Magnetic ionogels for fluid handling in microfluidic devices

Bartosz Ziółkowski

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EUROMAT 2011

Outline

1. The need for stimuli responsive materials

2. Ionogels as scaffolds for stimulus responsive materials

3. Magnetic ionogels

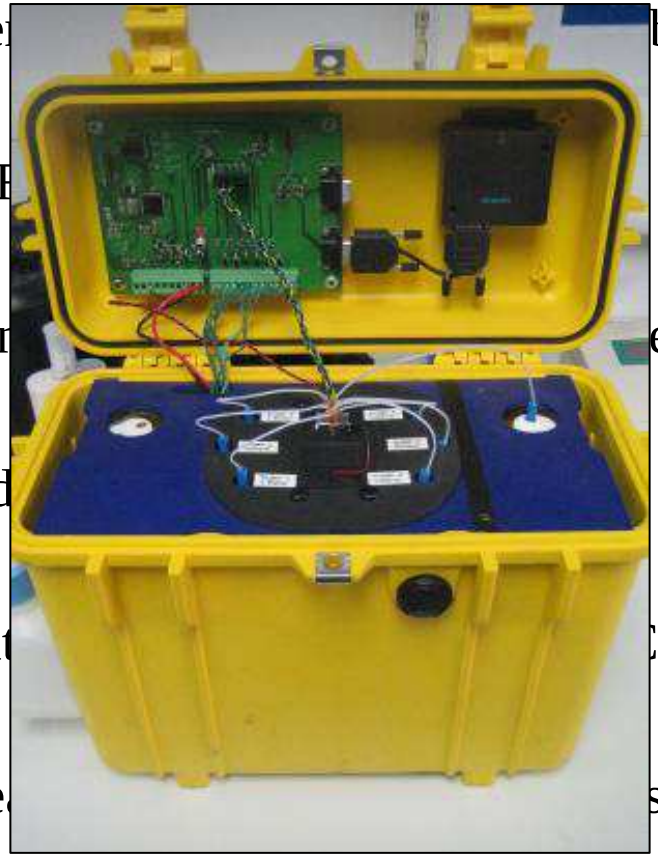
4. Future work

5. Conclusions

1. The need for stimuli responsive materials

EU wate ber

- Water E
- Environ ect
- Ground
- Integrat Con
- Europe sfe



Hazardous substances in Europe's fresh and marine waters — An overview
EEA (European Environment Agency) Technical report No 8/2011

1. The need for stimuli responsive materials

ATWARM

(**A**dvanced **T**echnologies for **WA**ter **R**esource **M**anagement)

Project 3.7

Next generation autonomous analytical platforms for remote environmental monitoring:

Microfluidic platforms incorporating stimulus responsive materials for water quality

Stimuli responsive materials

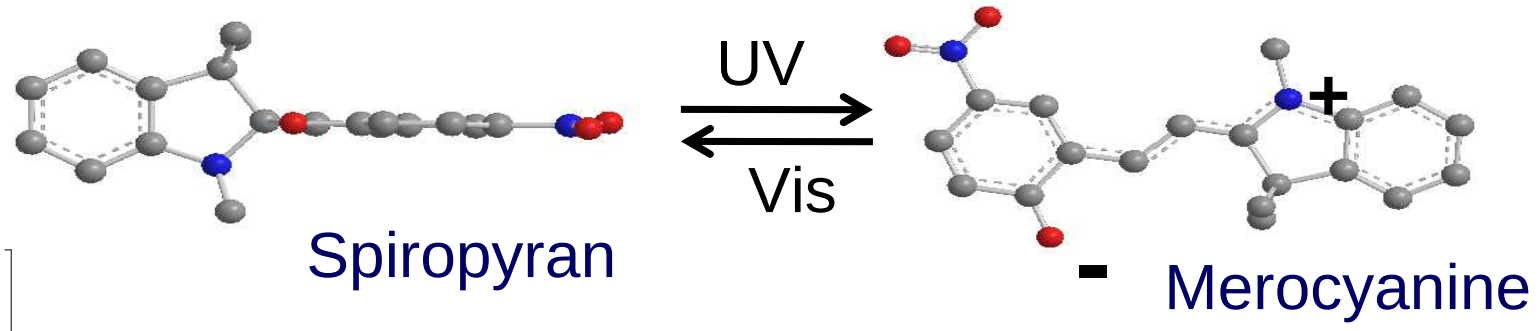
• Materials that change their properties (shape, volume, colour, stiffness, conductivity etc.)

• Stimuli includes:
  • Light
  • Electric current
  • Heat
  • Magnetic field
  • Presence of certain chemicals

• Potential for use as valves and pumps in analytical fluidic chips

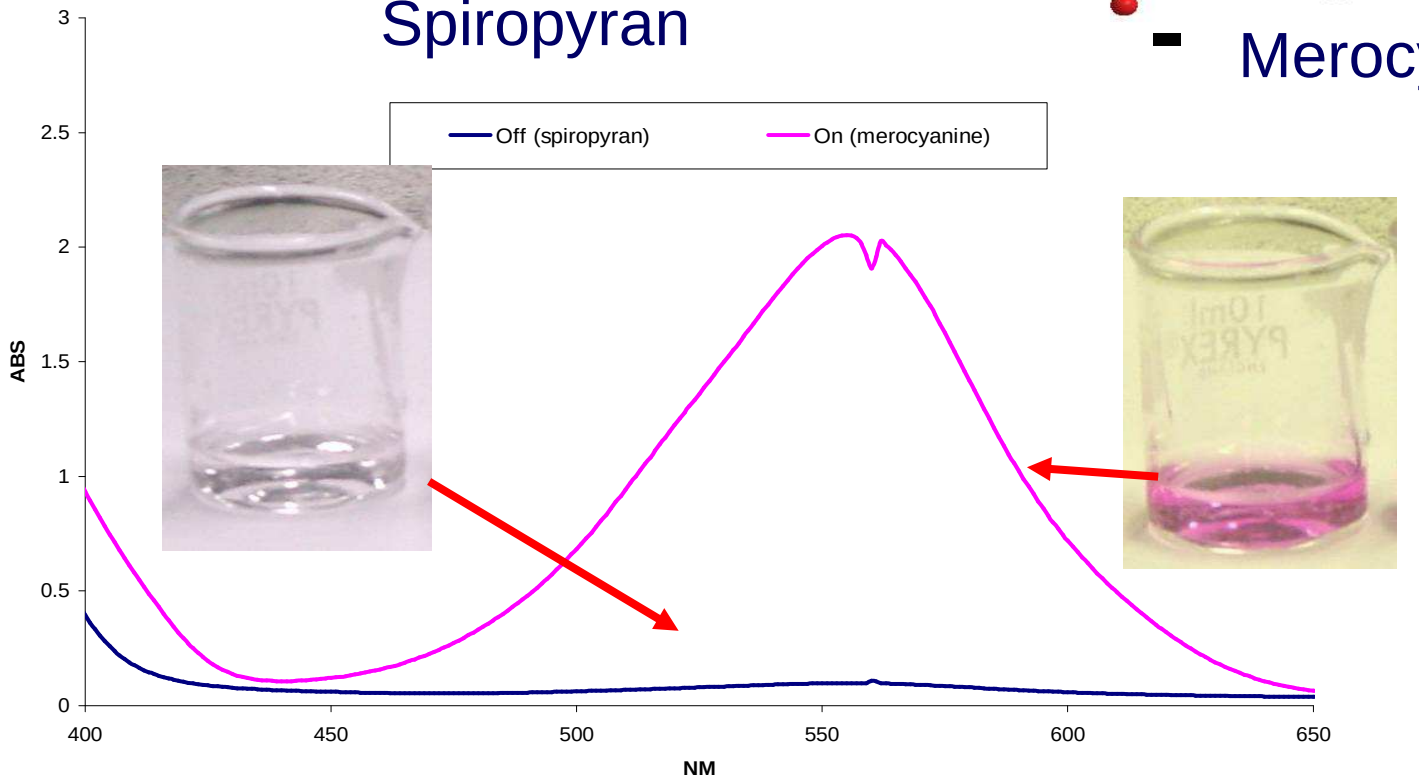
1. The need for stimuli responsive materials

Stimulus responsive materials



Spiropyran

Merocyanine



1. The need for stimuli responsive materials

Concept of ionogel

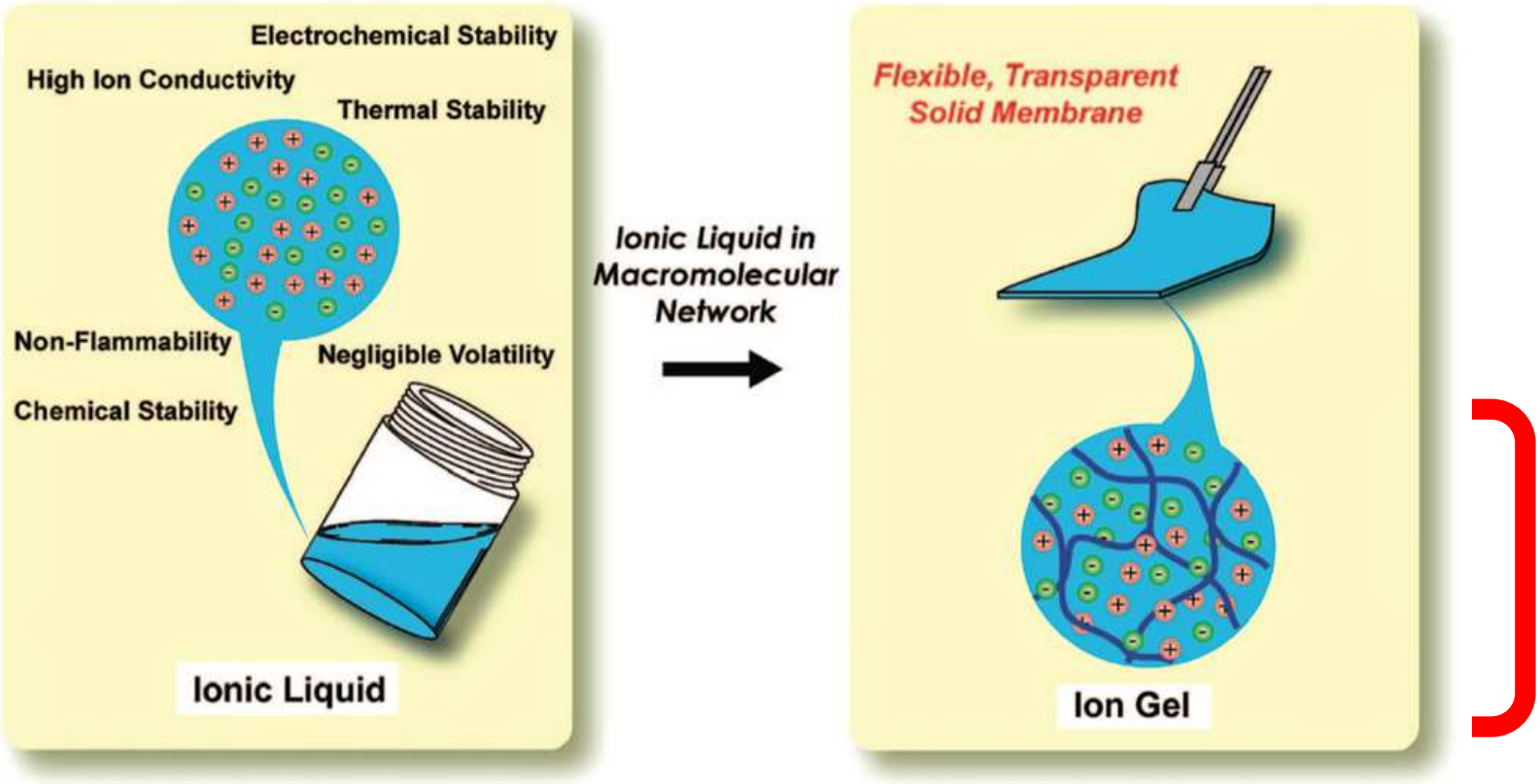
Iono

Inorg

• App

Organ

• App
micro

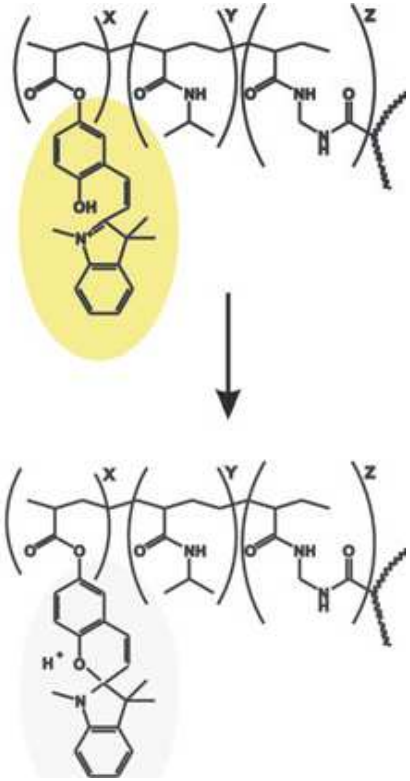


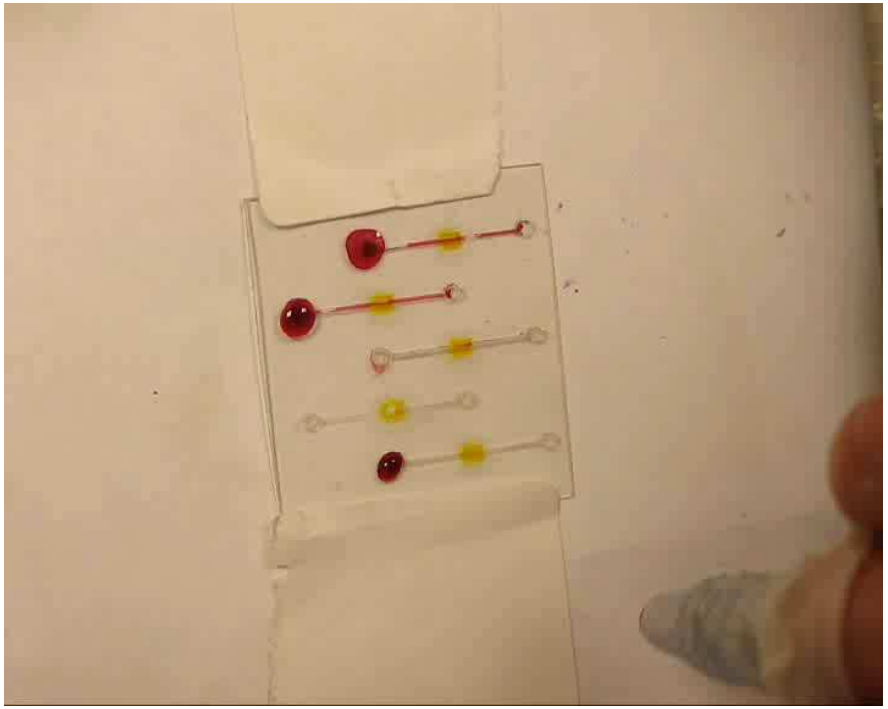
[1] M.-A. Nouze, J. L. Bideau, P. Gaveau, S. Bellayer and A. Vioux, *Chem. Mater.*, 2006, **18**, 3931-3936.

[2] T. Ueki and M. Watanabe, *Macromolecules*, 2008, **41**, 3739-3749.

1. The need for stimuli responsive materials

The combination of ionogels & stimuli responive materials

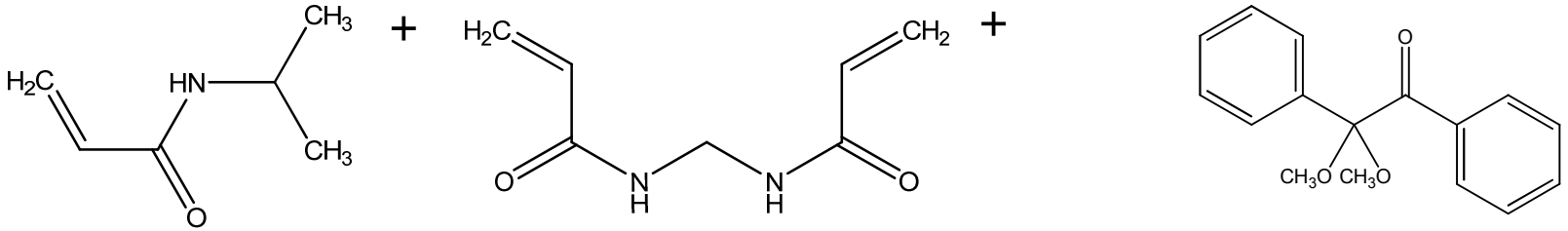




Benito-Lopez, F. *et al*. Lab on a Chip 2010, 10, 195.

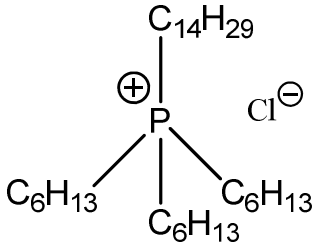
2. Ionogels as scaffolds for stimulus responsive materials

N-isopropylacrylamide + N,N'-methylenebis(acrylamide) + 2,2-Dimethoxy-2-phenylacetophenone



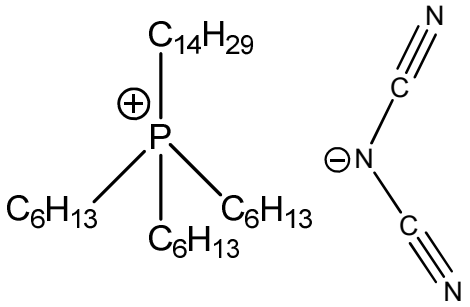
Trihexyltetradecylphosphonium chloride $[P_{6,6,6,14}][Cl]$

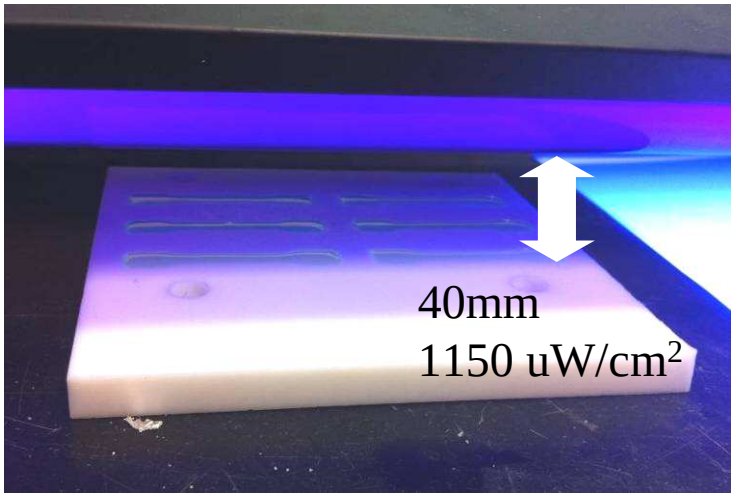
+



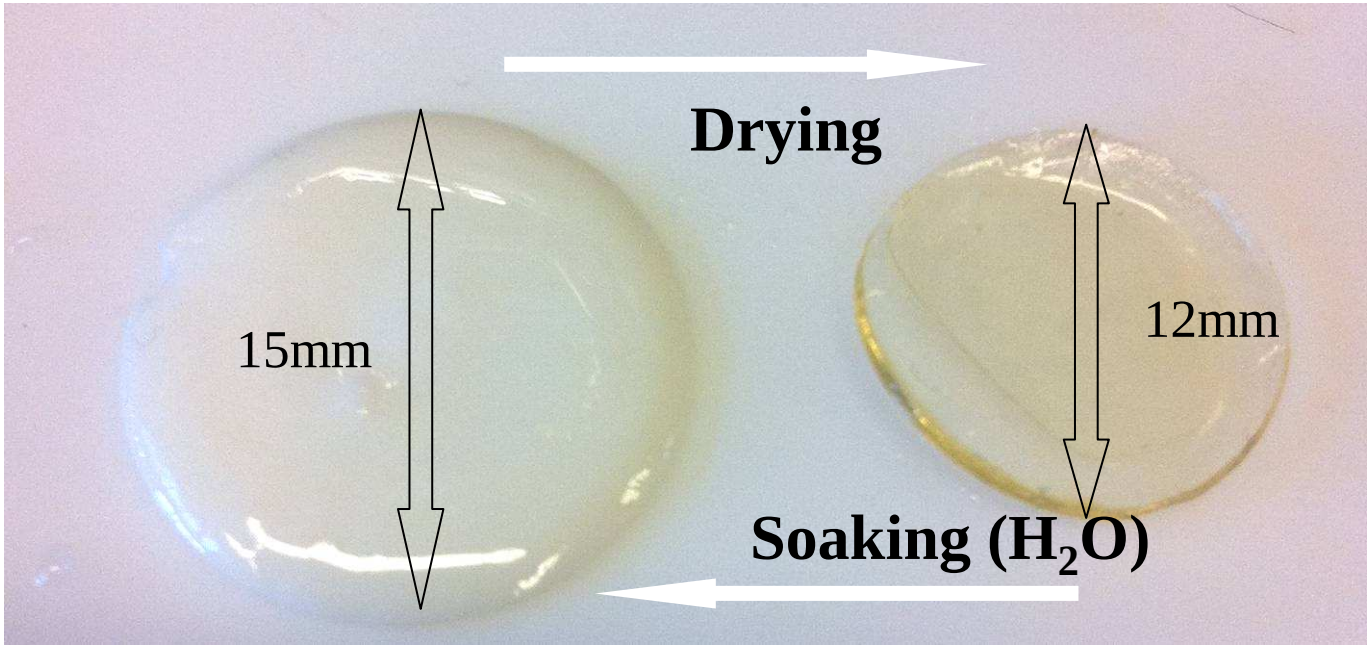
OR

Trihexyltetradecylphosphonium dicyanamide $[P_{6,6,6,14}][DCA]$





2. Ionogels as scaffolds for stimulus responsive materials

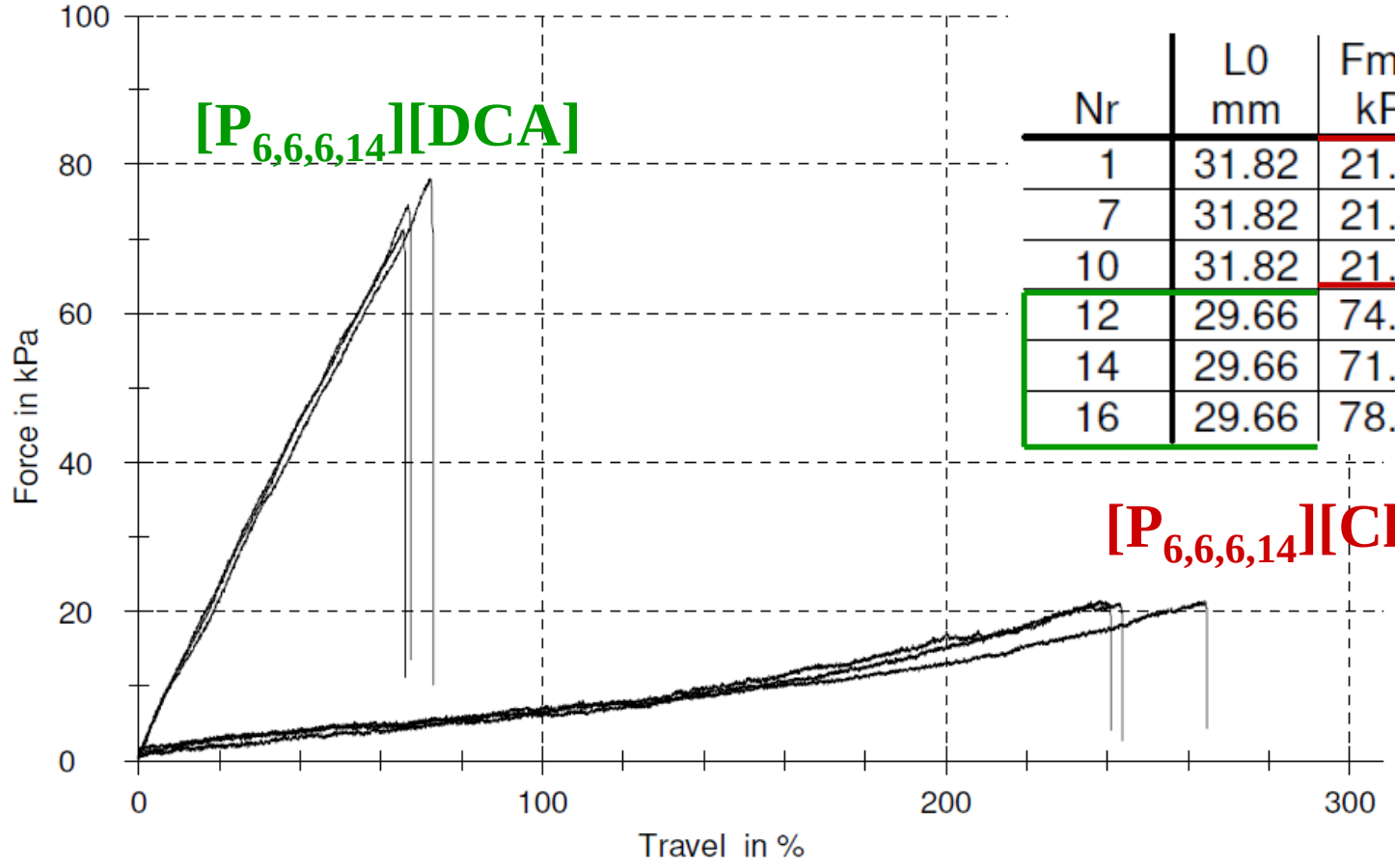


[$P_{6,6,6,14}$][DCA] - pNIPAM ionogels:

- ***Do not dry out completely – remain flexible***
- ***Do not leach in water – hydrophobic IL contained***
- ***Retain pNIPAM's LCST properties***

2. Ionogels as scaffolds for stimulus responsive materials

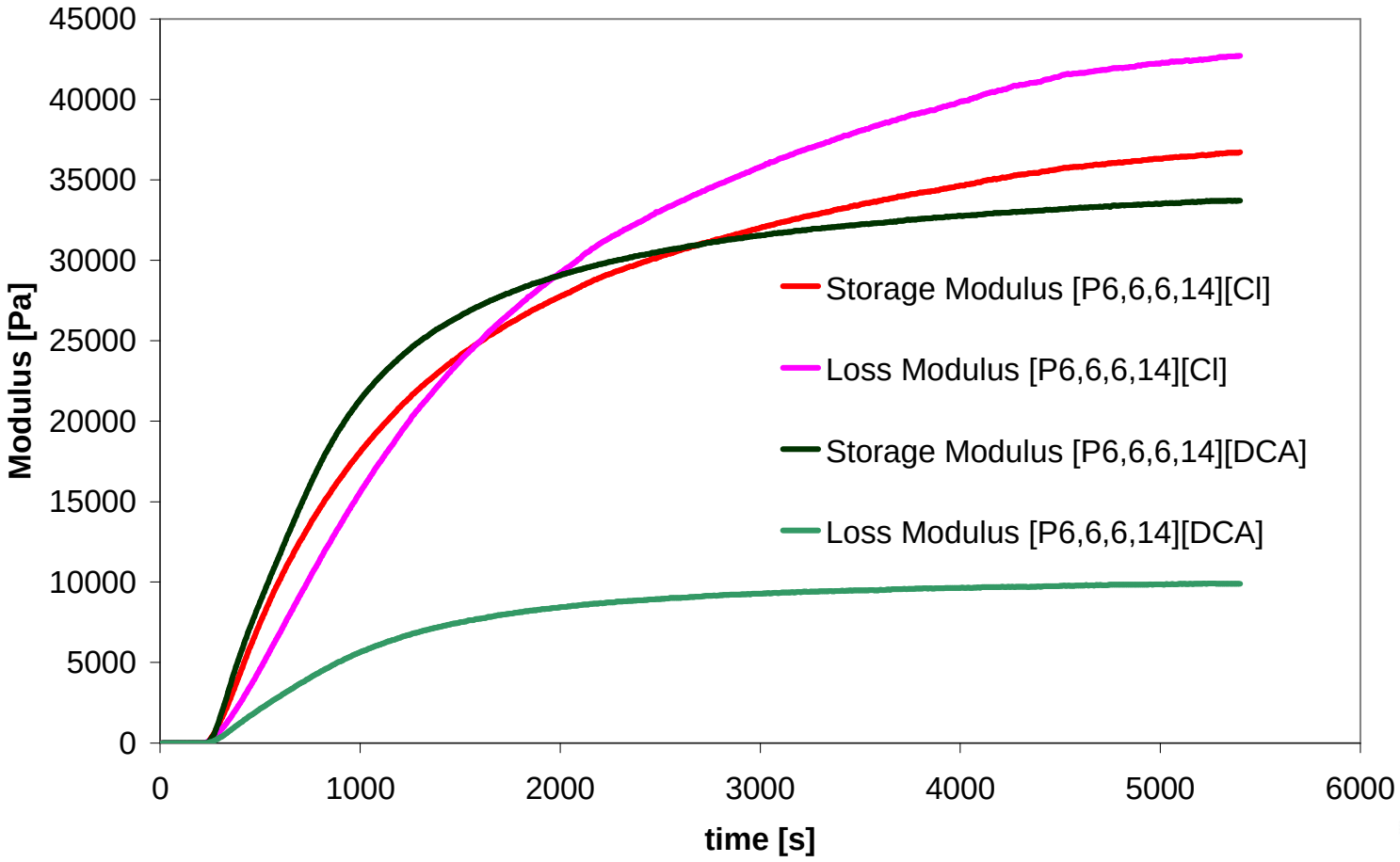
Tuning the flexibility of ionogels with IL anions



Nr	L0 mm	Fmax kPa	L at Fmax %
1	31.82	21.29	235.80
7	31.82	21.43	238.00
10	31.82	21.40	264.10
12	29.66	74.53	66.65
14	29.66	71.19	65.49
16	29.66	78.10	72.35

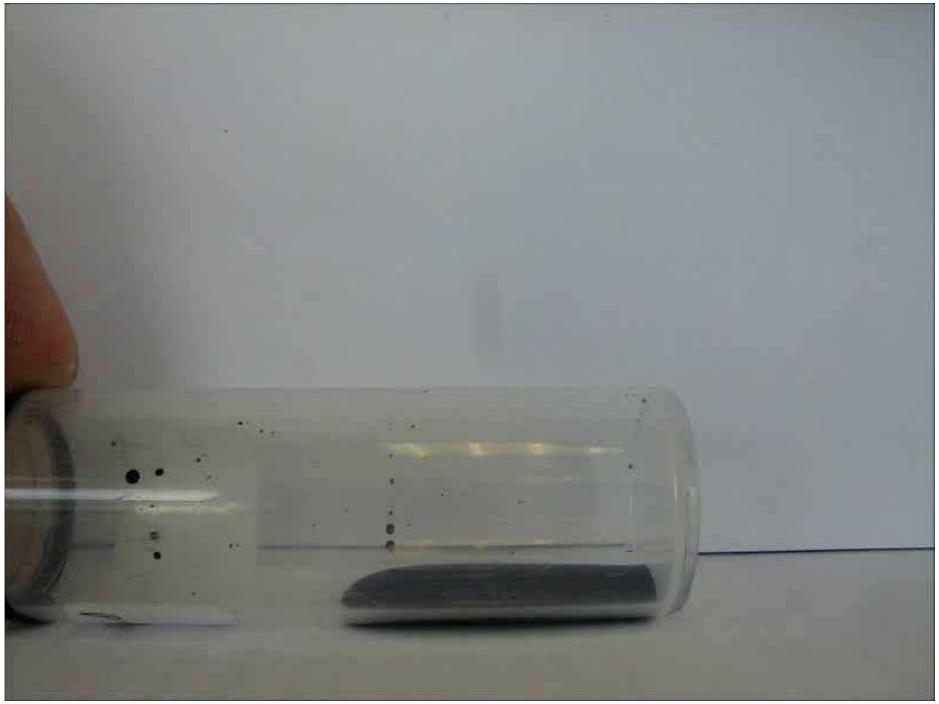
2. Ionogels as scaffolds for stimulus responsive materials

Curing characteristics of ionogels with different IL anions



3. Magnetic ionogels:

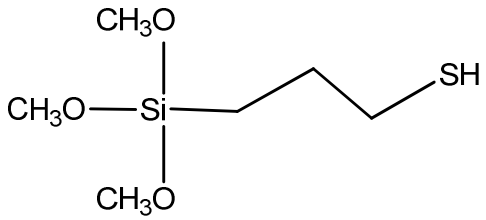
Another non-invasive stimulus
Magnetic field



3. Magnetic ionogels:

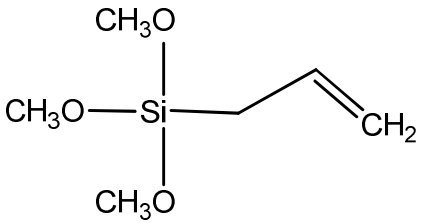
Linking the inorganic Fe_3O_4 with the ionogel network

(3-mercaptopropyl)trimethoxysilane

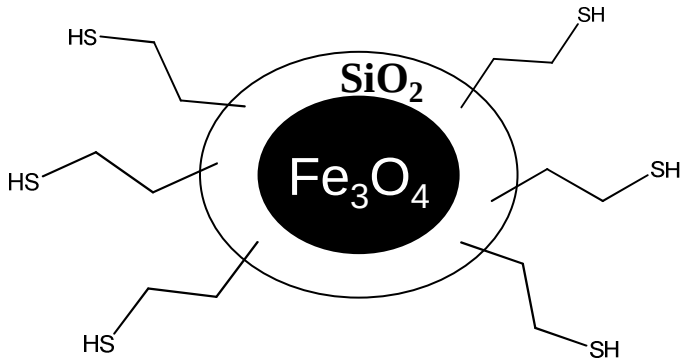


OR

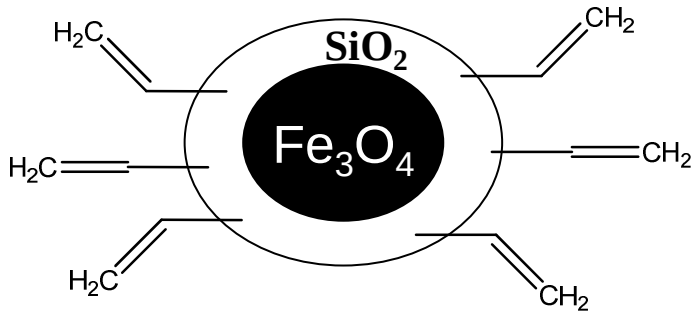
Allyltrimethoxysilane



+ Fe_3O_4



OR



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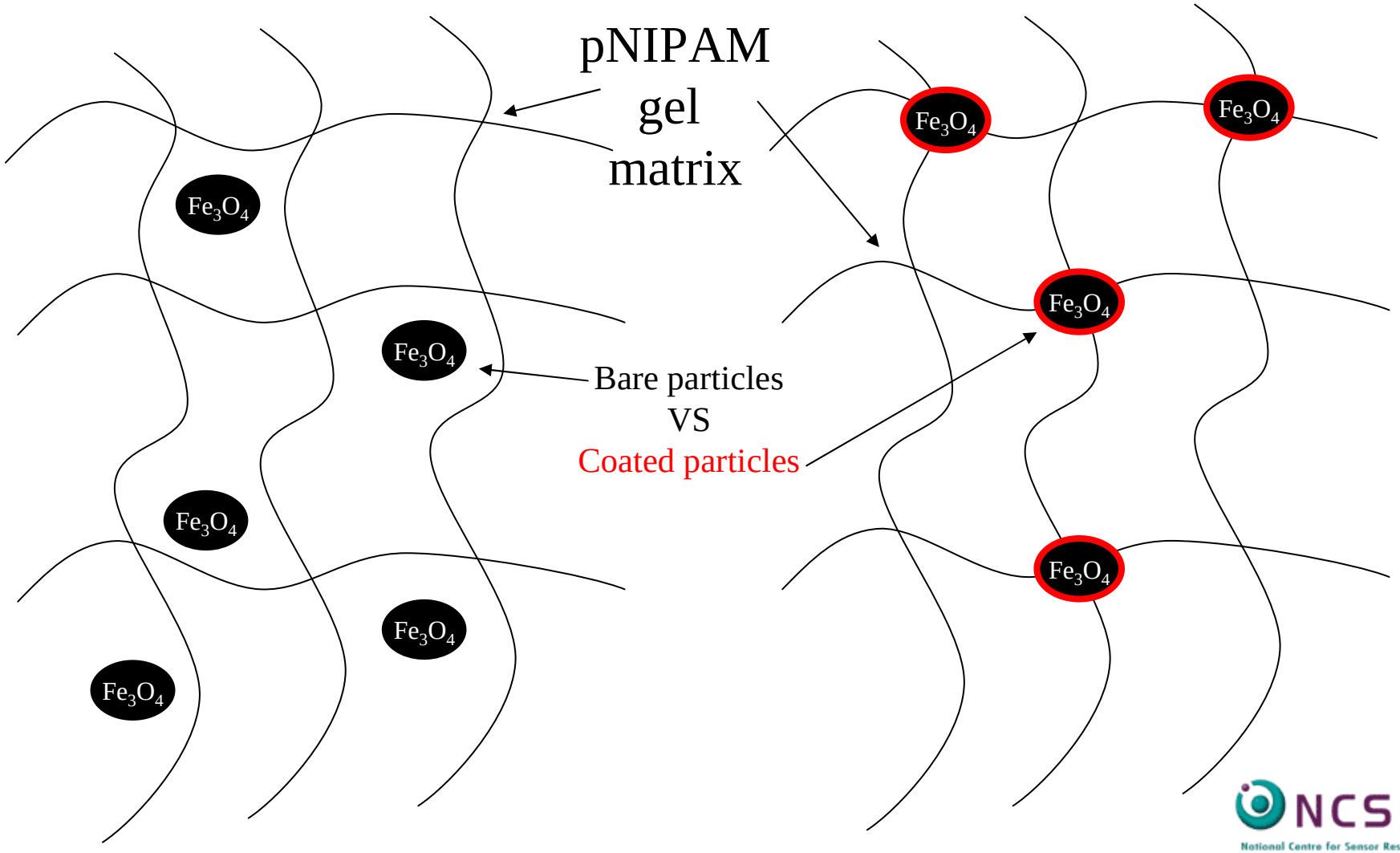
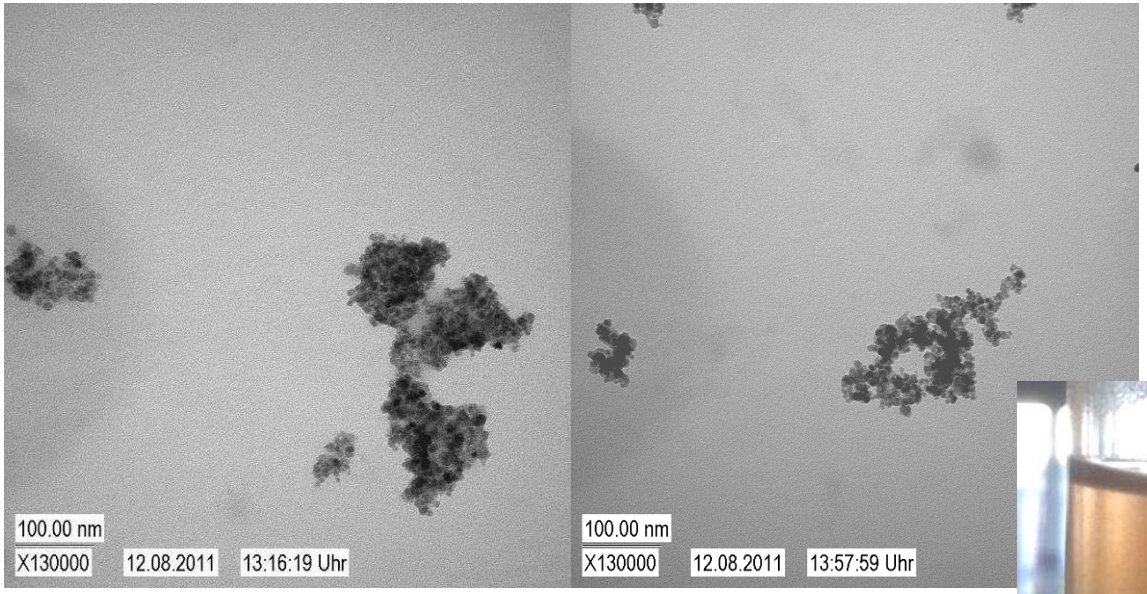


3. Magnetic ionogels:

Preliminary results – the particles

TEM picture of the magnetic nanoparticles coated with MPTMS (left) & ATMS (right)



Left: bare Fe_3O_4 in acetone
Right: MPTMS coated Fe_3O_4 in acetone

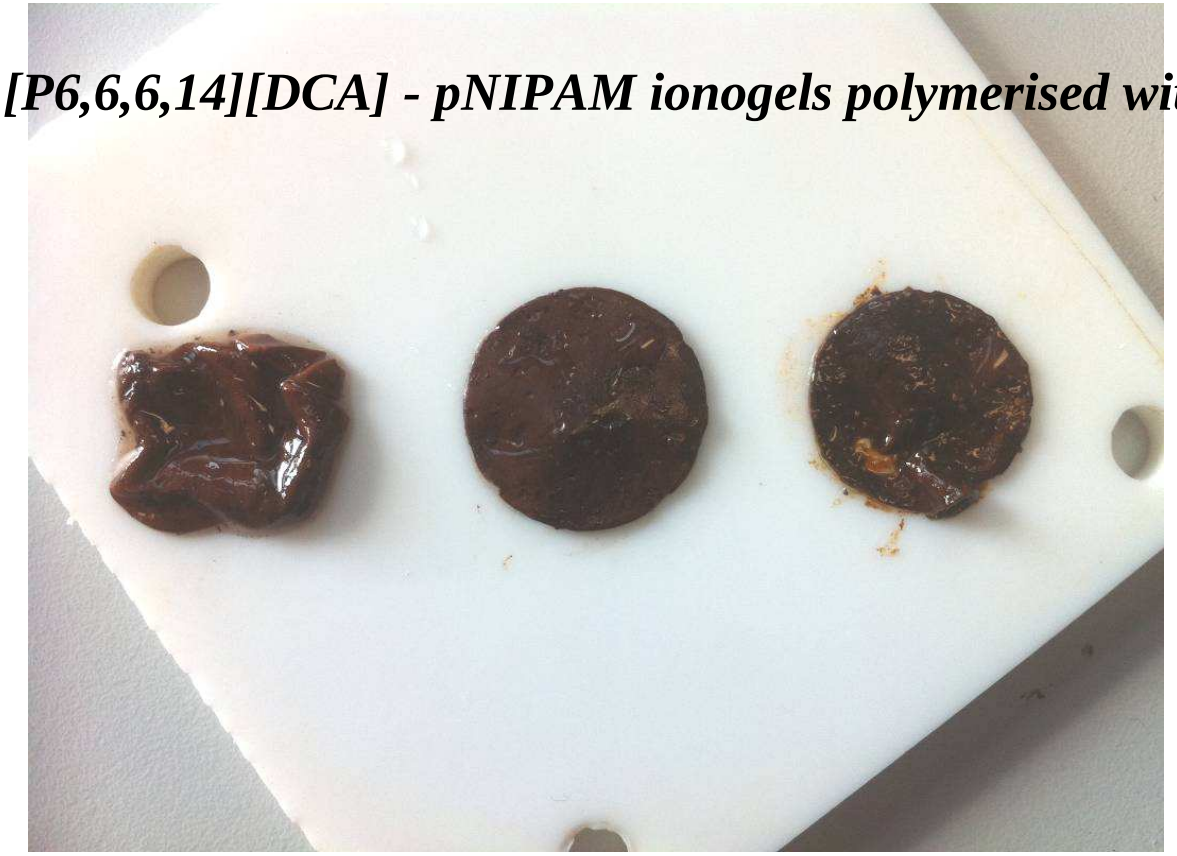
Table 1. Dynamic light scattering analysis of functionalised nanoparticles. Their sizes and size distributions.

	MPTMS@F_3O_4	ATMS@Fe_3O_4
DLS intensity peak [nm]	261	172
PDI [nm]	108	70

3. Magnetic ionogels:

Preliminary results – Ionogels

[P6,6,6,14][DCA] - pNIPAM ionogels polymerised with:

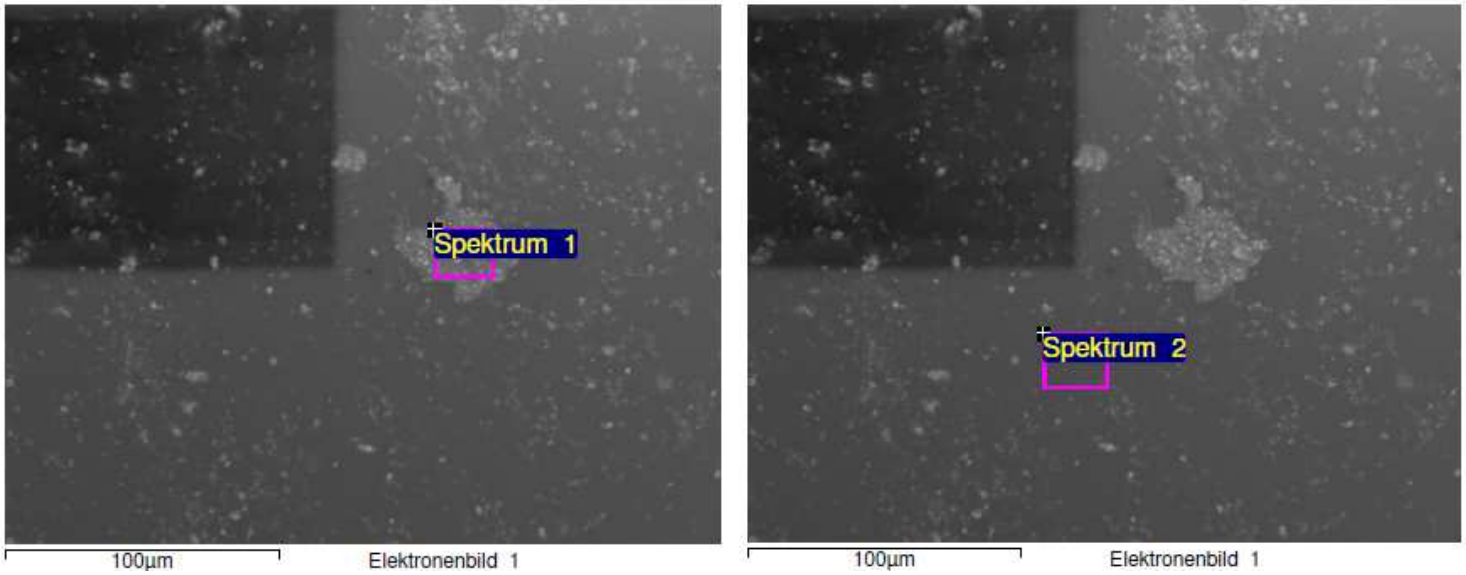


Left: bare Fe_3O_4 Middle: MPTMS coated Fe_3O_4 Right: ATMS coated Fe_3O_4

(20%wt in all)

3. Magnetic ionogels:

EDX analysis

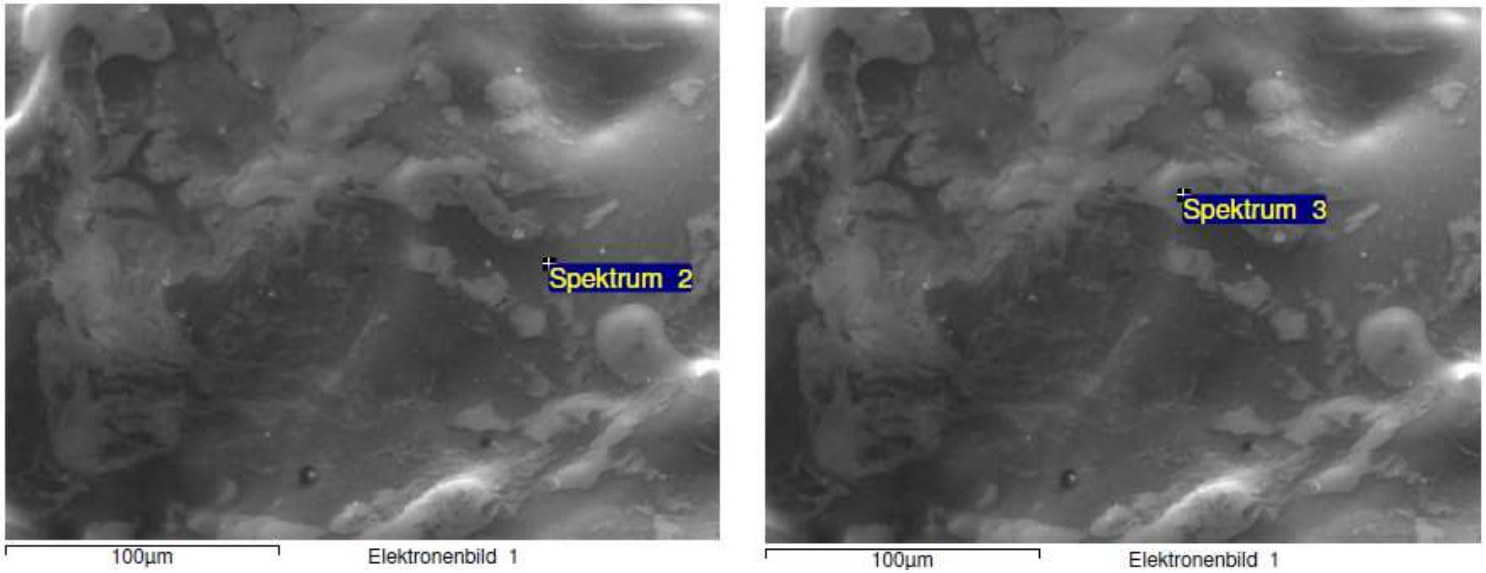


$[P_{6,6,6,14}][DCA]$ - pNIPAM ionogel polymerised with bare Fe_3O_4
Left: 25%Fe, 14%P
Right: 1%Fe, 27%P

Bare particles phase-separate in the final material

3. Magnetic ionogels:

EDX analysis



[$P_{6,6,6,14}$][DCA] - pNIPAM ionogel polymerised with ATMS coated Fe_3O_4
Left: 25%Fe, 14%P
Right: 36%Fe, 6%P

Coated particles do not phase separate

3. Magnetic ionogels:

Preliminary results – magnetic actuation of the polymer

4. Future work

- Optimisation of the organosilicon coating process of magnetite

- Mechanical analysis (rheometry) to determine the copolymerisation of particles

- Magnetic analysis of ionogels to determine their susceptibility to magnetic fields

- Integrating this composite material into microfluidic manifolds and demonstrating a working valve and a working pump

5. Conclusions

- Water resource management needs new technologies for water monitoring
- Smart - stimulus responsive materials can revolutionise sampling and analysis
- Ionogels – functional polymeric sponges filled with a non-volatile IL
- Photo-actuated ionogels can work as low-power microfluidic valves
- ILs impact the ionogel's curing and stiffness
- Magnetic field is another very attractive, non-invasive actuation method
- Magnetic nanoparticles can be coated with polymer linker organosilicon groups
  - Increased ionogel durability
  - Increased compatibility between the polymer and the particles
  - Reversible bending in non-uniform magnetic fields achieved

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