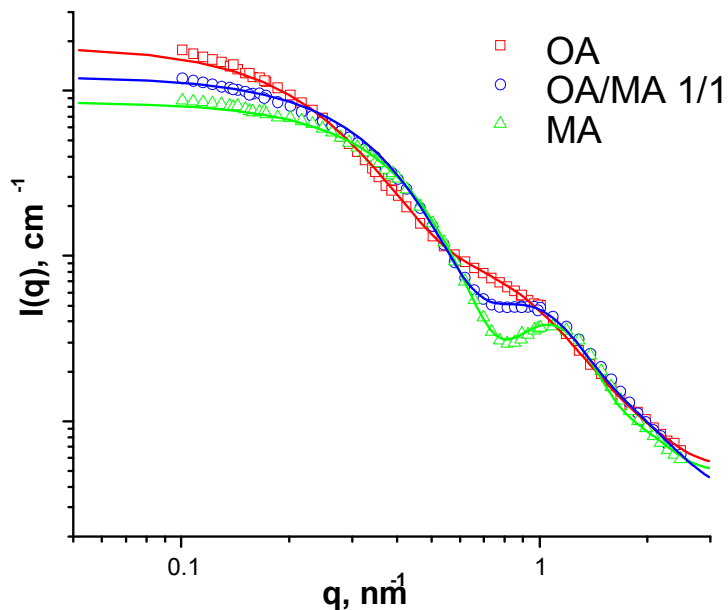
Investigatii SANS

- analiza procedului de "selectie chimica" a dimensiunii NPM -

NFM: solvent nepolar deuterat (D-benzen), $\phi=1.1\%$

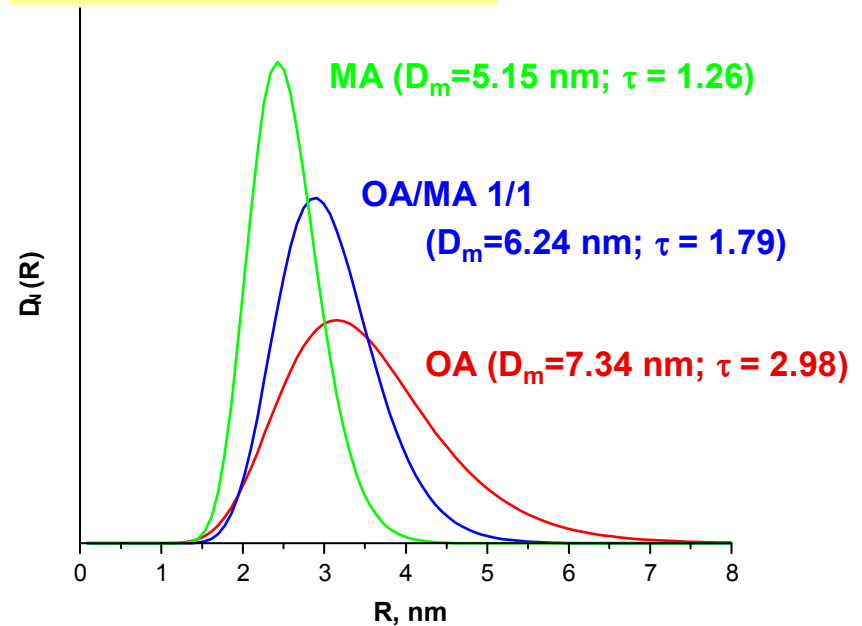
Stabilizant: monostrat: amestec de surfactanti (MA + OA), raport de amestec 1:0, 1:1 si 0:1

Curbe de imprastiere SANS



Nuclear scattering contribution. Solid lines are fits of the core-shell model

Distributii dimensionale



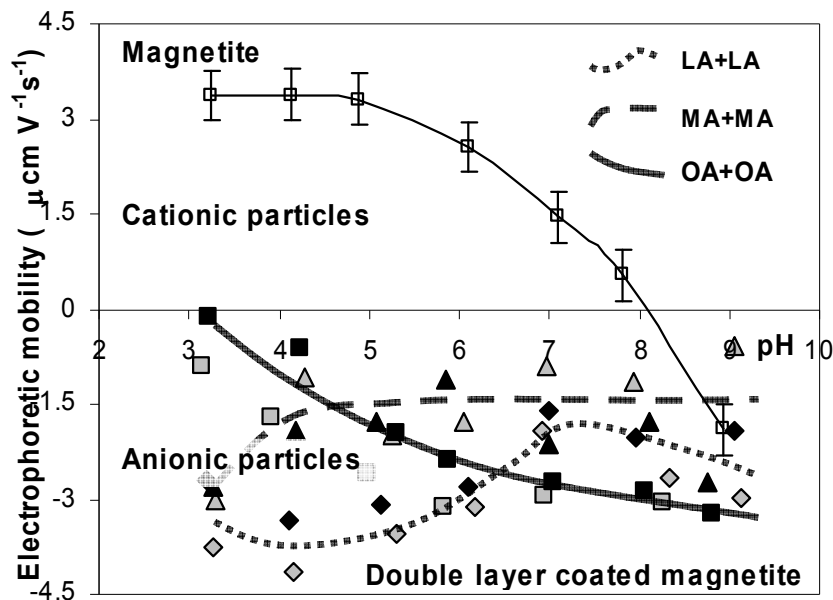
Resulting log-normal size-distribution functions

Increased MA content, more reduced diameter and standard deviation M.V. Avdeev, D. Bica et al. (MISM, 2008)

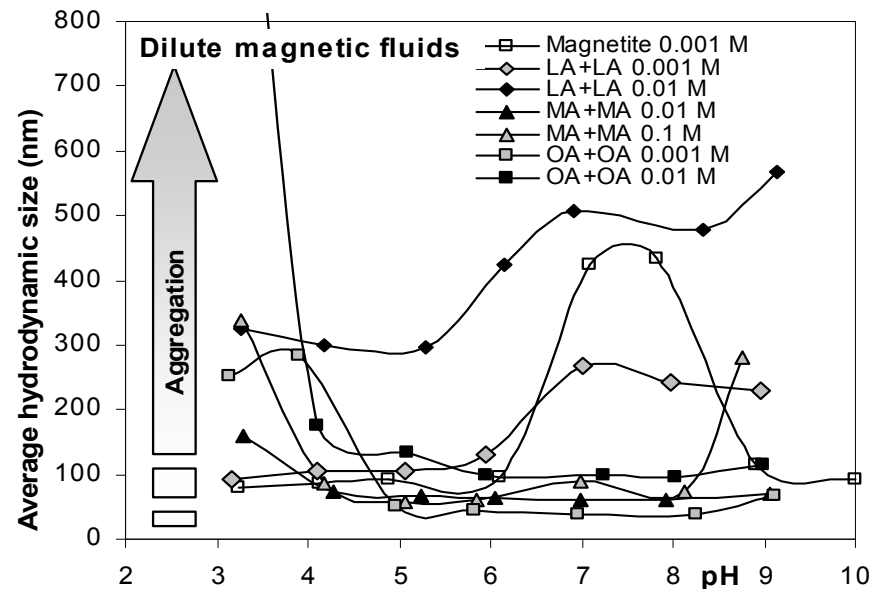
NFM pe baza de apa

- influenta surfactantilor cu diferite lungimi moleculare -

Investigatii prin imprastierea luminii – DLS (NanoZS)



Effect of anionic surfactant double layer coating on the pH-dependent charge state

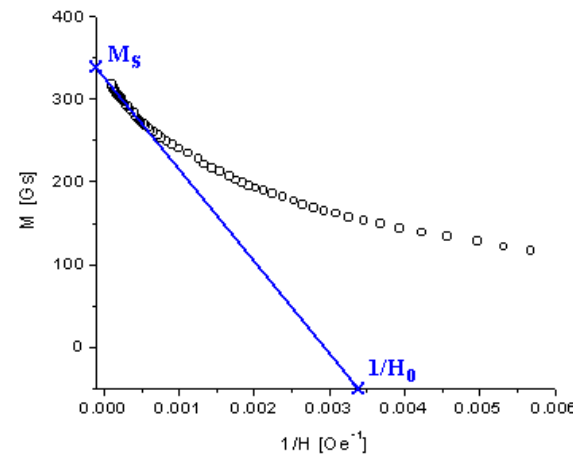
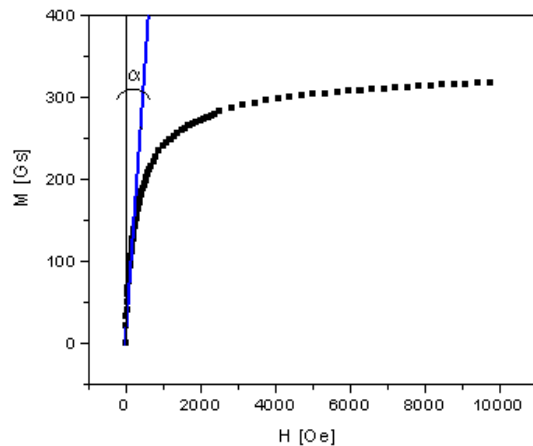


Aggregation of magnetite particles in 0.001, 0.01 and 0.1 M NaCl solutions at $25 \pm 0.10^\circ\text{C}$.

NFM stabilizate cu OA+OA si MA+MA isi pastreaza stabilitatea coloidala in conditii fiziologice pH (6-8)

Magnetometrie VSM si magnetogramulometrie

- Determinarea curbelor de magnetizare cu magnetometrul VSM 880 (DMS, USA)
- Prelucrarea datelor pe baza unui model de NMF cu particule polidisperse cu distributie log-normală



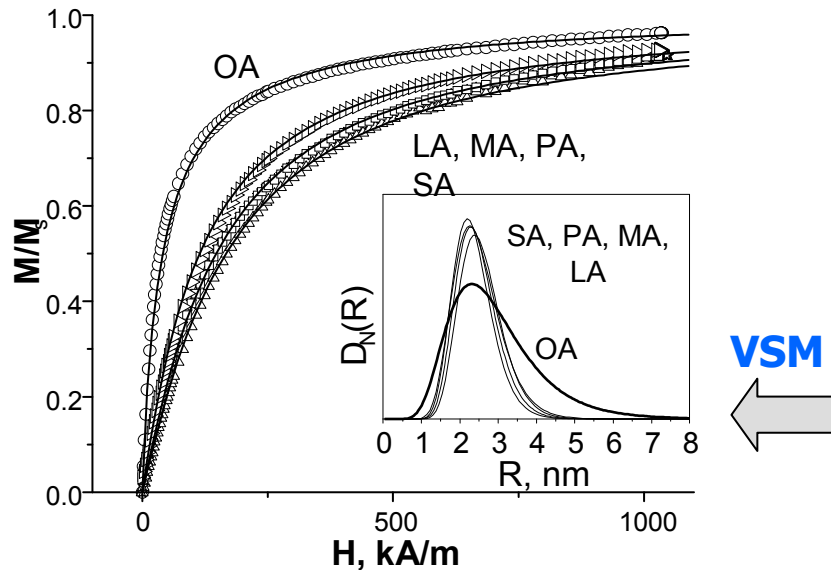
$$S = \frac{1}{3} \sqrt{\ln \frac{3 \cdot \chi_i \cdot H_0}{M_S}} \quad D_0^3 = \frac{6 \cdot k_B \cdot T}{\mu_0 \cdot \pi \cdot H_0 \cdot M_d} \sqrt{\frac{M_S}{3 \cdot \chi_i \cdot H_0}} \quad D_m = D_0 \cdot \exp\left(\frac{S^2}{2}\right) \quad \sigma = D_m \cdot \left[\exp S^2 - 1\right]^{1/2}$$

- Caracterizarea magnetica a NFM: χ_i ; M_s ; D_m ; σ_m

Comparatie analiza structurala si magnetica

- NFM stabilizate cu acizi carboxilici cu diferite lungimi ale lantului molecular -

Lab. Lichide Magnetice Timisoara

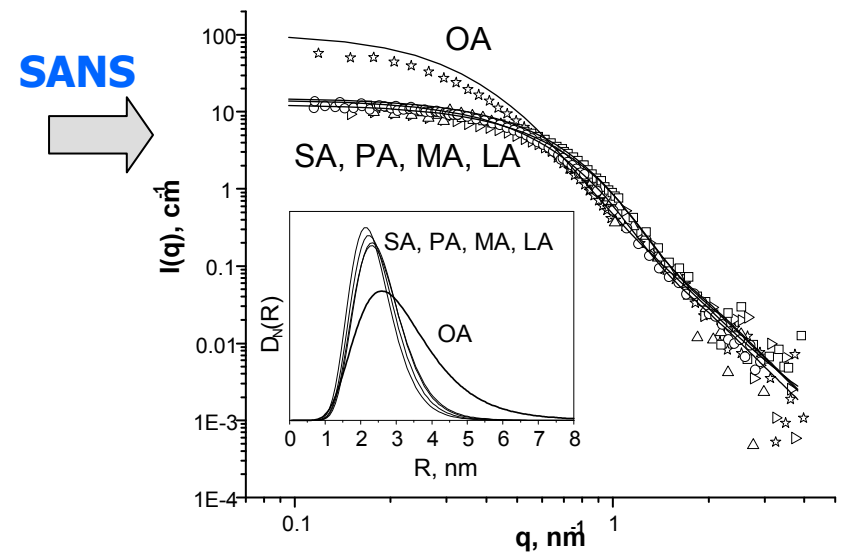


Magnetization curves (points) for ferrofluids/ DHN, $\phi_m = 1.5\%$. Lines are the results of the polydisperse Langevin approximation.

Inset : particle size distributions of magnetite (magnetic size)

Sample	D_m [nm]		σ [-]		h [nm] (scattering)
	magnetization	scattering	magnetization	scattering	
OA	5,83	7,31	2,37	2,89	1,40
SA	5,12	5,31	1,14	1,52	1,85
PA	4,92	5,16	1,10	1,48	1,55
MA	4,92	5,51	1,10	1,58	1,35
LA	4,71	5,22	1,05	1,49	1,25

GKSS Geesthacht BNC Budapest



SANS curves (points) FFs in DHN normalized to $\phi_m = 1.5\%$. Lines are the results of approximation by the model of polydisperse independent spheres

Inset : particle size distributions of magnetite (atomic size)

M.V. Avdeev, D. Bica, L. Vekas, V.L. Aksenov, A.V. Feoktystov, L. Rosta, V.M. Garamus, R. Willumeit JMMM 2008

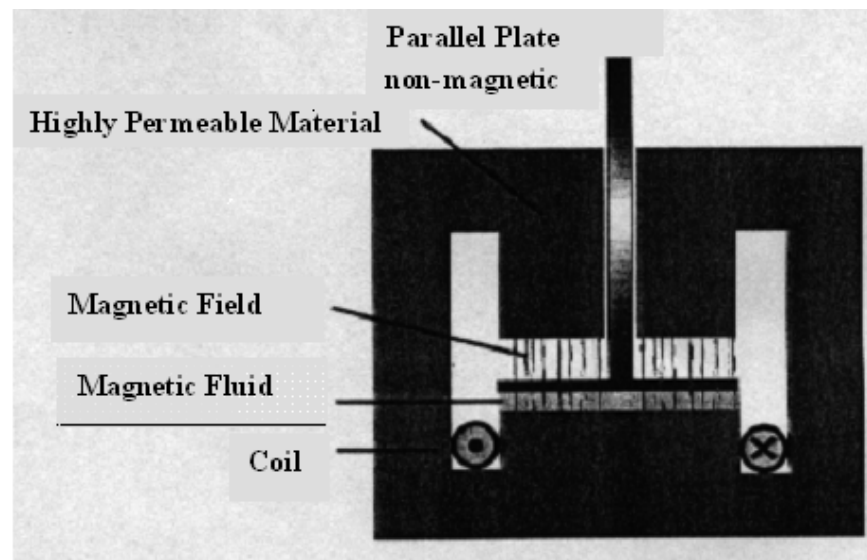
Echipament si metoda de masurare

- **Evaluarea comportarii reologice/magnetoreologice** a nanofluidelor magnetice

Reometrul PHYSICA MCR 300

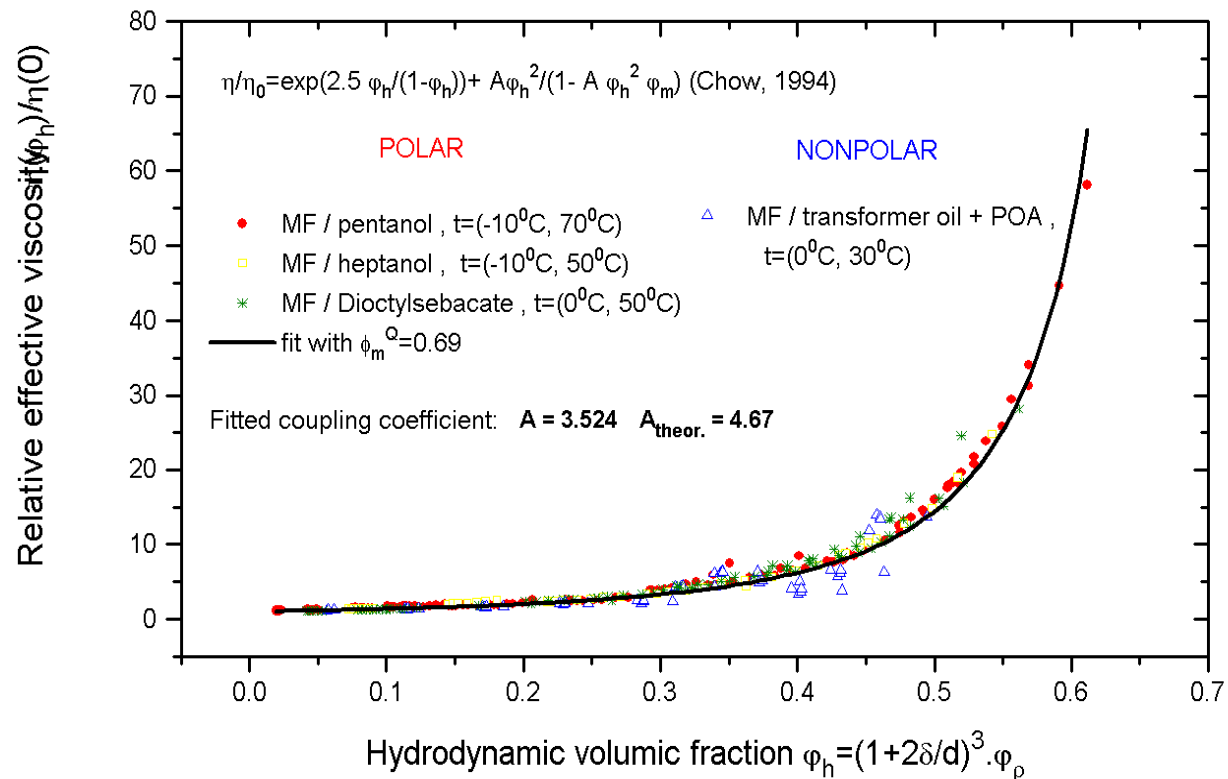


Celula magnetoreologica tip placa-placa



Comportarea reologica a nanofluidelor stabile

- influenta fractiei volumice a NPM -



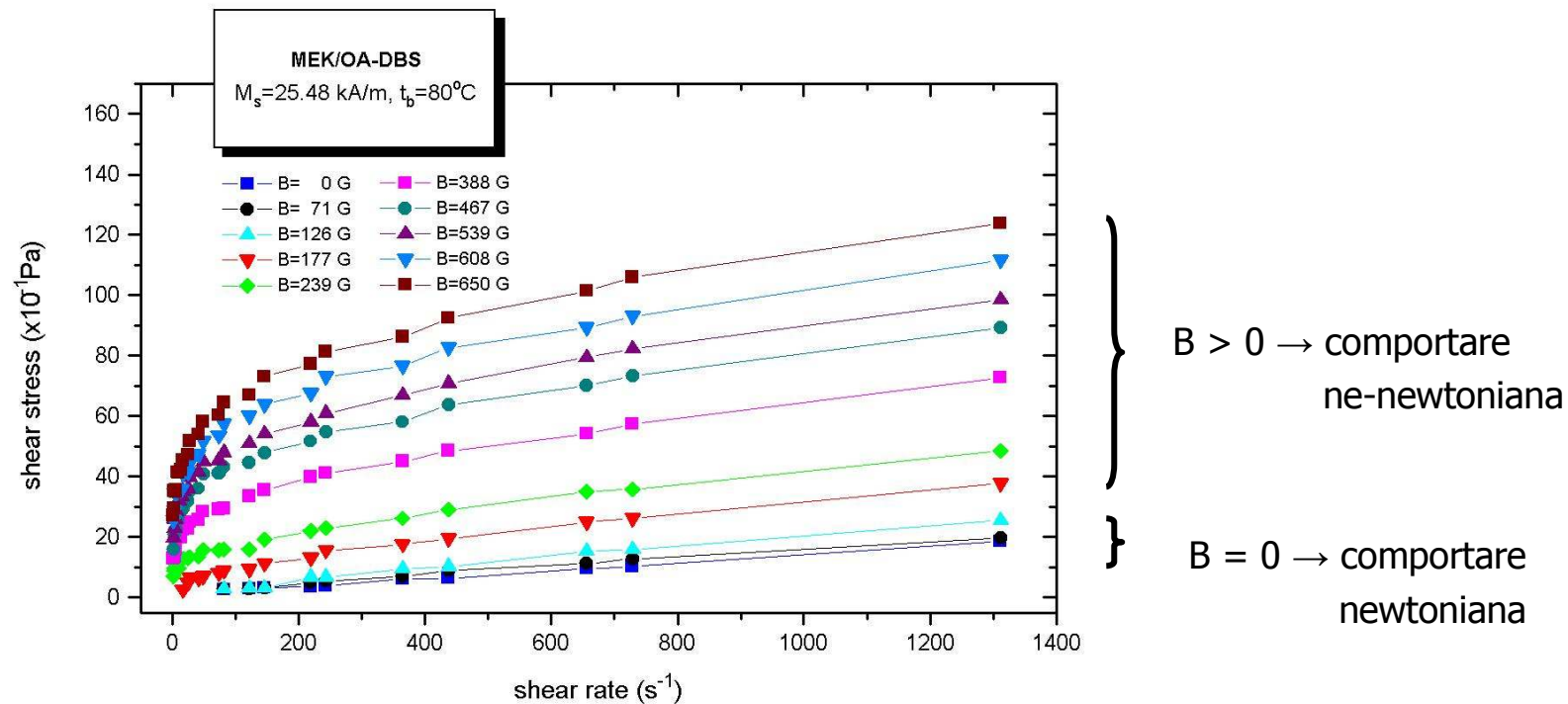
Corespondenta buna cu formula teoretica (Phys.Rev. E (1994)

Influenta interactiunii dipolare: $A(\text{fit}) = 3.5 < 4.6(\text{theor})$

Daniela Susan-Resiga, Teza de doctorat, 2001; JMMM 201 (1999)

Modificarea caracterului curgerii sub influenta campului

NFM/MEC puternic polar cu fractiune importanta de aglomerate

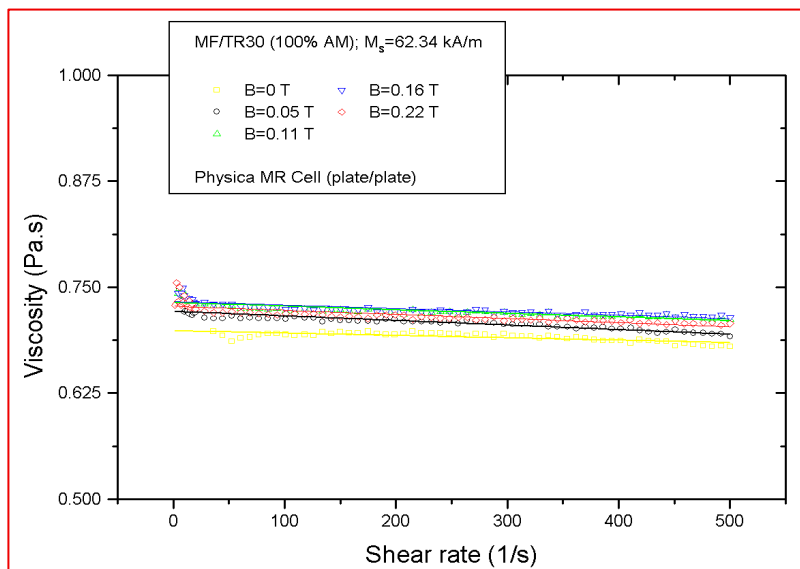


Evaluarea stabilitatii pe baza efectului magnetoreologic

- influenta lungimii lantului molecular al stabilizantului -

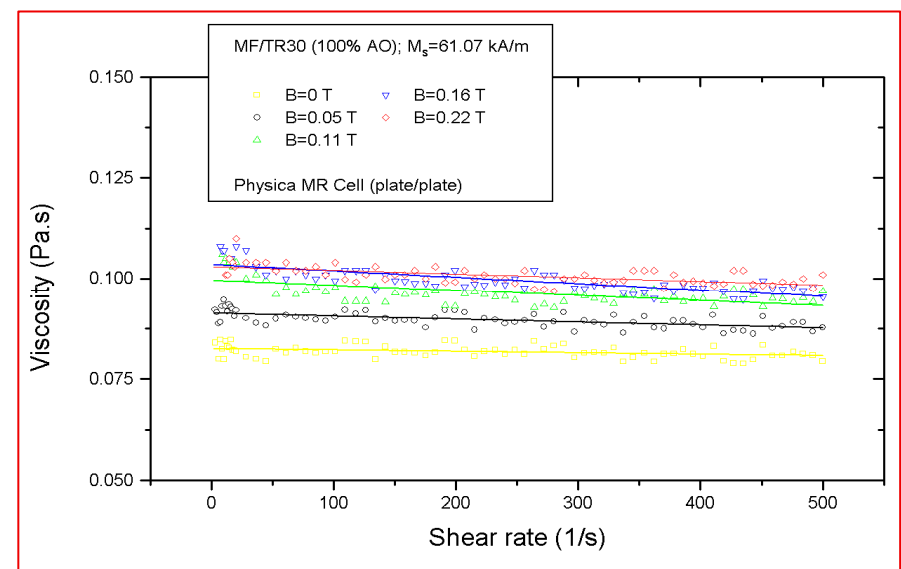
NFM/UTr concentrate ($M_s \cong 60 \text{ kA/m}$)

MA (C14)



MR effect $\leq 10\%$

OA (C18)



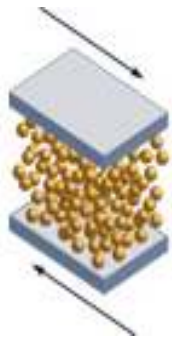
MR effect $\sim 20\text{-}30\%$

Compozitie & mecanism de structurare intensa

Particule magnetice: particule feromagnetice **multi-domenice** Fe, aliaje de Fe **1-10 μ m**

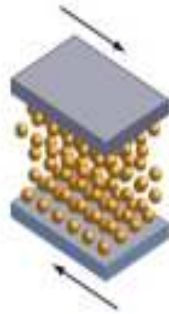
Lichide de baza: uleiuri minerale, uleiuri sintetice, apa

Agenti tensioactivi/stabilizanti: acizi carboxilici, stearati, polimeri



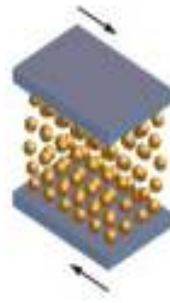
Camp zero: $H=0$

Particule de Fe dispuse haotic; placile in miscare cu rezistenta redusa



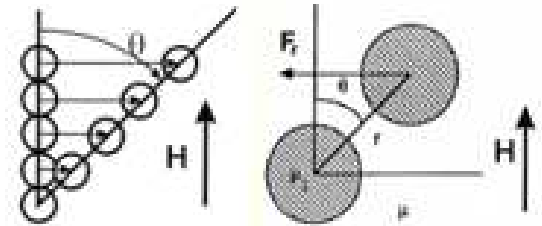
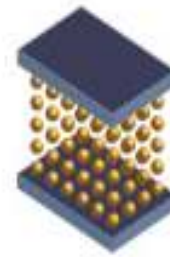
Camp aplicat nenul: $H > 0$

Particulele de Fe incep sa formeze lanturi; frecare vascoasa in crestere



Camp de saturatie: $H \approx H_{sat}$

Lanturi de particule-stare **quasi-solida**; miscarea relativa puternic franata



Fora F_r indusa de camp H

Moment magnetic al particulelor dependent de camp: $m = 4\pi\mu_0 \mu_f \beta a^3 H_0$; $\beta = (\mu_p - \mu_f) / (\mu_p + 2\mu_f)$

Parametru de cuplaj magnetic dependent de camp

$$\lambda_{int}^{MR} = \pi\mu_0 \mu_f \beta a^3 H_0^2 / (2kT)$$

$$\lambda_{int}^{MR} = 1 \text{ for } H_0 = 127 \text{ A/m; } 2a = 1 \mu\text{m}$$

$$\lambda_{int}^{MR} \sim 10^8 \gg 1 \text{ for usual } H \text{ values}$$



Comportare puternic ne-newtoniana

Yield stress: 50-100 kPa

Efect MR intens: crestere vascozitate efectiva de $\sim 10^2 - 10^3$

Fluid magnetoreologic "nano-micro" structurat

- compozitie & proprietati magnetice -

Lichid de baza: NFM cu magnetizatie ridicata ($M_s \cong 1200$ G)
cu NP magnetita < 10 nm

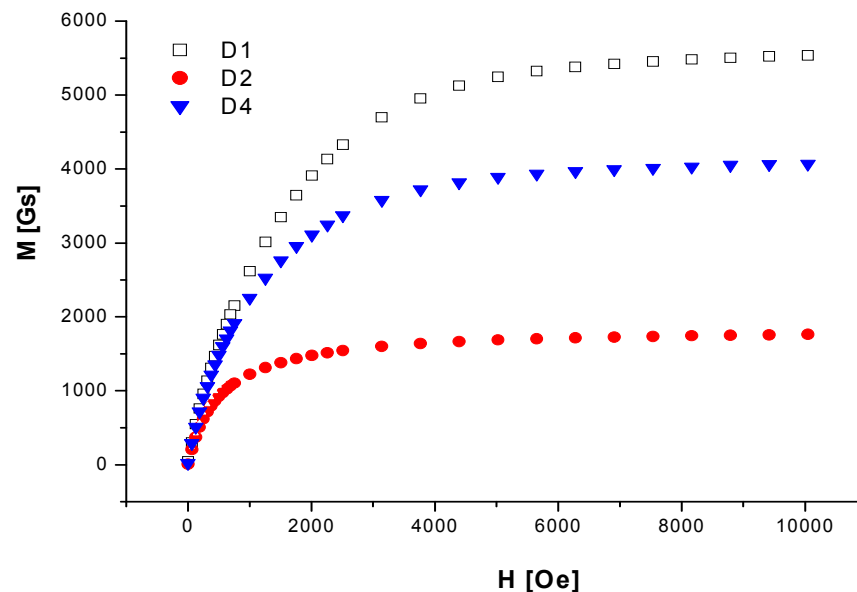
Particule multidomenice de Fe: ~ 10 μ m



Fluid compozit magnetizabil
extrem de bidispers tip "D"
(factor 10^3)



Curbe de magnetizare: influenta concentratiei particule de Fe



Particule magnetice
micrometriche dispersate in
"mediu continuu" magnetizabil



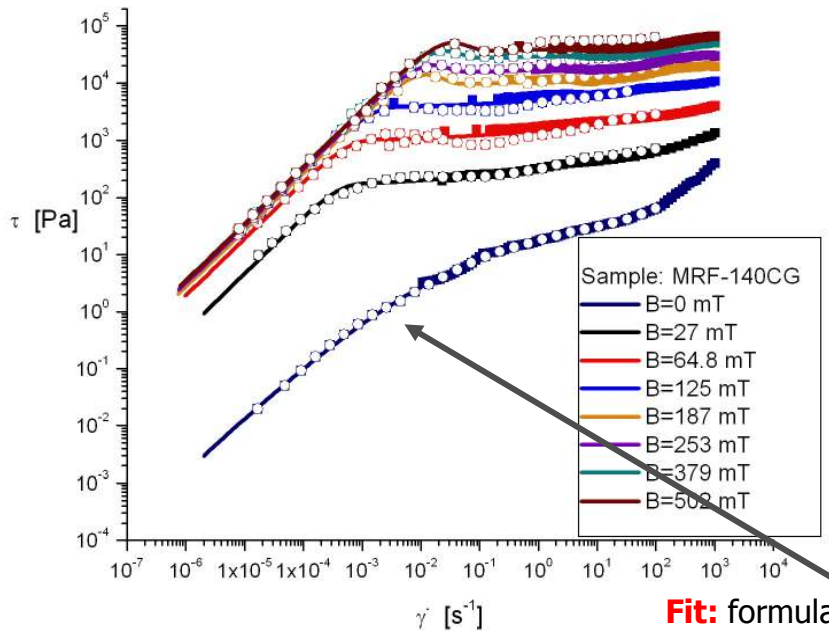
- stabilitate la sedimentare in camp magnetic
- efect magnetoreologic ridicat

D. Bica et al. Propunere de brevet de inventie, 2008

Fluid magnetoreologic "nano-micro" structurat

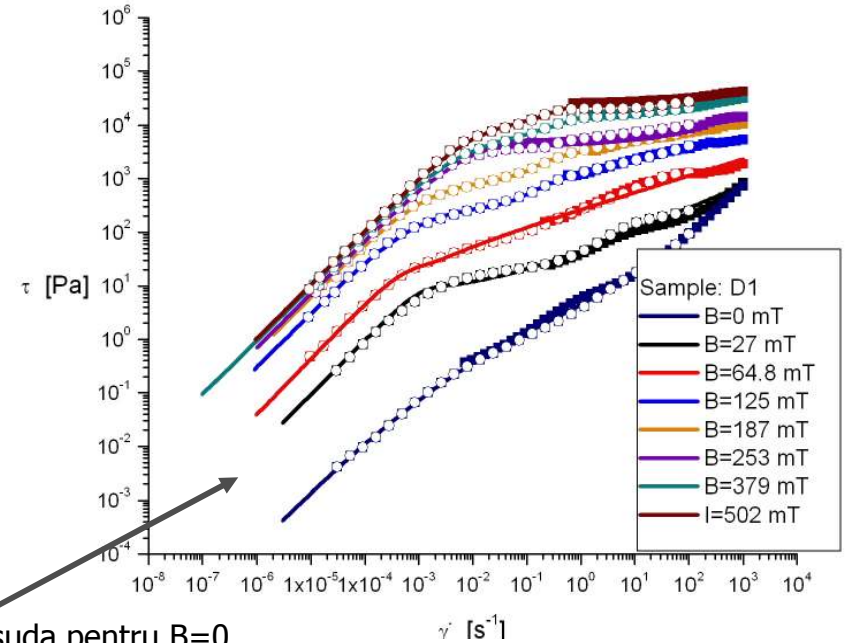
- comportare magnetoreologica -

Proba comerciala Lord Co($\sim\mu\text{mFe}$)
MRF-140CG; $\Phi_{\text{micro}} \approx 0.40$



Proba de laborator: MRF „nano-micro”

D1; $\Phi_{\text{total}} \approx 0.40$; $\Phi_{\text{micro}} \approx 0.2$; $\Phi_{\text{nano}} \approx 0.2$



$$\tau = \eta_0 \dot{\gamma} \left[1 - \tanh\left(\frac{\dot{\gamma}}{\dot{\gamma}^*}\right) \right] + \left[\tau_0 + \tau_1 \left(\frac{\dot{\gamma}}{\dot{\gamma}^*}\right)^{1-n} \right] \tanh\left(\frac{\dot{\gamma}}{\dot{\gamma}^*}\right)$$

Fit: formula Herschel-Bulkley (H-B) pentru B>0

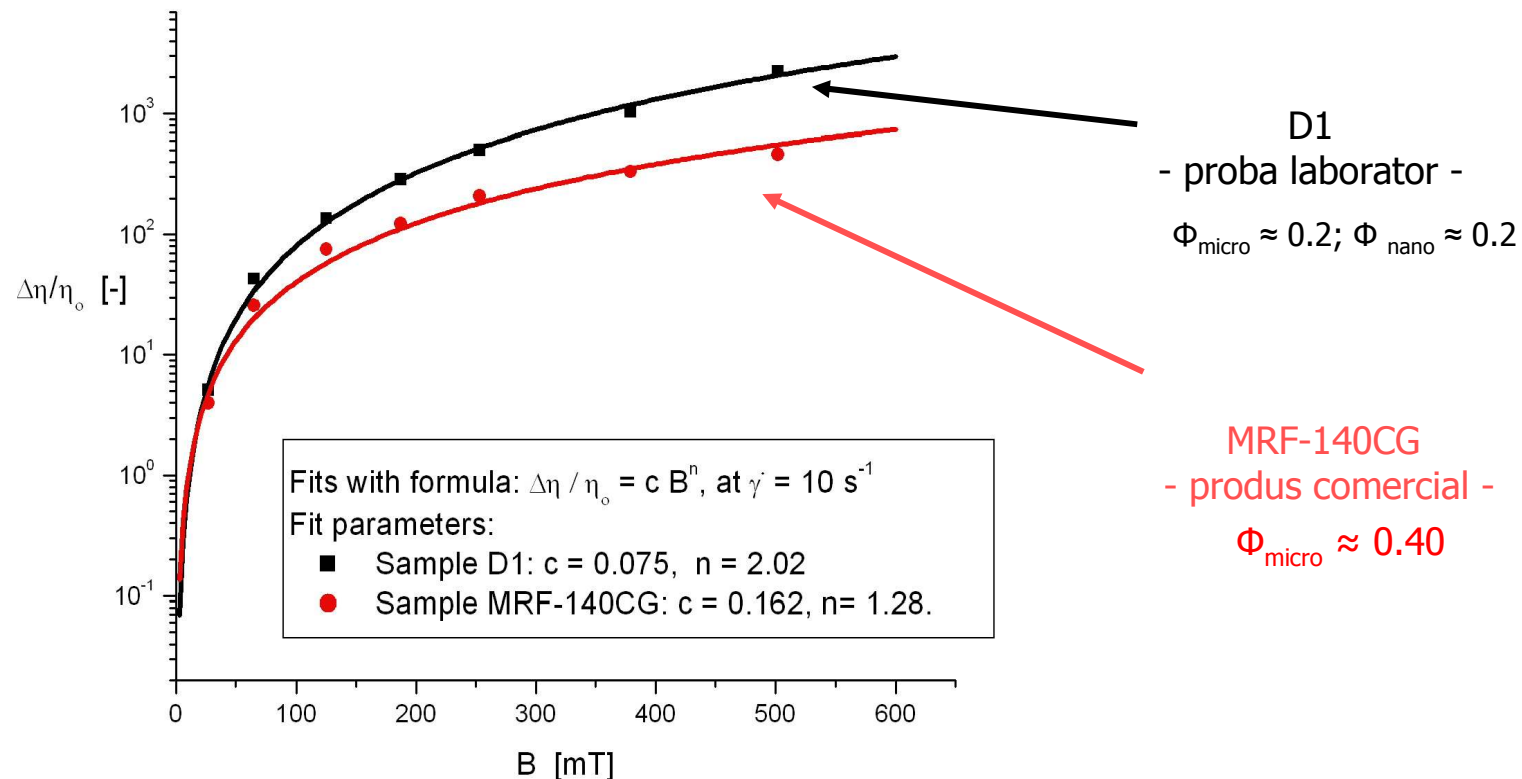
$$\tau = \frac{\eta_0 \dot{\gamma}}{1 + \lambda \left(\frac{\dot{\gamma}}{\dot{\gamma}^*}\right)^m} \left[1 - \tanh\left(\frac{\dot{\gamma}}{\dot{\gamma}^*}\right) \right] + \left[\tau_0 + \tau_1 \left(\frac{\dot{\gamma}}{\dot{\gamma}^*}\right)^{1-n} \right] \tanh\left(\frac{\dot{\gamma}}{\dot{\gamma}^*}\right)$$

Fit: formula Cross+ H-B pentru B>0

Fluid magnetoreologic "nano-micro" structurat

- influenta NPM asupra efectului magnetoreologic -

$$[\eta(B) - \eta(0)] / \eta(0) = f(B)$$



Proiect CEEEX: NanoMagneFluidSeal

Realizarea unei unitati de micro-productie de nanofluid magnetice

- SC ROSEAL SA -



Hala pilot



Instalatie micropilot – in curs de asamblare



Masa de lucru operator



Pregatire reactanti



Instalatie micropilot - ansamblu

Stand incercari pentru etansari rotitoare cu NFM

Panou de comanda



Subansamblu testare etansari rotitoare cu NMF



Unitate de vid

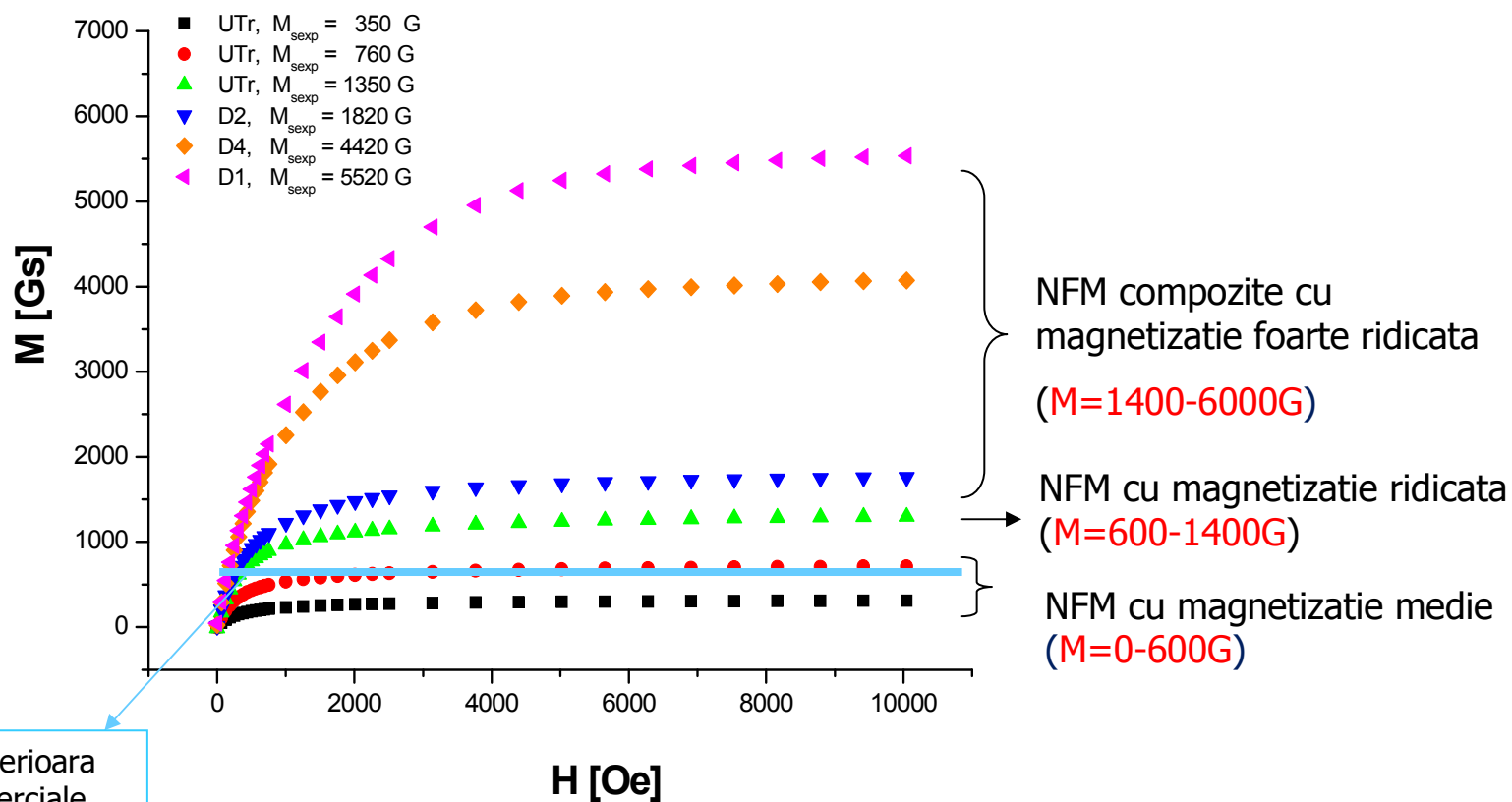
Unitate de achizitie si prelucrare date

10^{-7} – 50 bar

SC ROSEAL SA

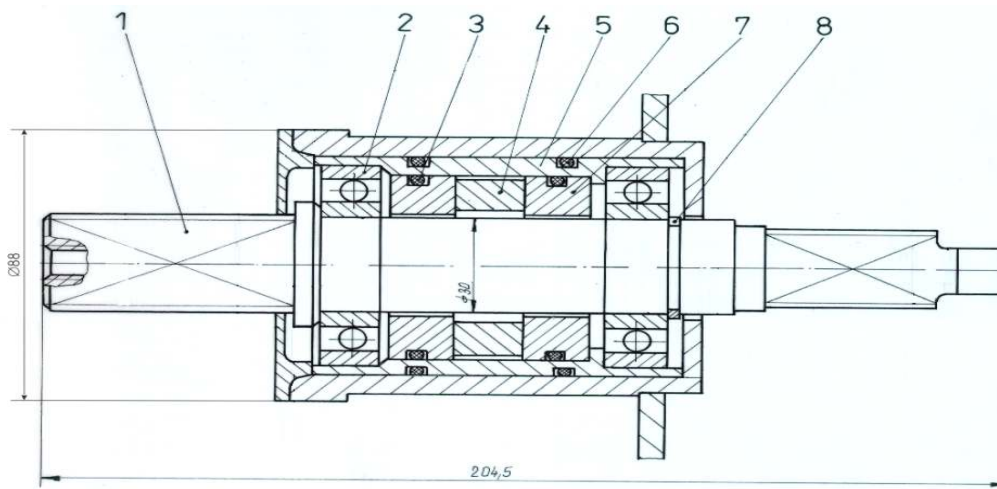
Fluide controlabile magnetic

- Nanofluidice magnetice NFM & Fluide compozite magnetizabile FCM -



Limita superioara
NFM comerciale

Etansari rotitoare fara scapari pentru vid si presiuni moderate

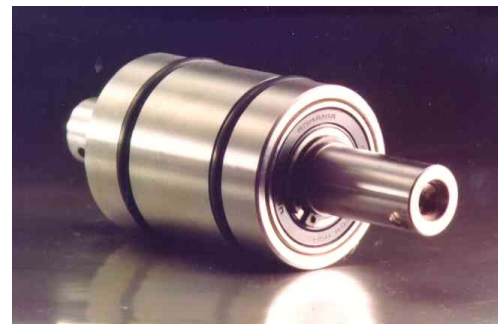


Elemente componente

- 1- shaft;
- 2- ball bearing;
- 3,6- "O" ring;
- 4- permanent magnet;
- 5- non-magnetic casing;
- 7- polar piece;
- 8- safety ring.



a.

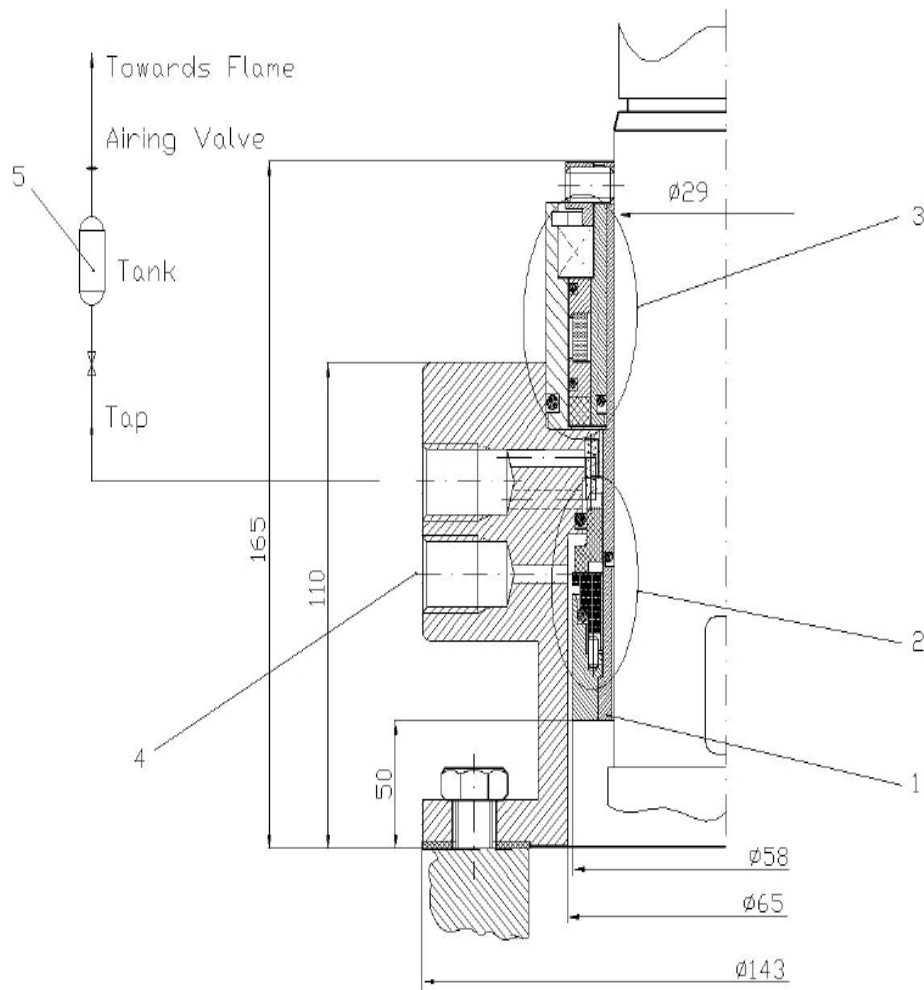


b.

Magnetic fluid feedthrough for

- a) high vacuum
- b) high power electric switches with SF6

Etansari combinate mechanic-magnetofluidic



Elemente componente:

- 1- shaft;
- 2- mechanical seal;
- 3- magnetic fluid seal;
- 4- inlet for cooling and lubrication fluid;
- 5- system for escaped process fluid evacuation

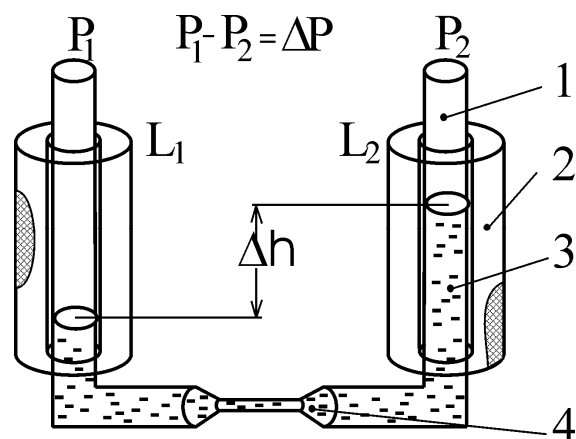


Manufacturer ROSEAL Co. Romania

Traductoare inductive cu NFM

- medii gazoase -

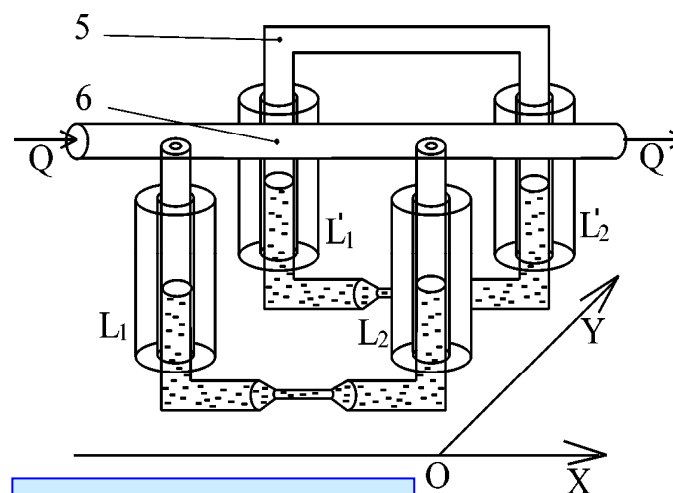
Traductor de presiune



$\Delta p \sim \mu\text{m H}_2\text{O} \rightarrow 100\text{mmH}_2\text{O}$

- 1 – tub in forma de "U";
- 2 – bobine electrice identice (L1 si L2);
- 3 – FM;
- 4 – portiune de sectiune redusa pentru amortizarea oscilatiilor coloanei de FM;

Traductor de debit



$Q \sim \text{cm}^3/\text{min} \rightarrow 100\text{m}^3/\text{min}$

- 5 – tub de legatura a capetelor superioare;
- 6 – element de masurare debit in curgere laminara;
- Q – debit de gaz
- P1, 2 – presiuni;
- Δh – gap

I. Potencz, N.C. Popa, et al, **RO Patent 98431 (1989)**

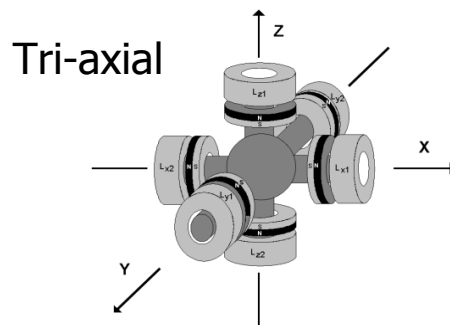
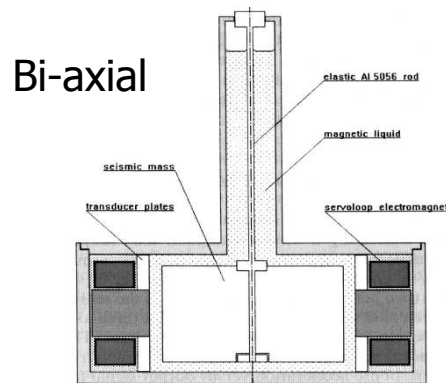
I. De Sabata, N.C. Popa, I. Potencz, L. Vekas, *Inductive transducers with magnetic fluids*, **Sensors and Actuators, A 32(1992)678**

N.C. Popa, I. Potencz, L. Vekas, *Magnetic fluid flow meter for gases*, **IEEE Trans. Magnetics, 30(1994)936**

Traductoare de acceleratie

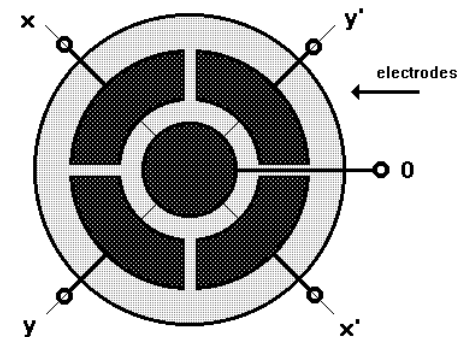
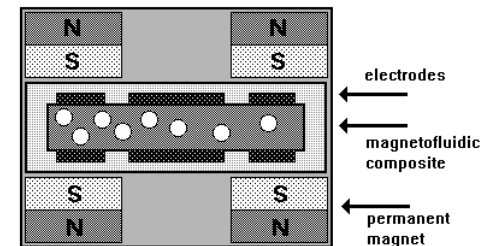
- aplicatii bazate pe efectul de levitatie magnetofluidica de ordinul I si II -

Accelerometre



Sensibilitate $10^{-6} - 10^{-9} \text{ m/s}^2$

Accelerometru cu FM compozit



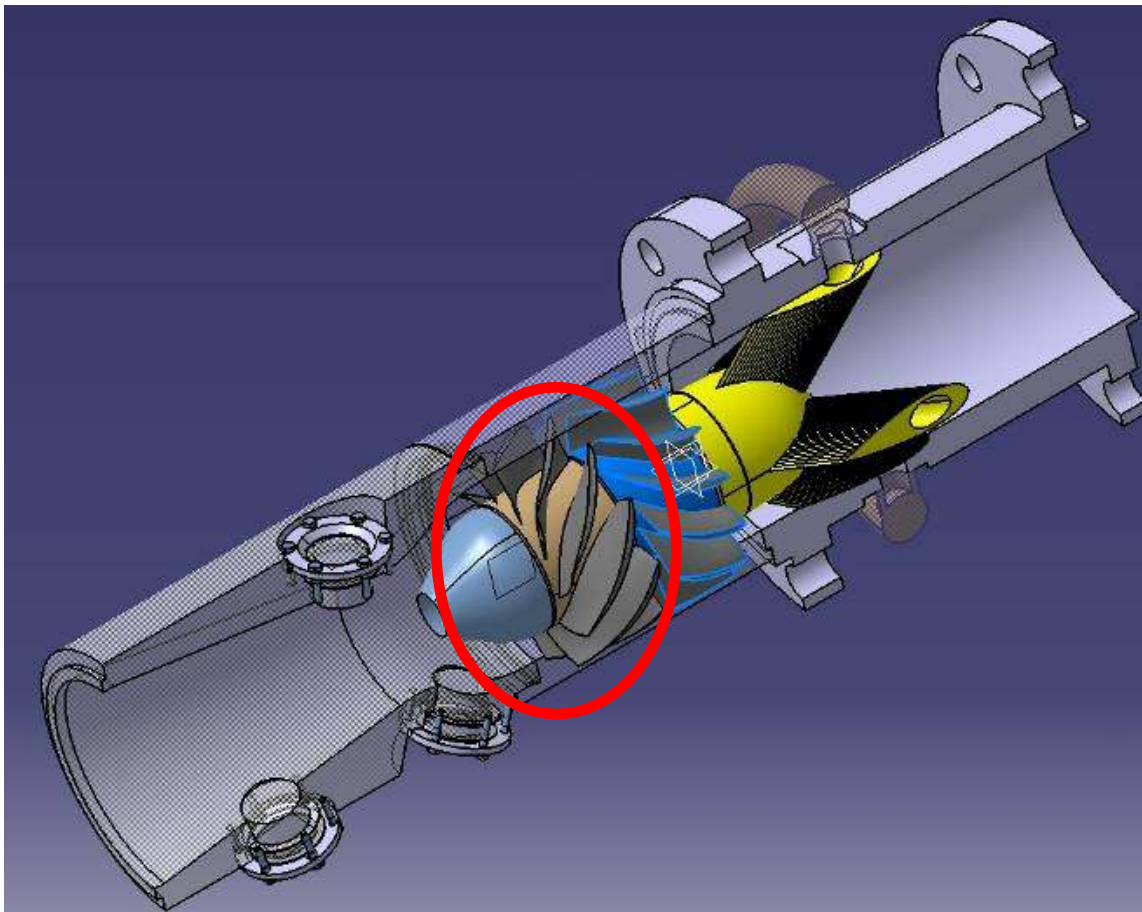
Domeniu larg de sensibilitate $10^{-3} - 10 \text{ m/s}^2$

M.I. Piso, RO Patents 98569(1990), 99568 (1990), 99036 (1992), 100632(1991)

M.I. Piso, Magnetofluidic inertial sensors, Rom.Rep.Phys.47(1995)437

Controlul curgerii cu fluide magneto-reologice

- aplicatie bazata pe efectul magneto-reologic -



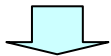
**controlul turatiei
rotorului generatorului
de vartej prin
modificarea vascozitatii
efective a fluidului
magneto-reologic**

**sistem de franare
magneto-reologica**

Consideratii finale

Rezultate

- Proprietatile fluidelor controlabile magnetic se adapteaza aplicatiilor prin dimensiunea si fractiunea volumica a componentei magnetice $10^0 \dots 10^4$ nm
- Magnetizatia de saturatie a NFM se extinde cu un ordin de marime in cazul fluidelor compozite magnetizabile $10 \dots 7 \times 10^3$ G
- Energia de interactiune adimensionala acopera un domeniu foarte larg $0.5 \dots 10^8$
- Efectul magnetoreologic $\Delta\eta/\eta$ se regleaza prin compozitia fluidului $10^{-1} \dots 10^3$
- Implementare industriala a producerii fluidelor controlabile magnetic



Perspective

- Fabricatie de etansari magnetofluidice, amortizoare, senzori
- Extinderea directiilor de aplicatie spre biotehnologii, biologie si medicina

❖ **Academician Prof.Dr.-ing.DrHC Ioan ANTON**

Fondator al Laboratorului de Lichide Magnetice de la Timisoara

❖ **Dr. Doina Bica (1952 - 2008)**

❖ Colectivului **Laboratorului de Lichide Magnetice si al Centrului National pentru Ingineria Sistemelor cu Fluide Complexe** si in special colegilor

S.I. Dr. Daniela Susan-Resiga, S.I.Dr.-ing. Adelina Han, CS1Dr.ing. N.C. Popa, CS1 Dr.ing. S. Muntean

❖ **SC ROSEAL SA Odorheiu Secuiesc:** ing. I. Borbáth, ing. T. Boros

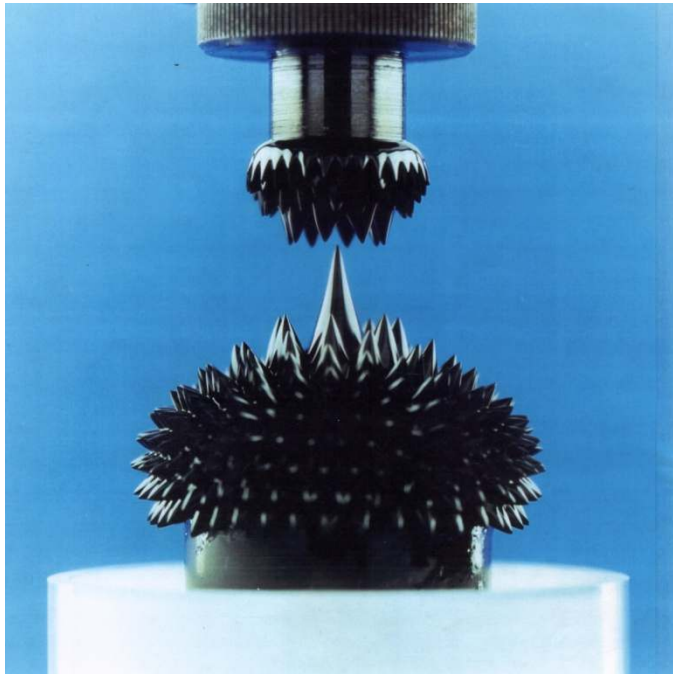
❖ Dr. M.V. Avdeev - JINR Dubna

❖ Prof.Dr. Etelka Tombácz - Univ. Szeged

❖ Dr.ing. I. Morjan - INFLPR Bucuresti

❖ Dr. V. Garamus - GKSS Geesthacht

❖ Dr. L. Rosta, Dr. Gy. Török - KFKI Budapest



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