Nanomaterials for electrical engineering

Acoustic and dielectric diagnostic of insulation materials

doc. RNDr. Jozef KÚDELČÍK, PhD.

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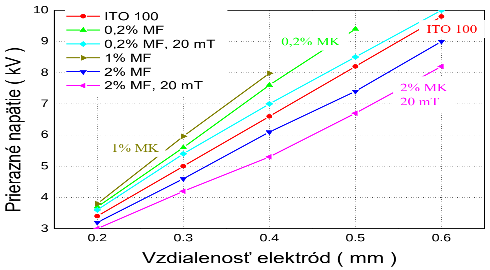
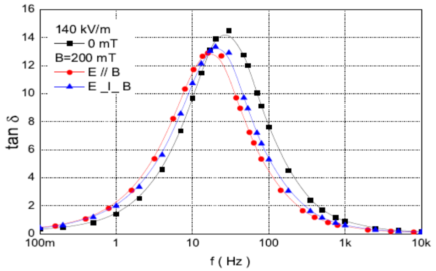
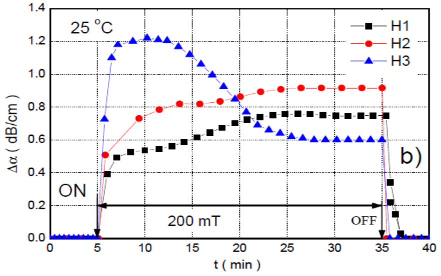
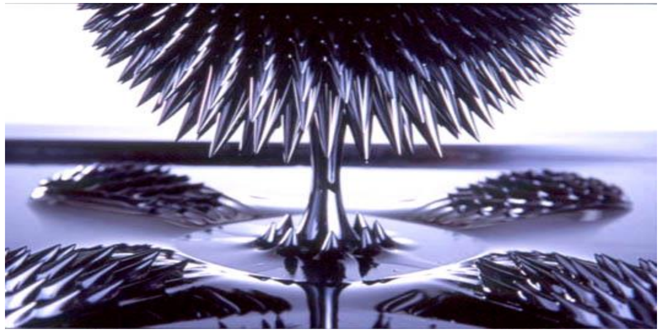
Content of the lecture

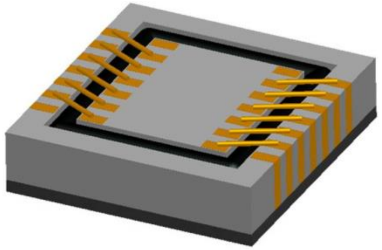
1. University of Žilina
2. Nanoparticles and magnetic fluid
3. Breakdown
4. Dielctric spectroscopy
5. Acoustic spectroscopy











University of Žilina

member of EUA

Location

University of Žilina

member of EUA

Faculties

FEIT (1953)	**FME** (1953)	**FOETC** (1953)
Faculty of Electrical Engineering and Information technology	Faculty of Mechanical Engineering	Faculty of Operation and Economics of Transport and Communications

FCE (1953)	**FMSI** (1990)	**FH** (1998, 2010)	**FSE** (1953, 1998)
Faculty of Civil Engineering	Faculty of Management Science and Informatics	Faculty of Humanities	Faculty of Security Engineering

2020:	*University*	*FEIT*	
	8 149	1 124	students
	607	115	teachers
	1 493	162	employees

Faculty of Electrical Engineering and Information Technology

Organization structure

Dean’s Office

- Dean
  - Vice-Dean for Study Affairs
  - Vice-Dean for Research & Science
  - Vice-Dean for Development & International Affairs
  - Secretary
  - Administrative Staff

Department of Multimedia & ICT
DMI

Department of Mechatronics & Electronics
DME

Department of Control & Information Systems
DCIS

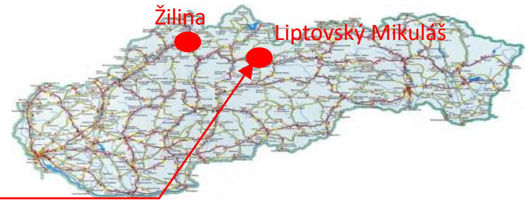
Department of Electromagnetic & Biomedical Engineering
DEBE

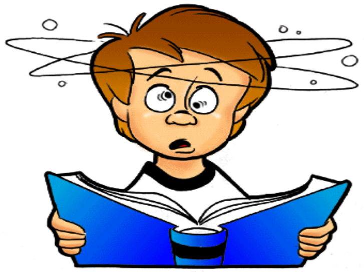
Department of Physics
DP

Department of Power Electrical Systems
DPES

Department of Measurement & Applied Electrical Engineering
DMAE

Institute of Aurel Stodola in Liptovský Mikuláš
IAS





Study

Bachelor programs

- Electrical Engineering
- Control Engineering
- Telecommunications
- Digital Technologies
- Multimedia Technologies
- Biomedical Engineering
- Autotronics
- Electrooptics

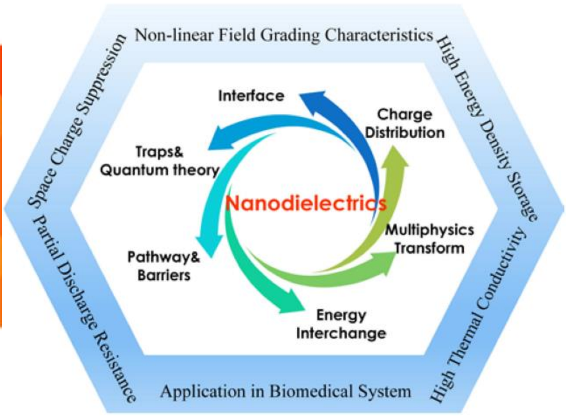
MSc. programs

- Multimedia Engineering
- Electrical Drives
- Electric Power Systems
- Power Electronic Systems
- Process Control
- Telecommunication and Radiocommunication Engineering
- Biomedical Engineering
- Applied Telematics
- Photonics

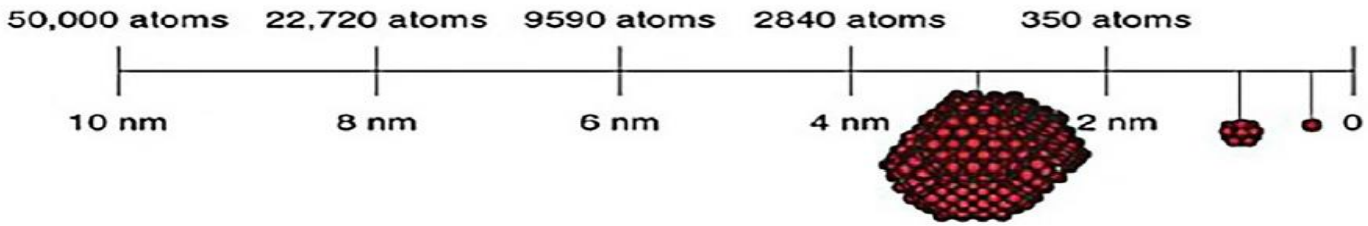
PhD. programs

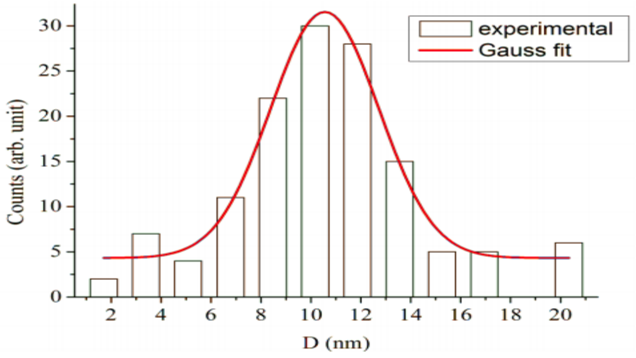
- Telecommunications
- Theory of Electrical Engineering
- Power Electrical Engineering
- Process Control
- Electric Power Systems
- Electrotechnologies and Materials

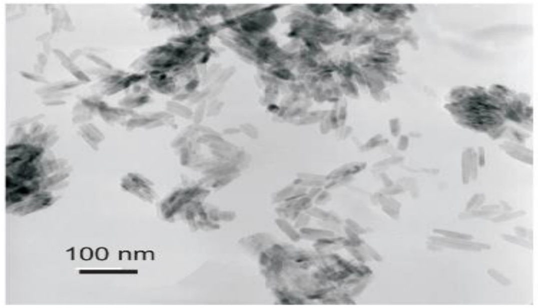
2. Nanoparticles

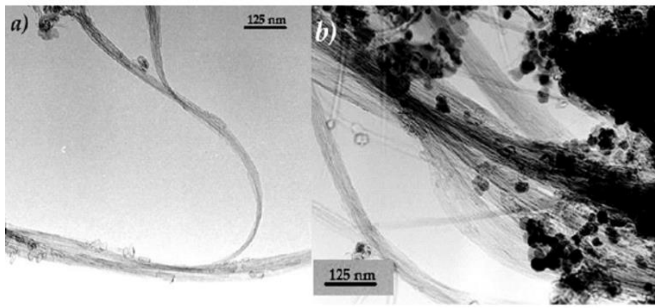


- technology and interest in the creation of new structures, materials
- are characterized by a size of 1 nm - 100 nm in at least one dimension and a certain spatial arrangement - spherical, needle, nanowires, nanotubes, nanocomposites and nanolayers
  - SiO_2, ZnO, TiO_2, Fe_3O_4, MWCNT
- a big increase in the ratio of surface area to nanoparticle volume - affects most chemical and physical bonds







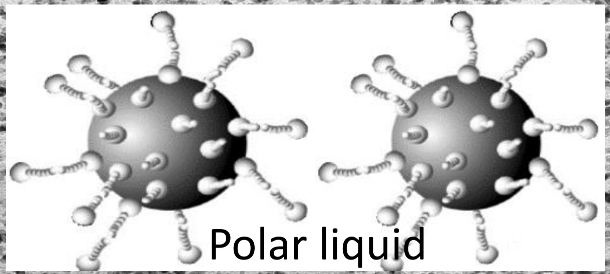


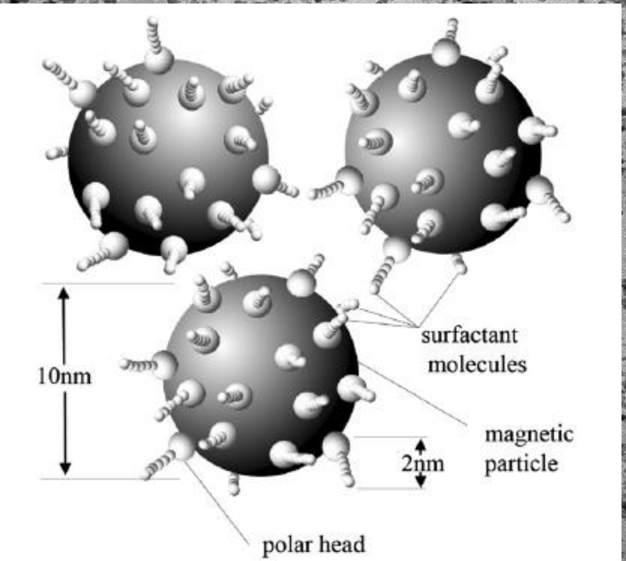
Magnetic liquid

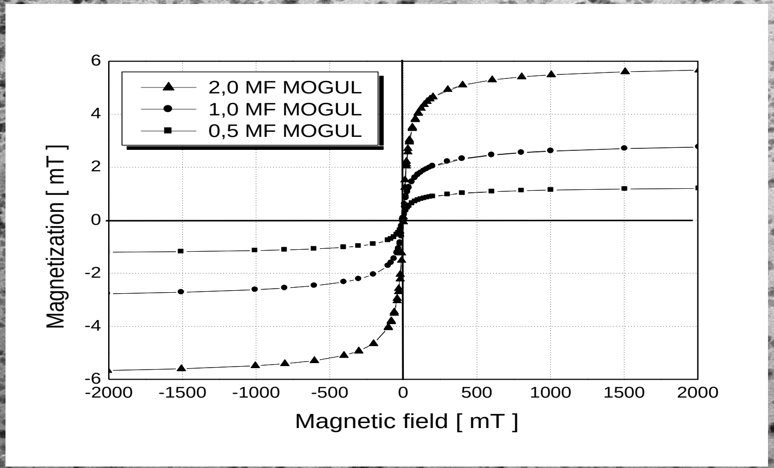
- colloidal suspensions of magnetic particles nanometer size covered by a surfactant layer in a carrier liquid
- monodomain, paramagnetic - rotation of magnetic domains in the direction of an external magnetic field

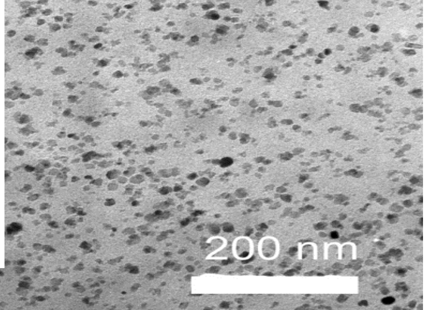
mag. nanoparticles - Fe_3O_4

- Transformer oil
- water
- Carbon nanotubes
- Liquid crystals



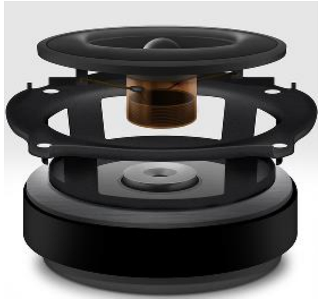


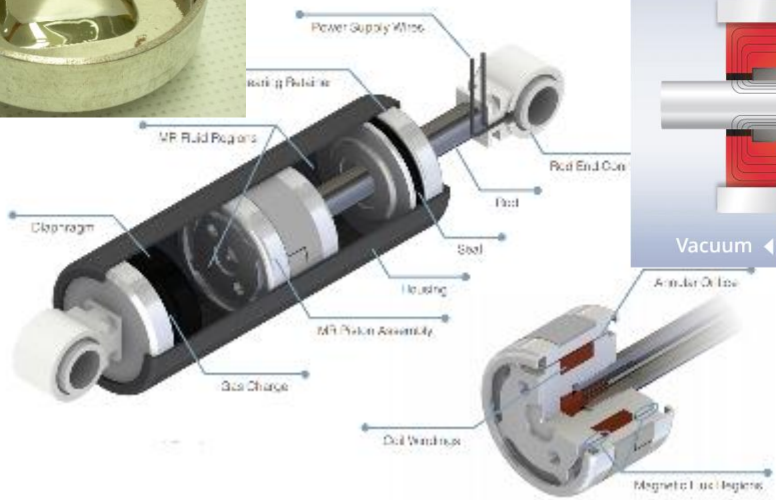


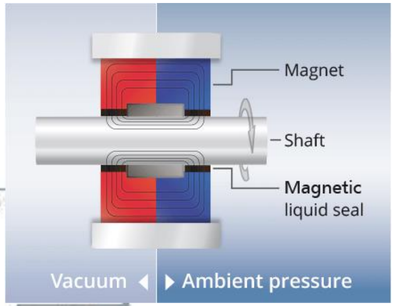


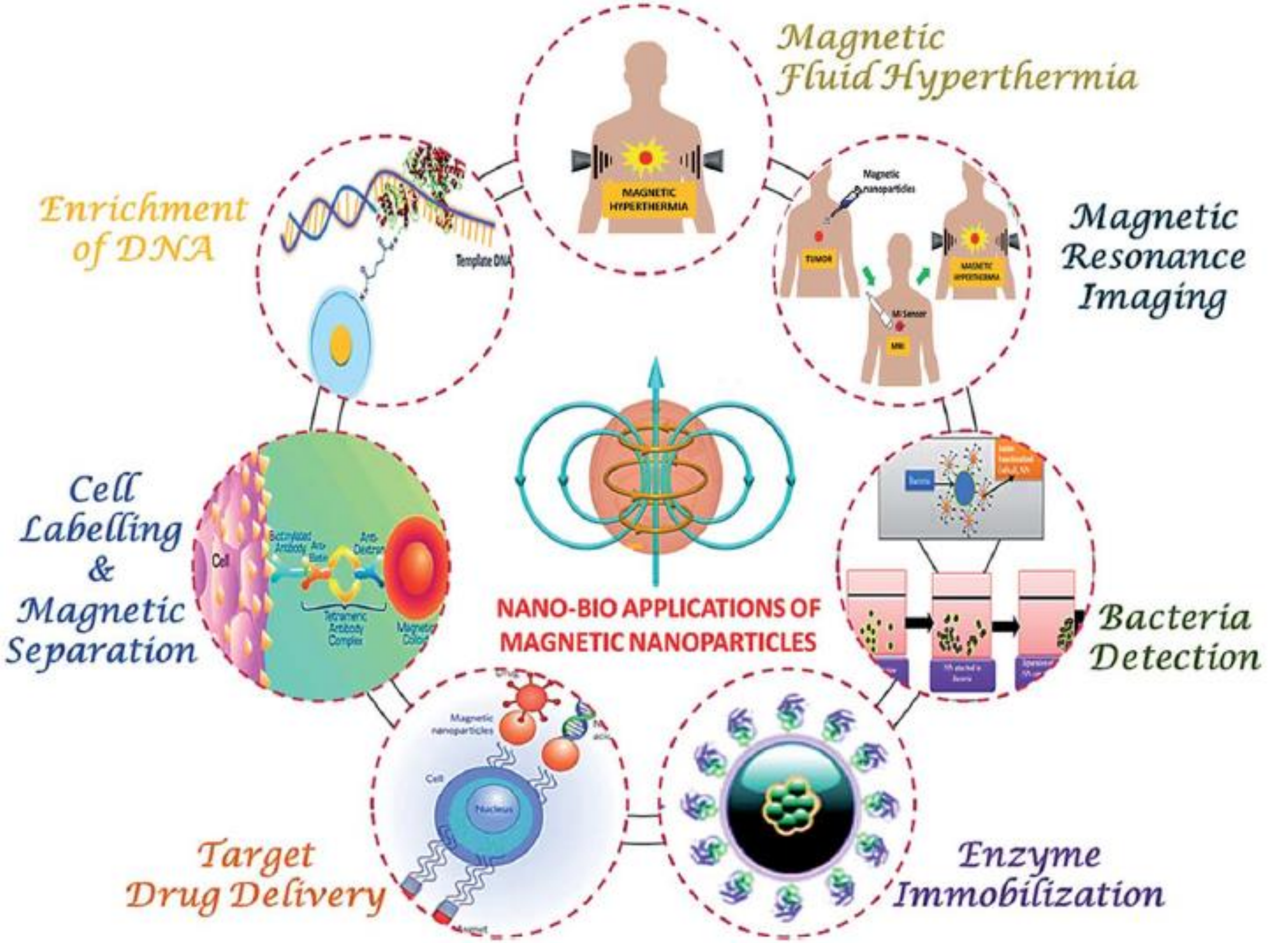
TEM
2MF MOGUL
(11±3) nm

Applications of Magnetic fluid



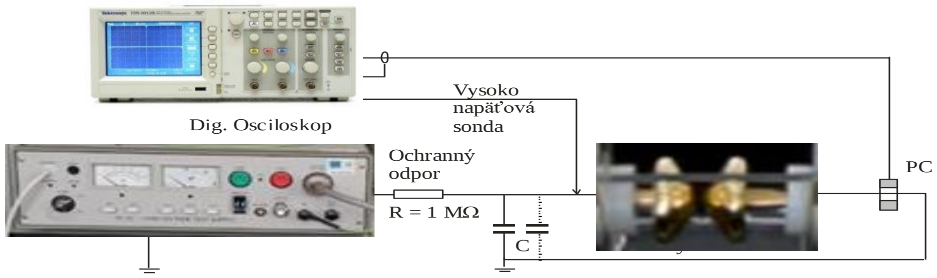


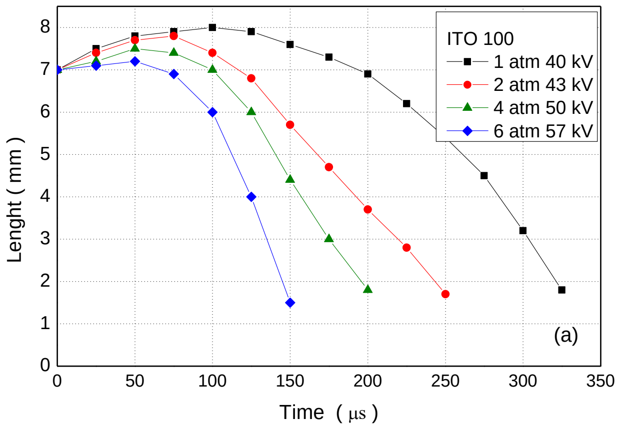


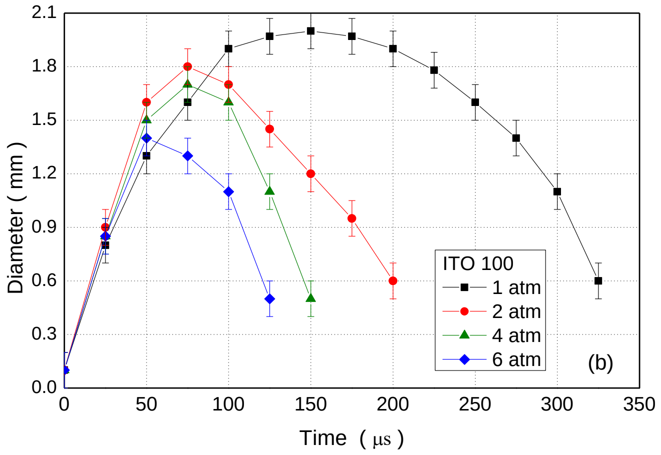


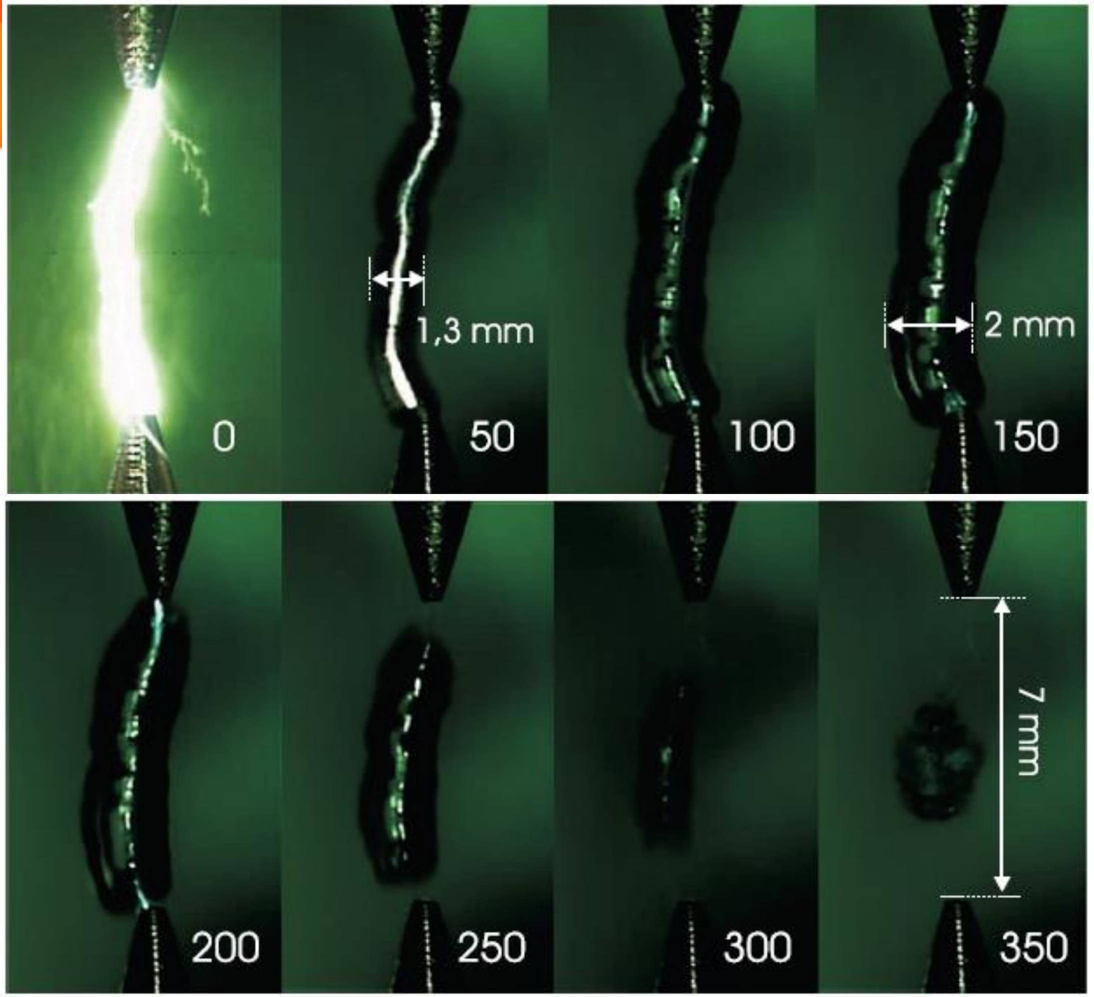
Bohara, et al. *RSC Adv.* 2016, 6, 43989–44012

3. Study of breakdown in transformer oil and magnetic fluid



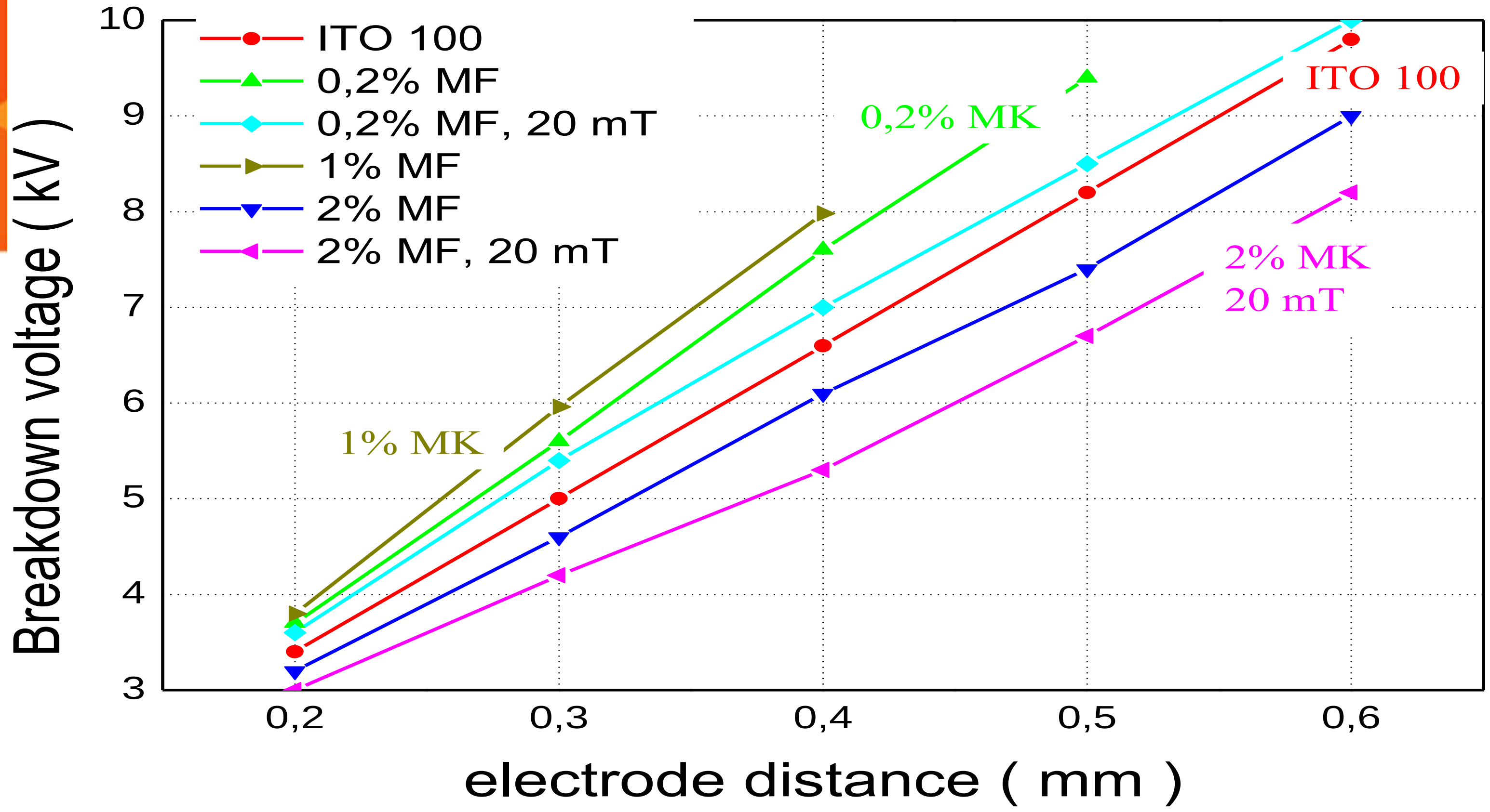






Time evolution of the length and width of the plasma channel in transformer oil ITO 100 for different external pressures at a given fault voltage. The electrode distance was 7 mm and the cathode electrode diameter was 0.6 mm

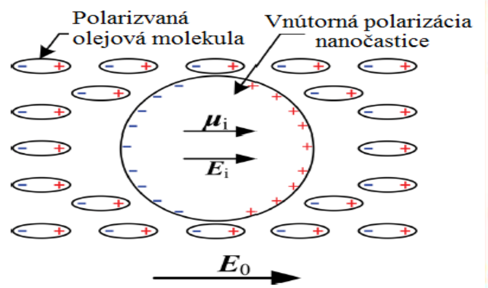
KÚDELČÍK, J., VARAČKA, L., JAHODA, E., S. Poljak: *Post-breakdown stages in transformer oil*, European Physical Journal Applied Physics Roč. 78 (2), 20801, 2017

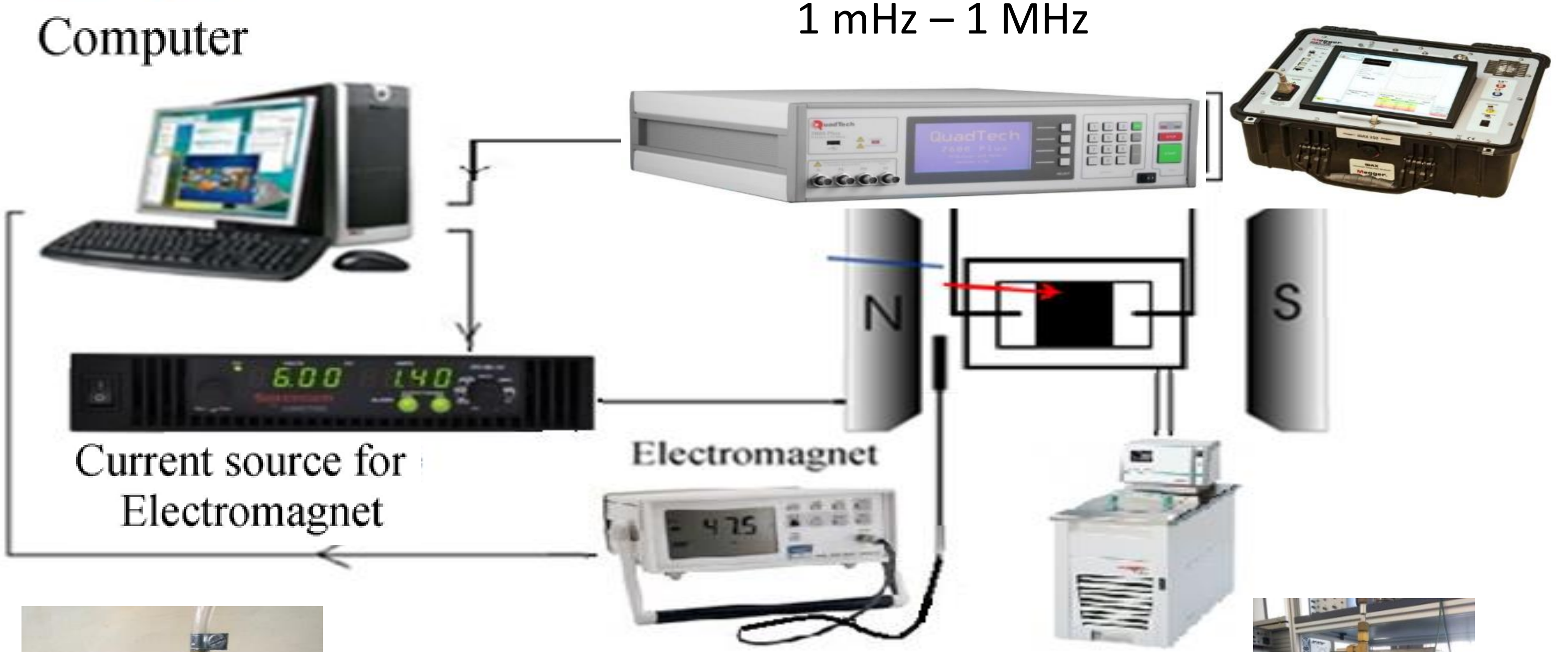


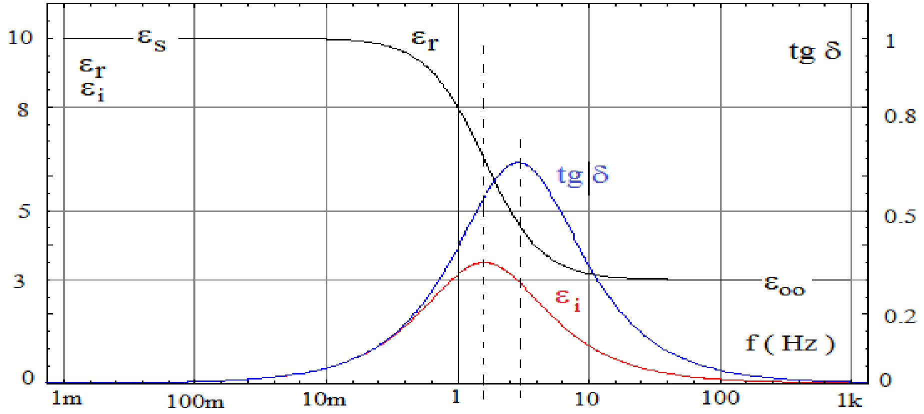
Dependence of breakdown voltage on distance between electrodes in transformer oil ITO 100 at the concentration of magnetic nanoparticles (0.2%, 1% and 2%) without and with magnetic field.

KÚDELČÍK, J. - BURY, P. - KOPČANSKÝ, P. - TIMKO, M. 2010. Dielectric breakdown in mineral oil ITO 100 based magnetic fluid. In: *Physics procedia*. Vol. 9, str. 78-81. Scopus, WoS (IF2011 = 0.45(Scopus)) (32 SCI citácií)

4. Dielectric spectroscopy





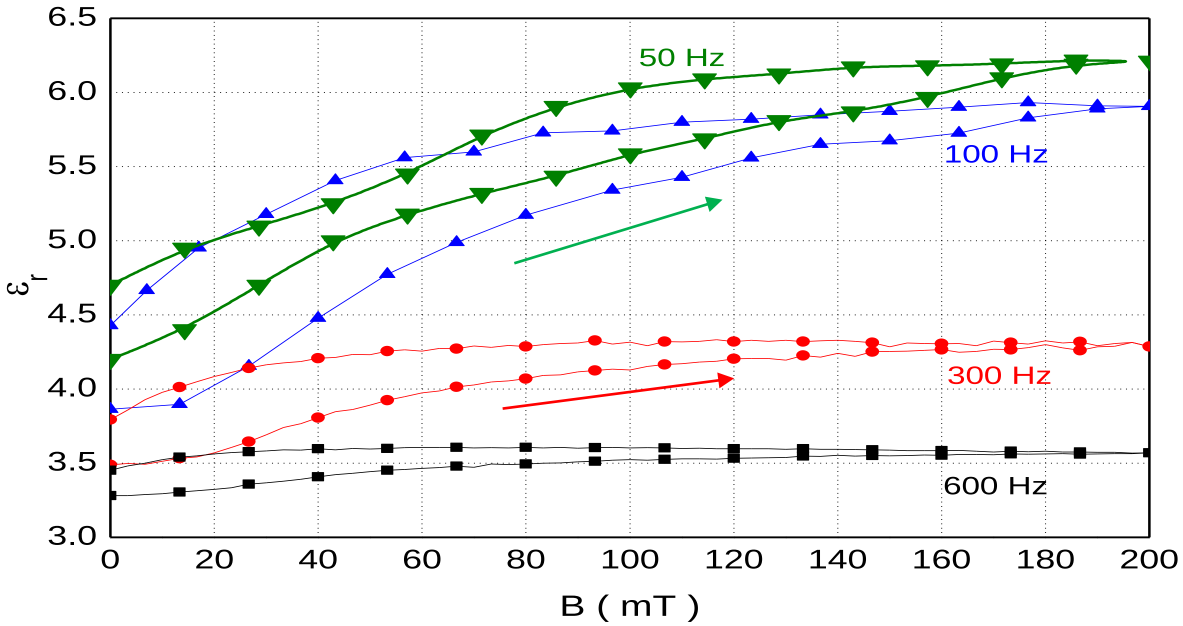


Dielectric with one relaxation process:
ε_s=10, ε_n=3, τ_0=0.1, $\omega_0 = 1/\tau_0$

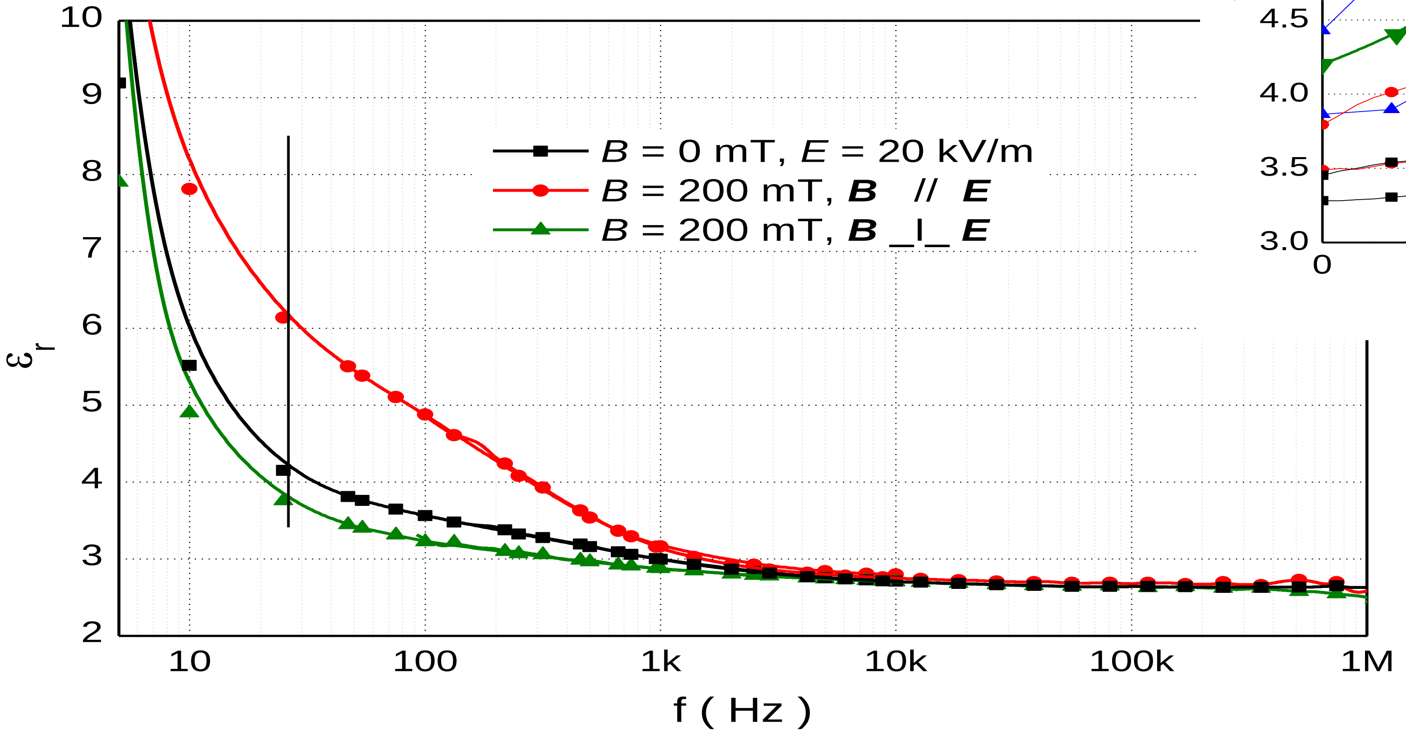
$$\varepsilon^* = j\frac{\sigma}{\varepsilon_0\ \omega^n} + \varepsilon_\infty + \frac{\varepsilon_S - \varepsilon_\infty}{1 + (j\omega\tau_0)^{(1-\alpha)}}$$

$$C = \varepsilon_r \varepsilon_0 \frac{S}{d} \qquad R = \frac{d}{\sigma\, S} \qquad \varepsilon_i = \frac{\sigma}{\omega\varepsilon_0}$$

Magneto-dielectric effect



Dependence of permittivity with a linear change of the magnetic field to 200 mT (3.3 mT / min) for different frequencies of the electric field.

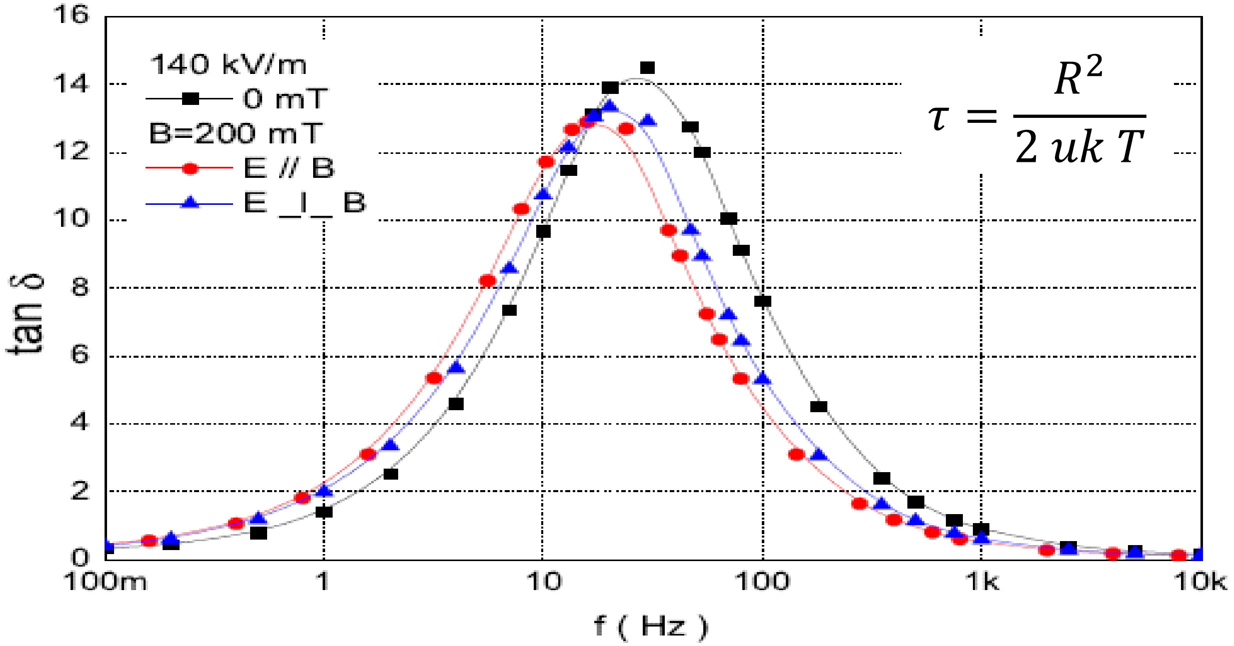


Dependence of real permittivity on frequency from different orientation of magnetic and electric field in magnetic fluid EMG-909 (10 nm, 3.8% Fe_3O_4).

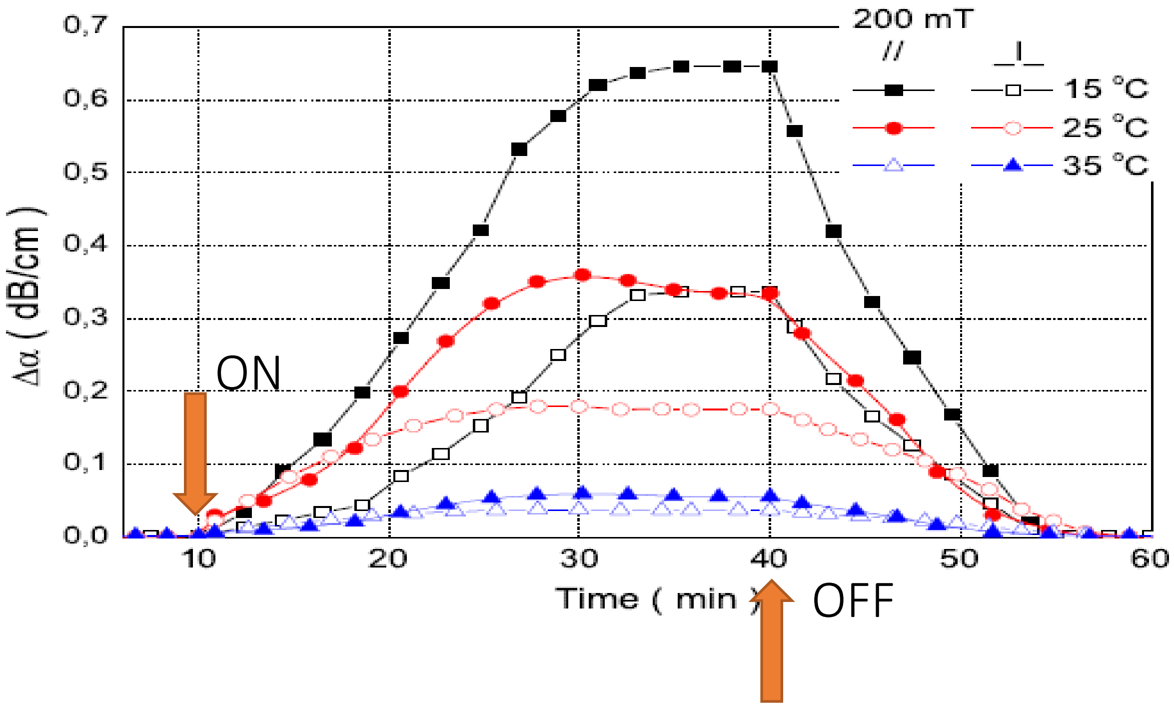
KÚDELČÍK, J. et al. 2017. *Acta Phys. Pol. A*. Vol. 131(4) 931-933. Scopus, WoS, (IF2017 = 0.802, CC Q4)

Comparison of dielectric and acoustic spectroscopy

40 A MOL + 3.9% Fe_3O_4 (12.2 nm)



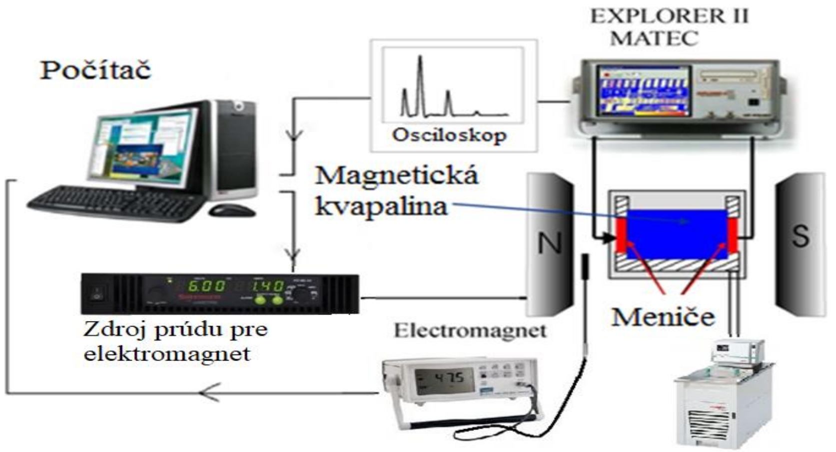
Frequency dependence of the magneto-dielectric effect at different orientations of the electric and magnetic fields.



Influence of the magnetic field at 200 mT on the change of acoustic attenuation for the perpendicular and parallel orientation of MF on the direction of propagation of the acoustic wave.

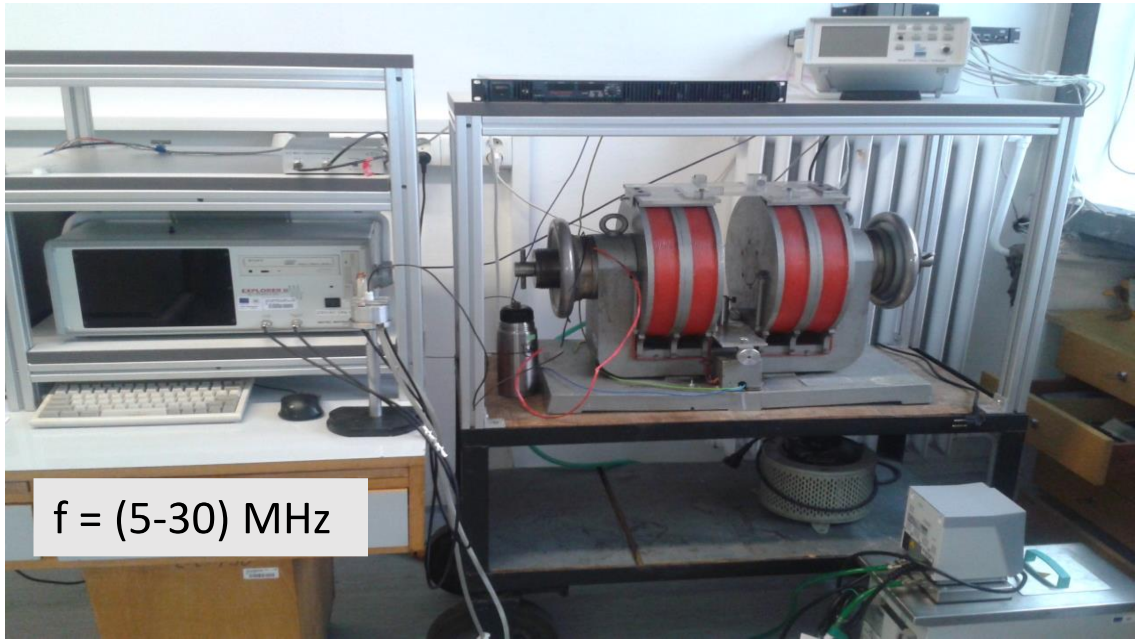
HARDOŇ, Š., KÚDELČÍK, J. et al. *Romanian J. Phys*. Vol. 64. 602 (2019) (IF 1.197, CC Q3)

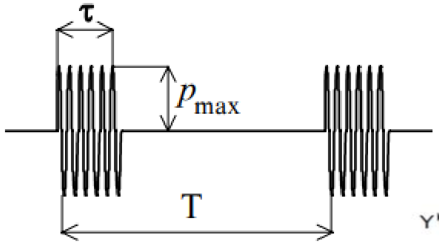
5. Acoustic spectroscopy

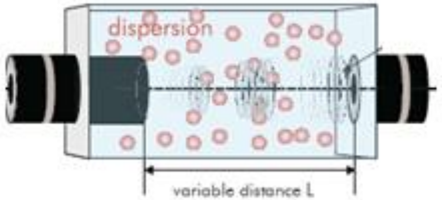


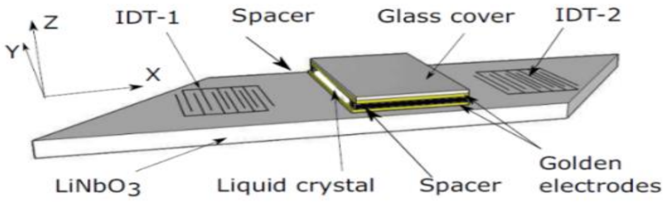
Study of acoustic attenuation changes in fluids on
a) magnetic field
b) temperature

$$\alpha = \frac{1}{L} 20\, Log\left(\frac{A1}{A2}\right)$$



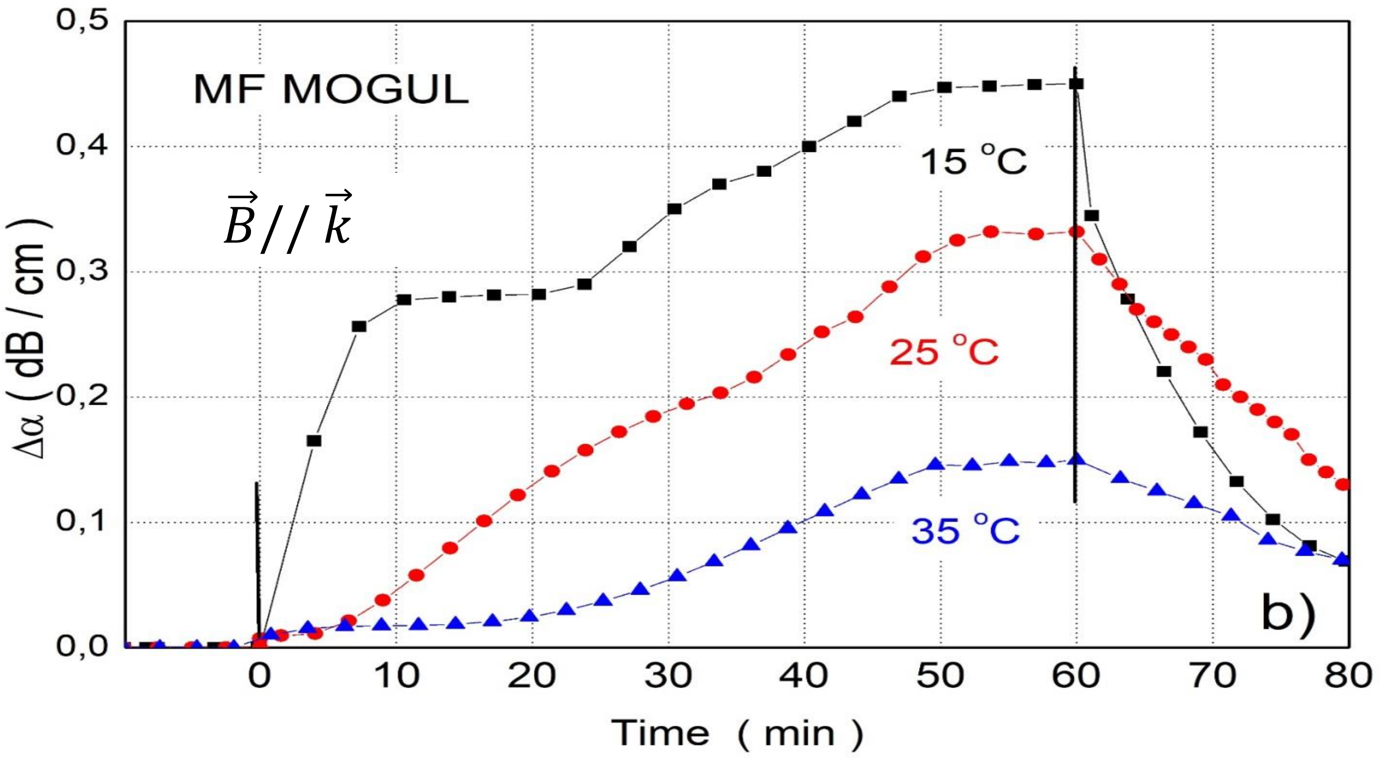


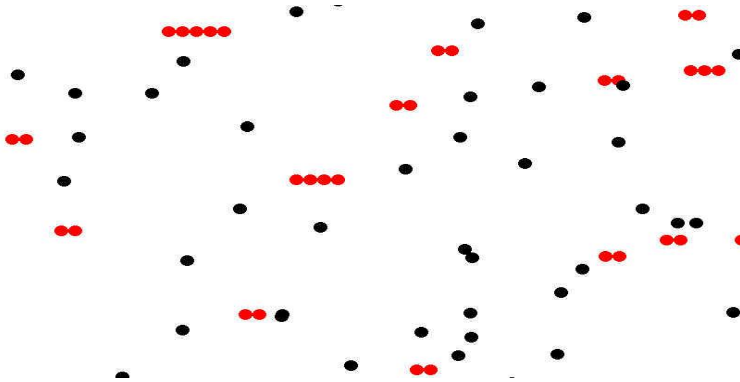


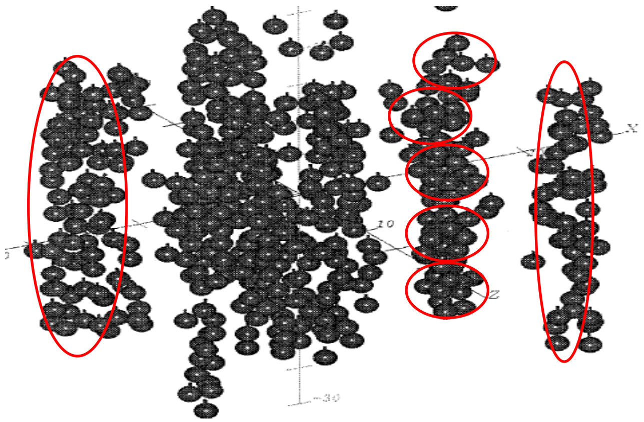


SAW – surface acoustic wave

Influence of a magnetic field



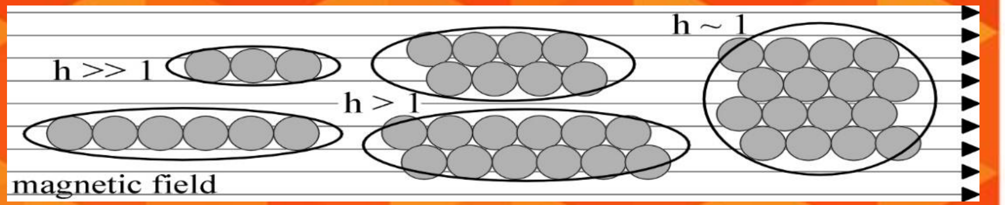


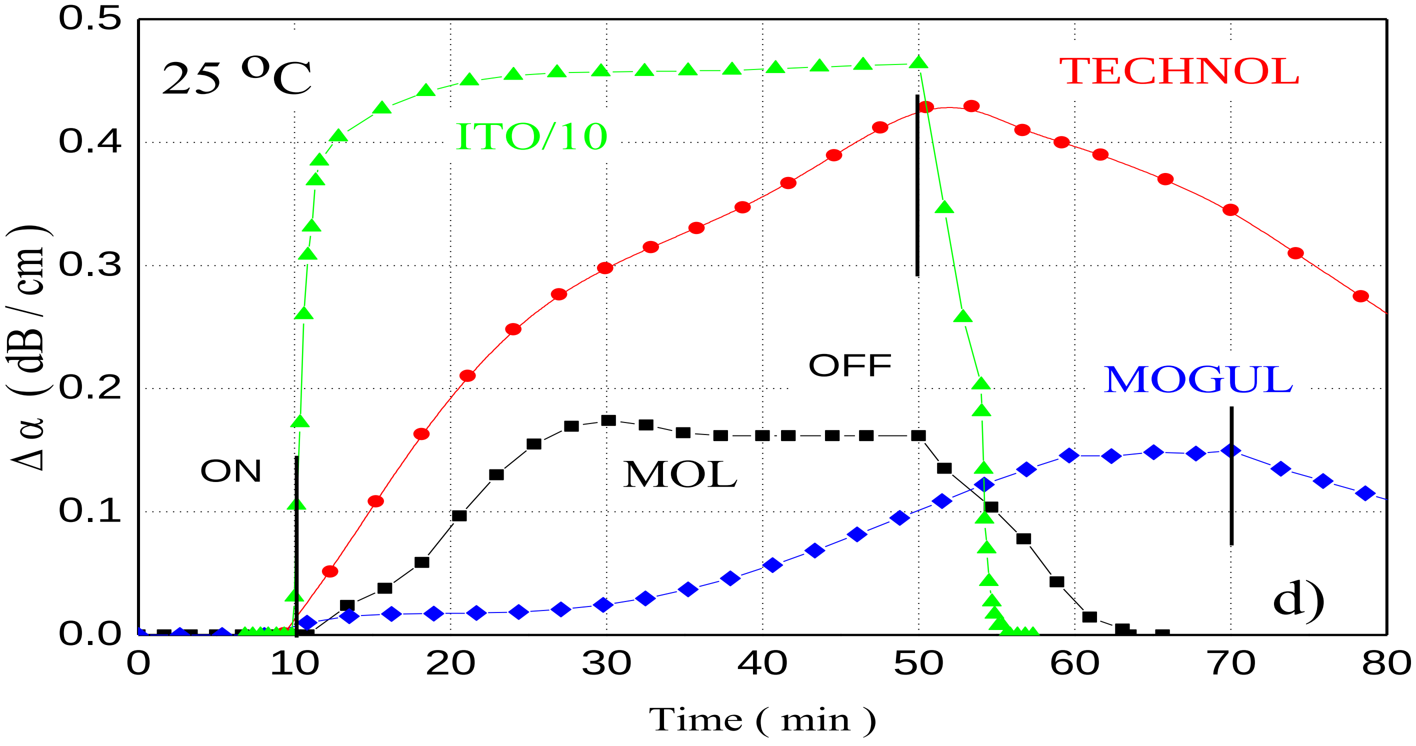


Time dependence of the change in acoustic attenuation for jump changes of the magnetic field to 200 mT at different temperatures.

KÚDELČÍK, J. et al, *J Magn Magn Mater Vol* 388 p. 28-34, (IF2015 = 2.357, CC Q2)

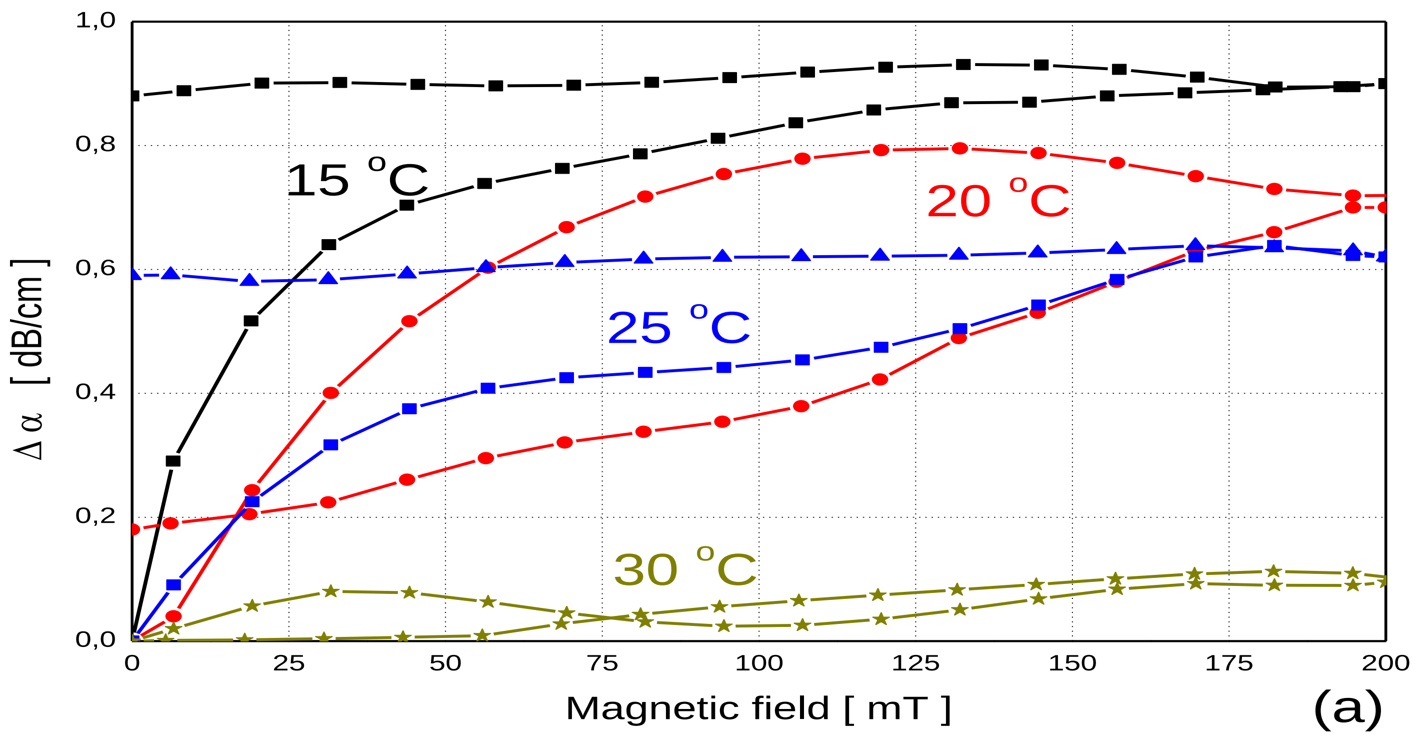
Step change of the magnetic field





Experimental data of changes in the acoustic attenuation for the step change of the magnetic field to value 200 mT measured at various types of MF at temperatures 25 °C

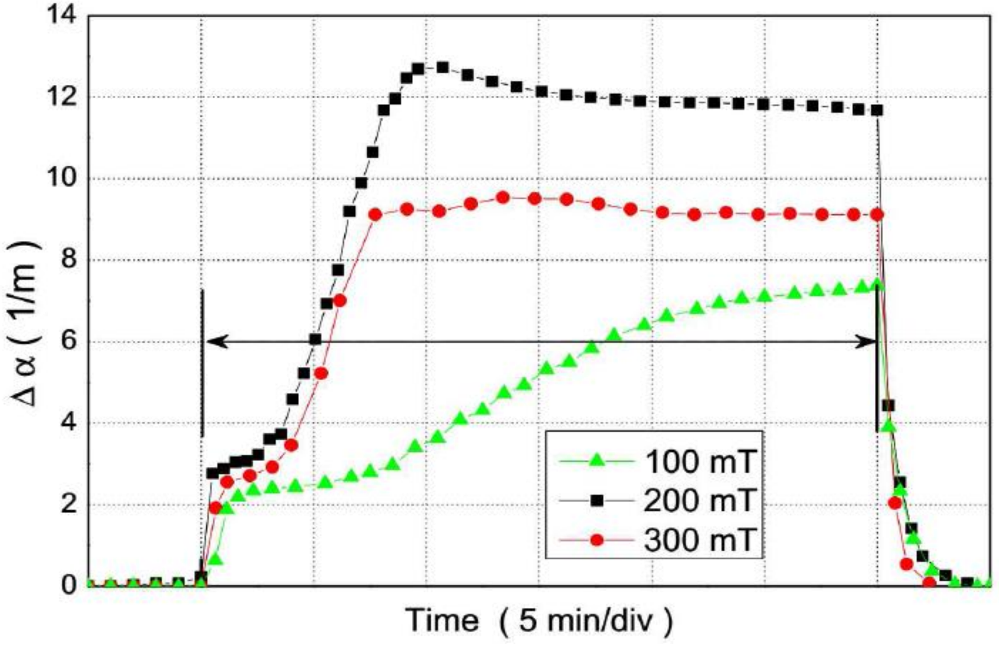
Linear change of the magnetic field



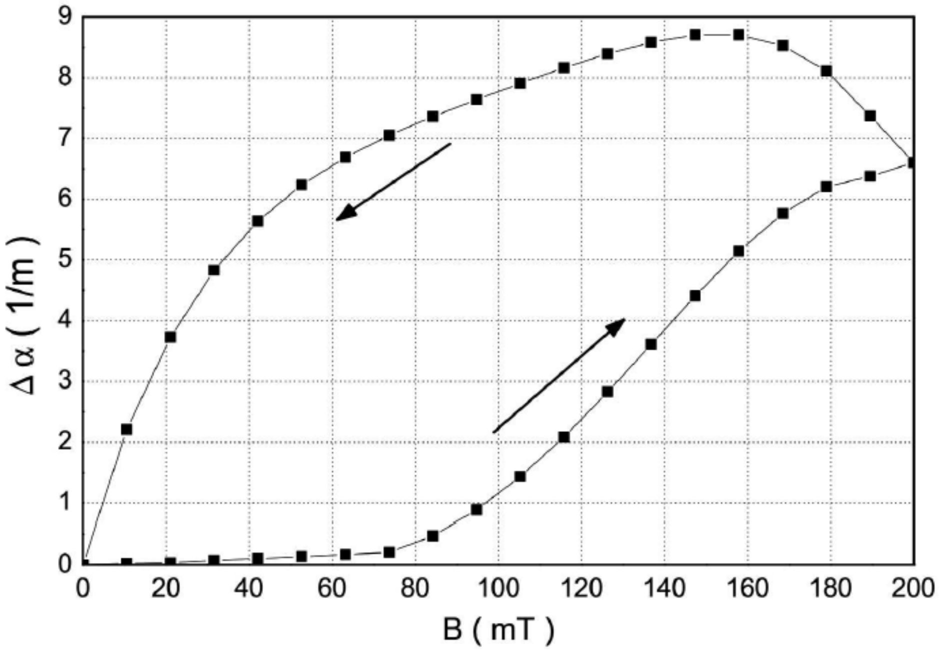
The temperature dependence of changes attenuation in external magnetic field for 1.0 % (sweep rate 2,2 mT/min) MF TECHNOL for frequency *f* = 13.3MHz (■ 15C, ● 20C, ▲ 25C, ∗ 30C).

Biocompatible liquid

3.3% Fe_3O_4 70 mg/ml
d = (9.47 ± 0.67) nm
M_s = 13.7 mT



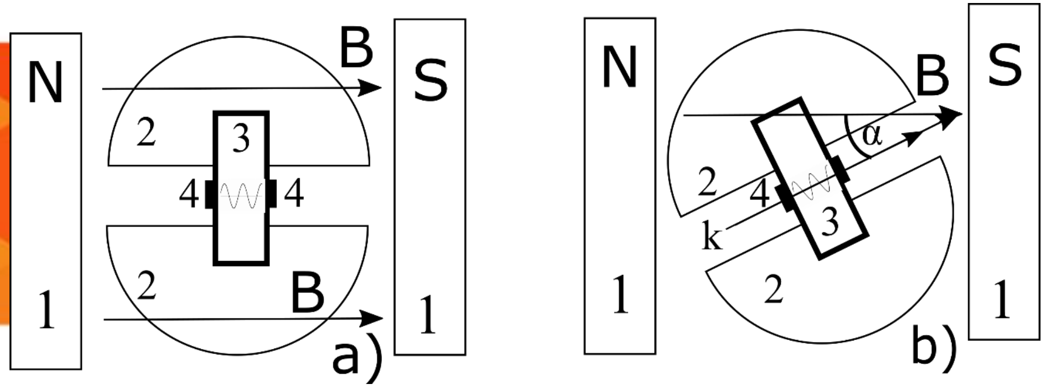
$\vec{B} // \vec{k}$

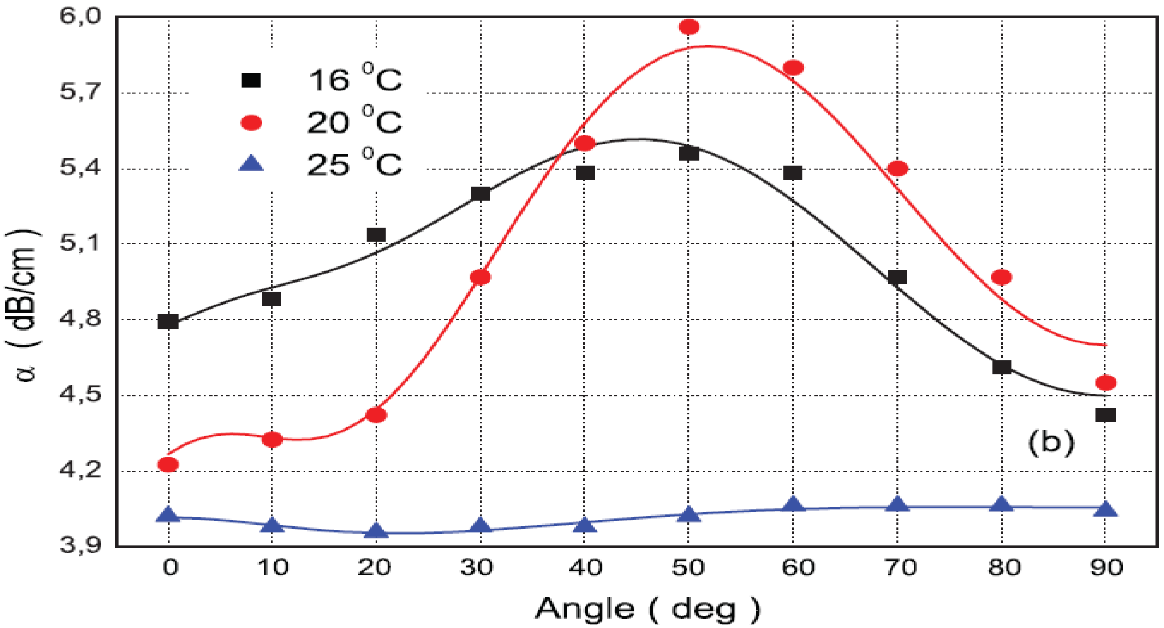


Time dependence of the change in acoustic attenuation for a) jump and b) linear change of the magnetic field up to 200 mT for a temperature of 20 °C.

KÚDELČÍK, J. et al. 2017. *Acta Phys. Pol. A.* Vol. 131(4) 919. Scopus, WoS, (IF2017 = 0.802, CC Q4)

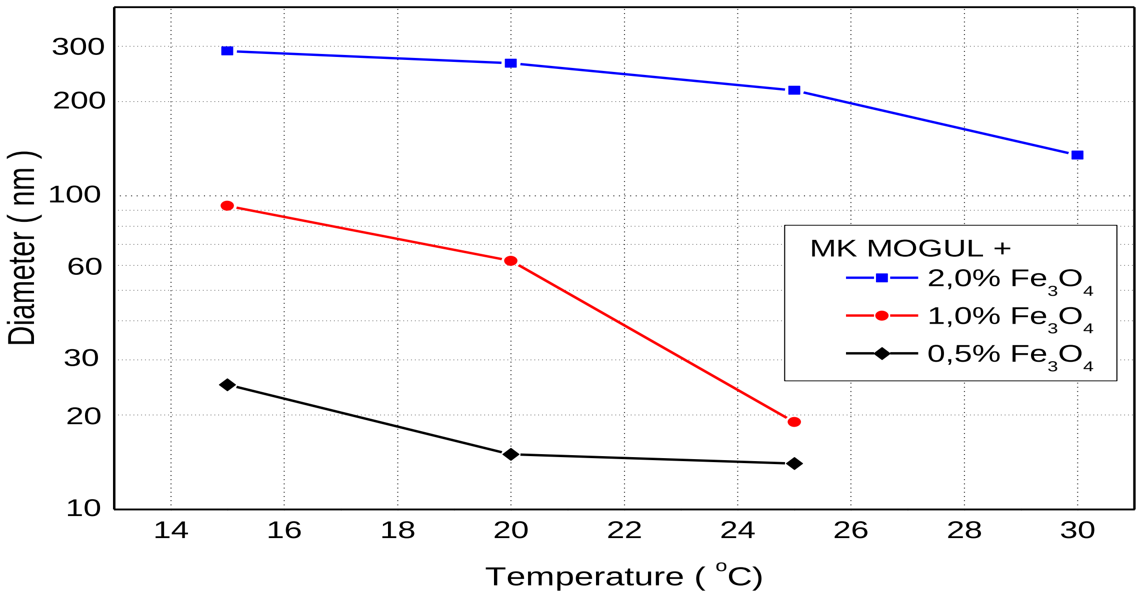
Anizotropy – angle dependence





Acoustic attenuation anisotropy measured at B = 200 mT for different temperatures in 1,0 % MF MOGUL at different temperature.

Taketomi´s theory



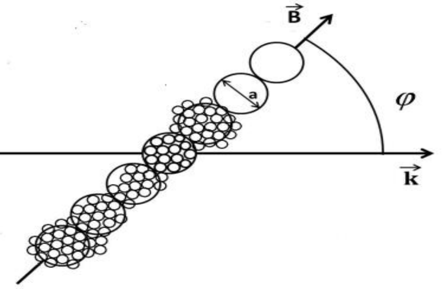
Cluster diameter as a function of temperature for different concentrations of magnetic nanoparticles in MOGUL oil transformers.

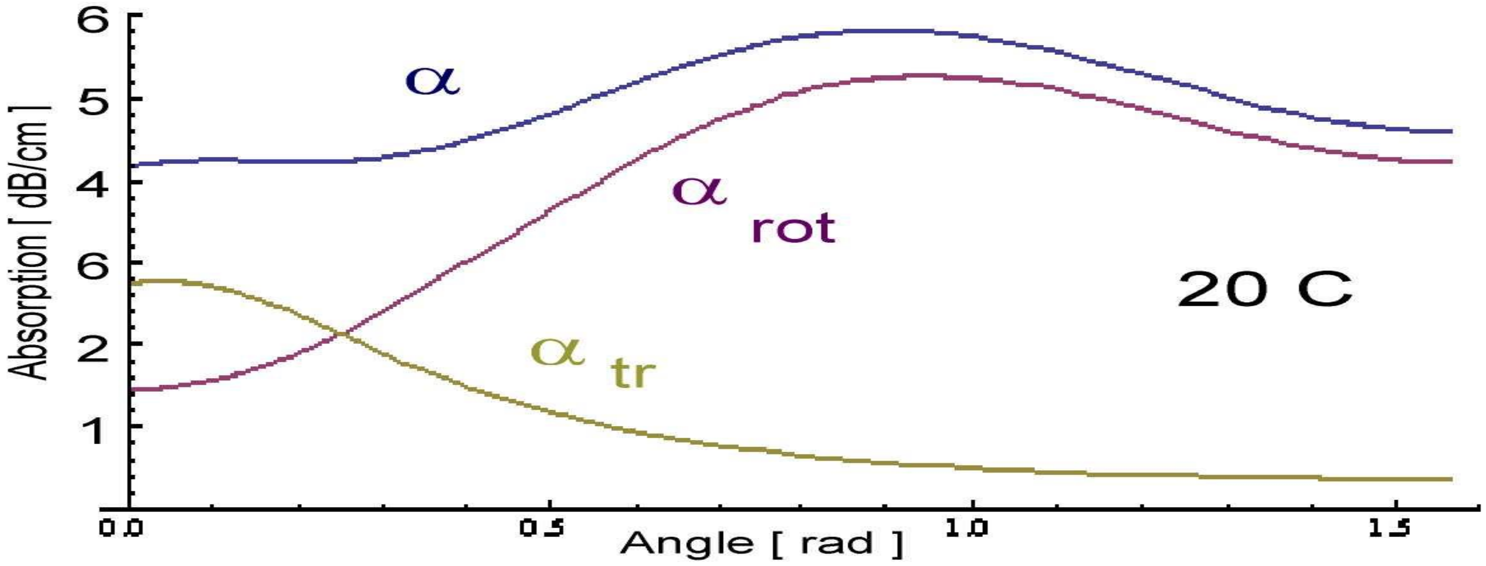
KÚDELČÍK, J. et al. *J Intel Mat Syst Stur* Vol. 27(7) p. 935-943, (IF2016 = 2.255, CC Q2)

Taketomi´s theory

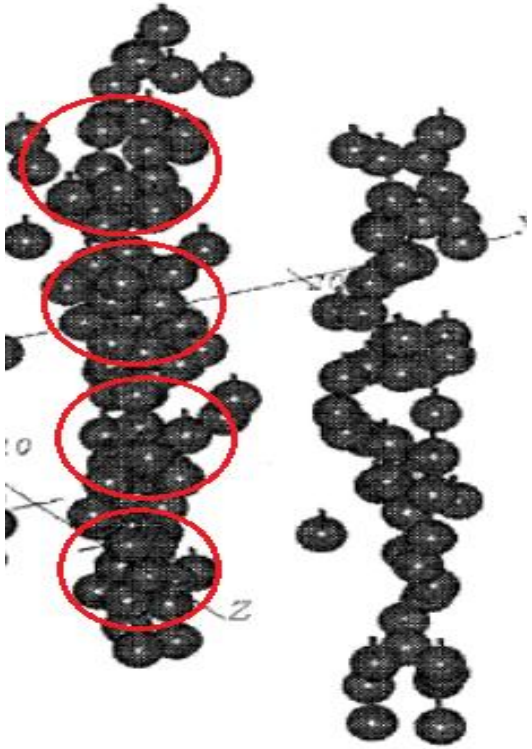
$$\alpha_{rot} = \frac{2\pi^2 f}{\rho_0 c^3}\left(\frac{4}{3}\eta + \eta_V + 2\alpha_5\cos^2\varphi + \alpha_1\cos^4\varphi\right)$$

$$\alpha_{tr} = \frac{3\pi\eta_0 a\omega^3\rho_0 V\, N\,(6\pi\eta_0 a + \rho_0 V\omega)/(k c^2)}{(\sin\varphi - \rho_m V\omega^2/k)^2 + (6\pi\eta_0 a\omega/k)^2}$$

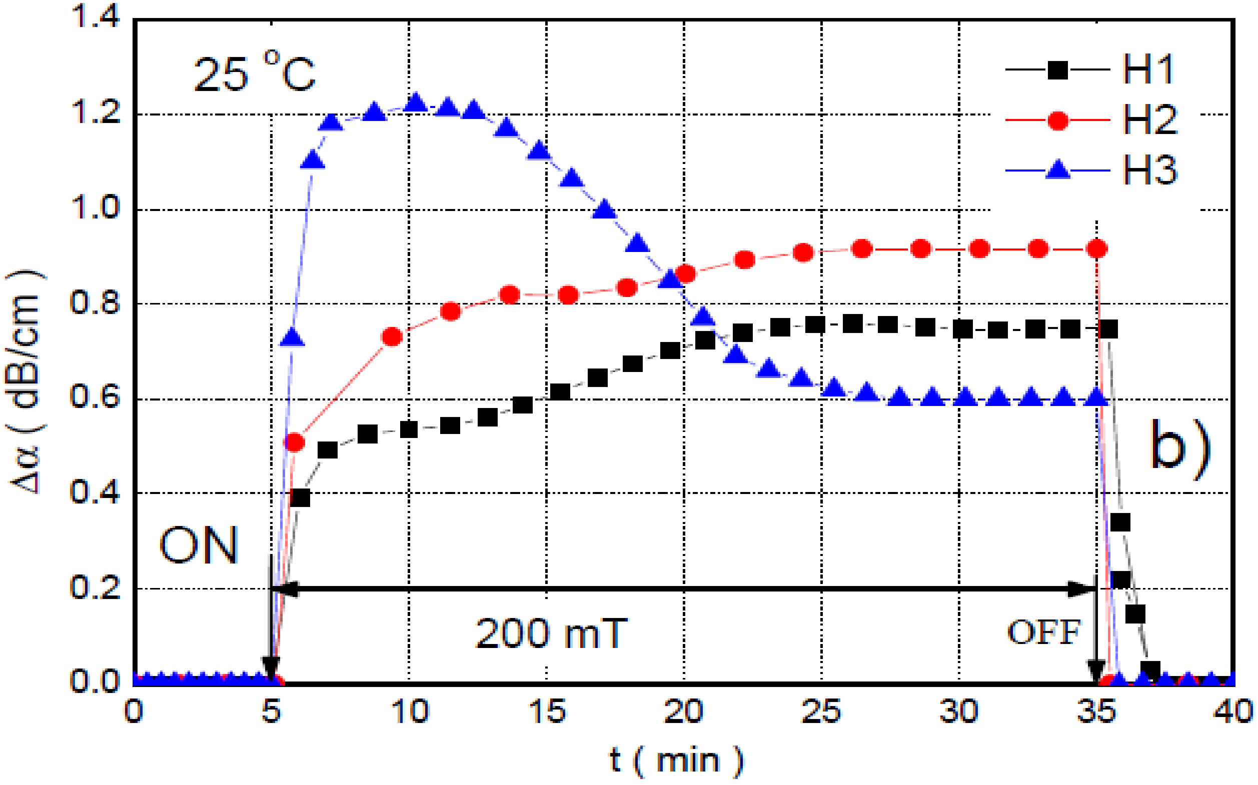




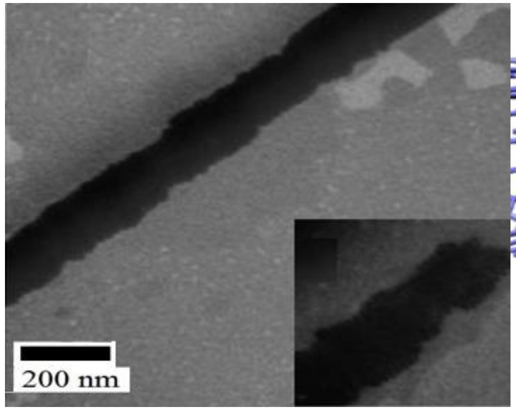
Anisotropy measurement of the acoustic attenuation (*f* = 12,6 MHz, *B* = 200 mT) in the 1% MF based MOGUL and the components α_{rot} , α_{tr} of the Taketomi functions calculated for 20 ^{0}C.

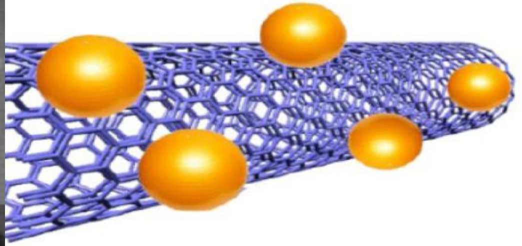


Influence of magnetic field on functionalized carbon nanotubes



Change of acoustic attenuation during a jump change of the magnetic field to 200 mT in different samples.



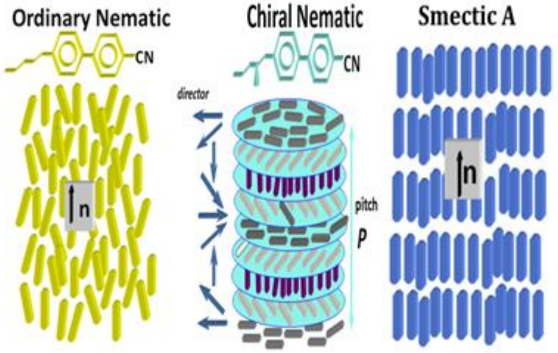


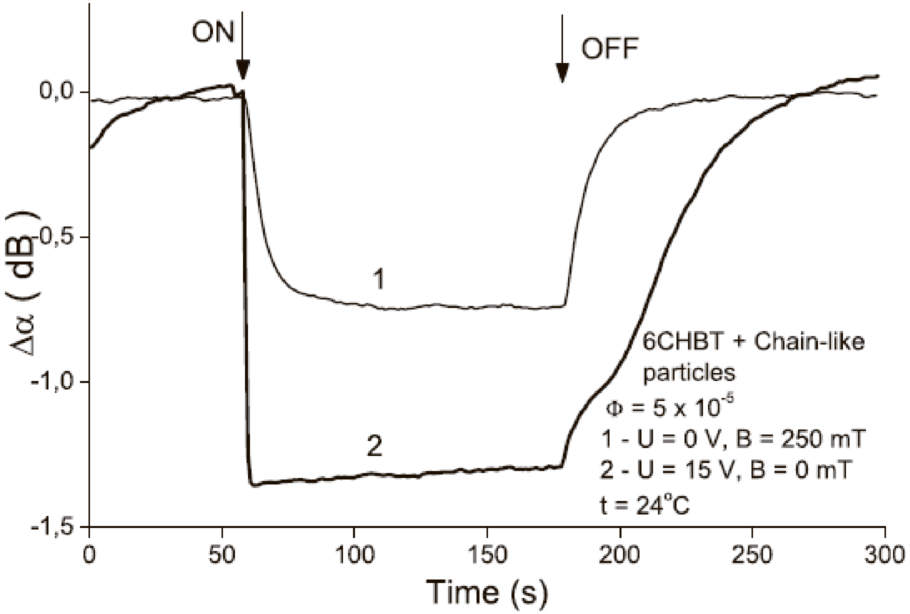
MWCNT (1μm, 20-25 nm) functionalized Fe_3O_4 magnetic nanoparticles diluted in transformer oil MOL

KÚDELČÍK, J. et al, *J Magn Magn Mat* Vol. 503 (IF2020 = 2.002, CC Q2)

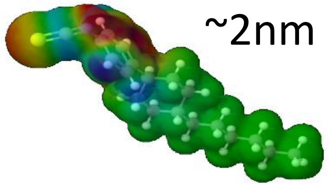
ICMF 2019

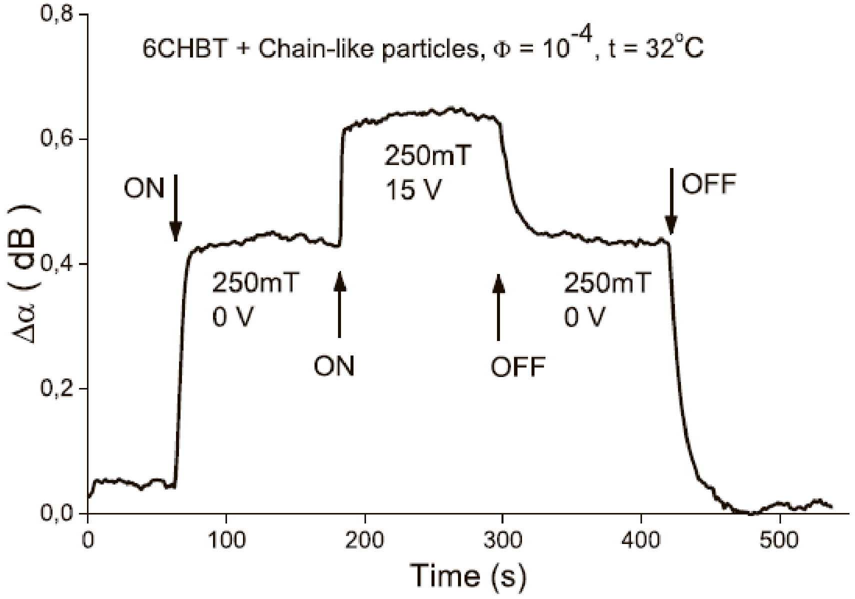
Effect of Magnetic Particles on Structural Changes and Magneto-optical Behavior of Liquid Crystal



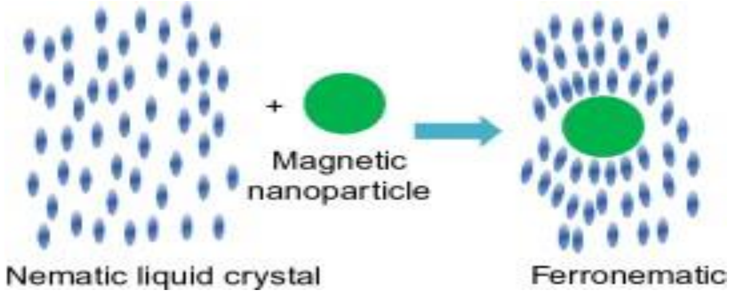


Effect of applied voltage (15 V) and magnetic field (250 mT) on SAW attenuation for doped 6CHBT.





Effect of gradual application of electric and magnetic field on SAW attenuation in doped 6CHBT



Conclusion

- the dielectric and acoustic spectroscopy
  - transformer oil and water based magnetic fluid
  - MWCNT and liqiud crystal with magnatic naoparticle Fe_3O_4
- the structural changes by the magnetic field were detected
  - stuctures ⇑ with concentration and ⇓ with temperature
  - breakdown voltage
  - magneto-dielectric effect
  - acoustic attenuation
- anisotropy measurements -- the basic parameters of structures
- at temperatures higher than 30 ^{o}C the magnetic field had minimal effect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THANK YOU FOR YOUR ATTENTION.

Acknowledgment

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