

Velev Research Group

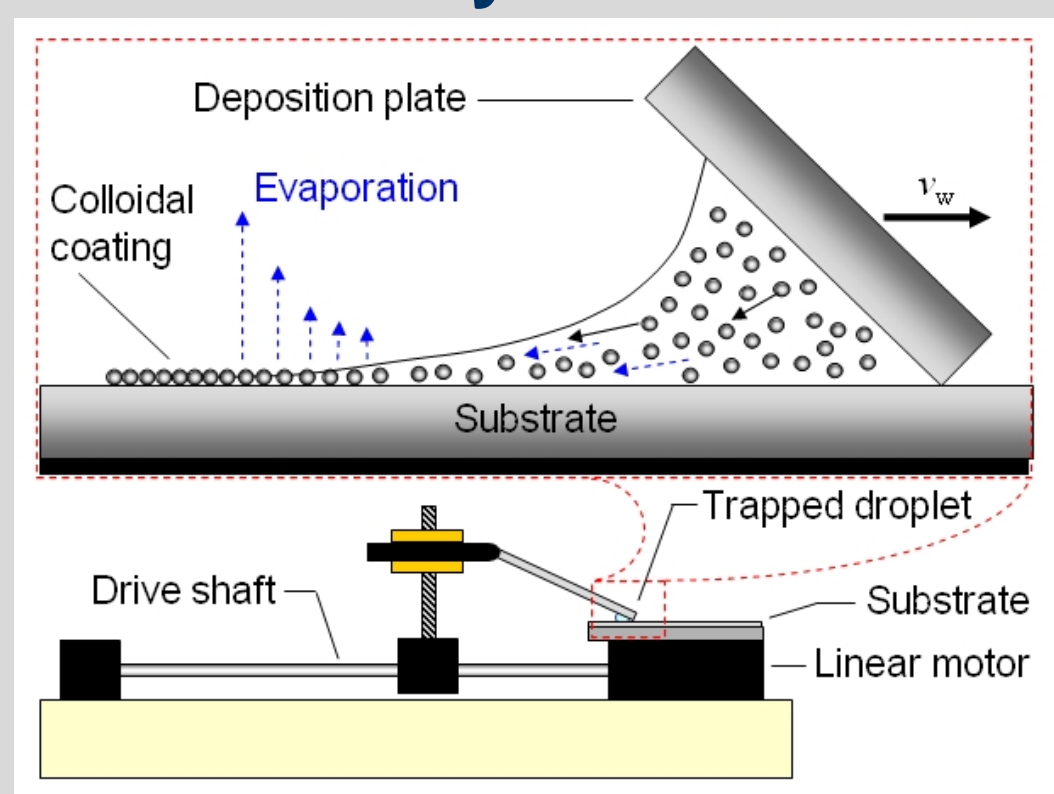
Department of Chemical & Biomolecular Engineering, North Carolina State University

<http://www.che.ncsu.edu/velevgroup/>



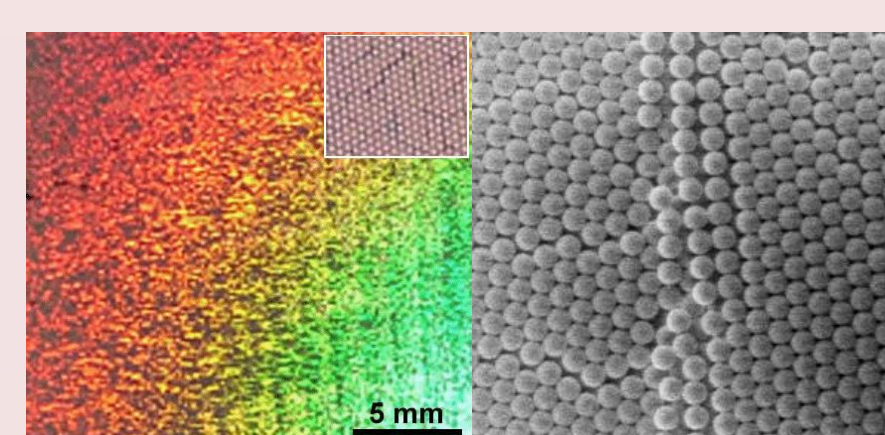
Novel nanocolloidal materials

Continuous convective assembly of colloids

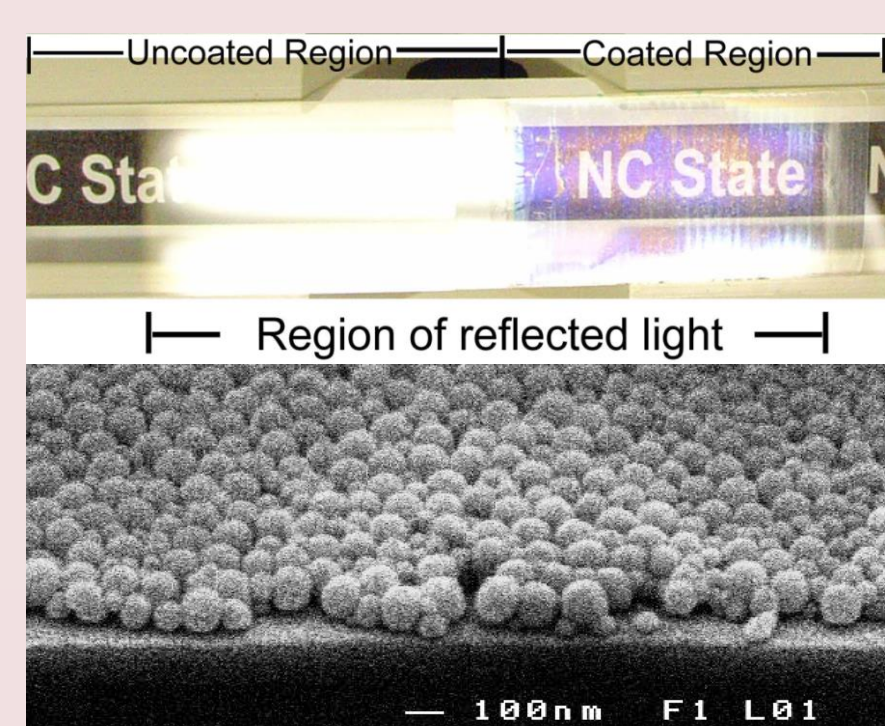


Convective assembly allows rapid controlled deposition of particle nanocoatings (Velev et al.)

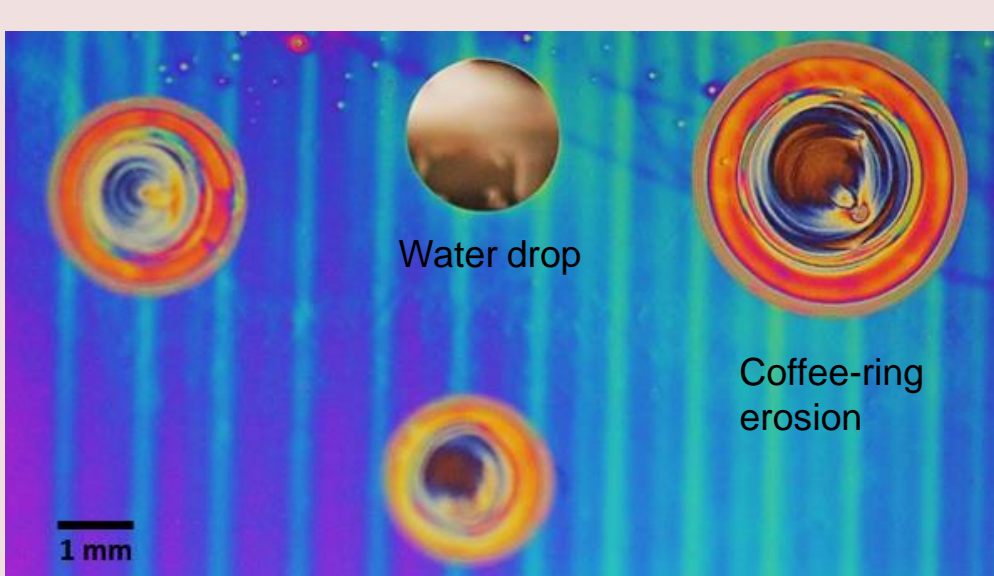
Engineered deposition of functional nanocoatings



Latex colloidal crystals deposited in an engineered film
Prevo et al. *Langmuir* (2004)

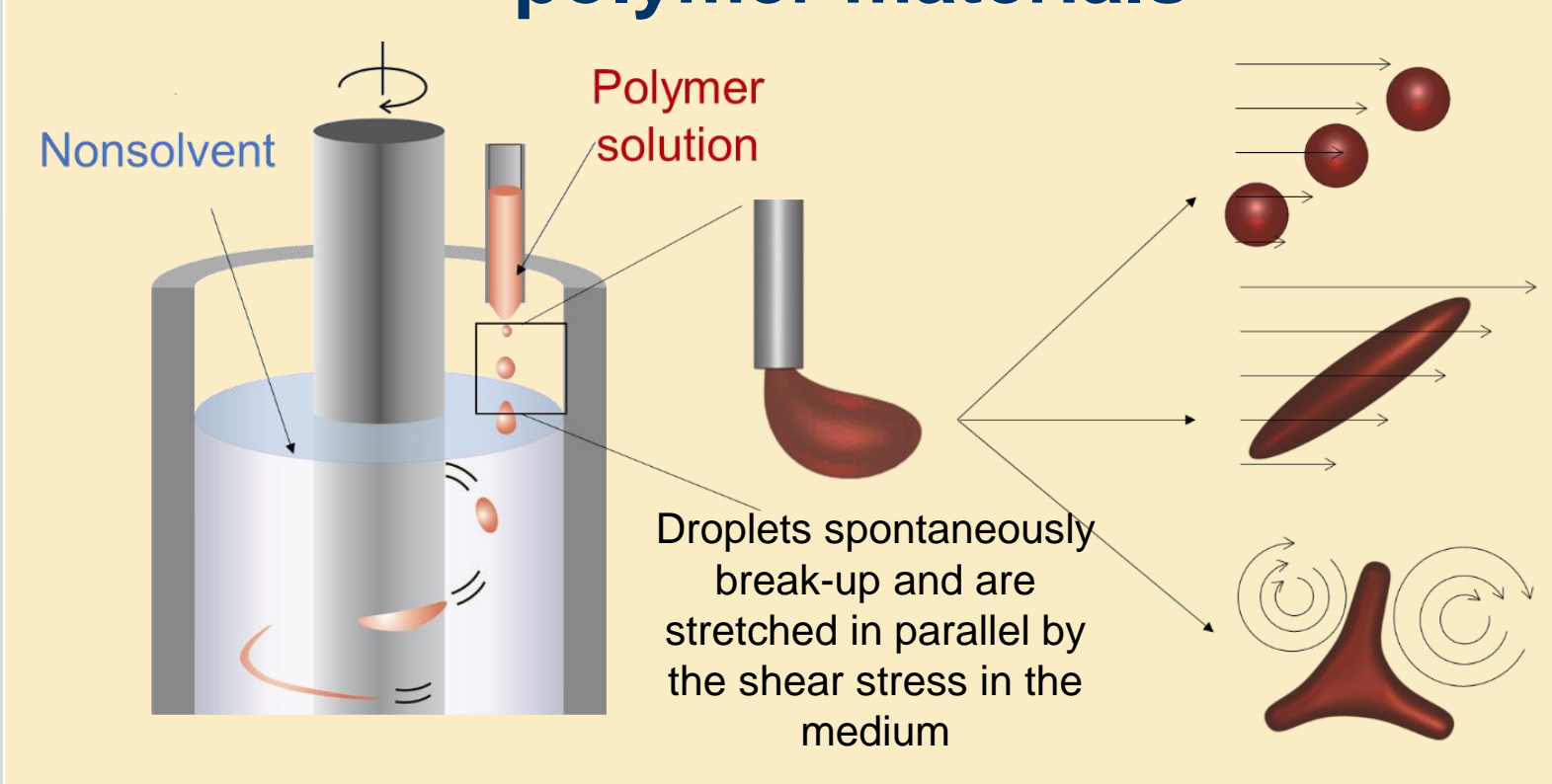


Antireflective coatings of colloidal silica
Prevo et al. *J. Mater. Chem.* (2007)
Prevo et al. *Chem. Mater.* (2005)

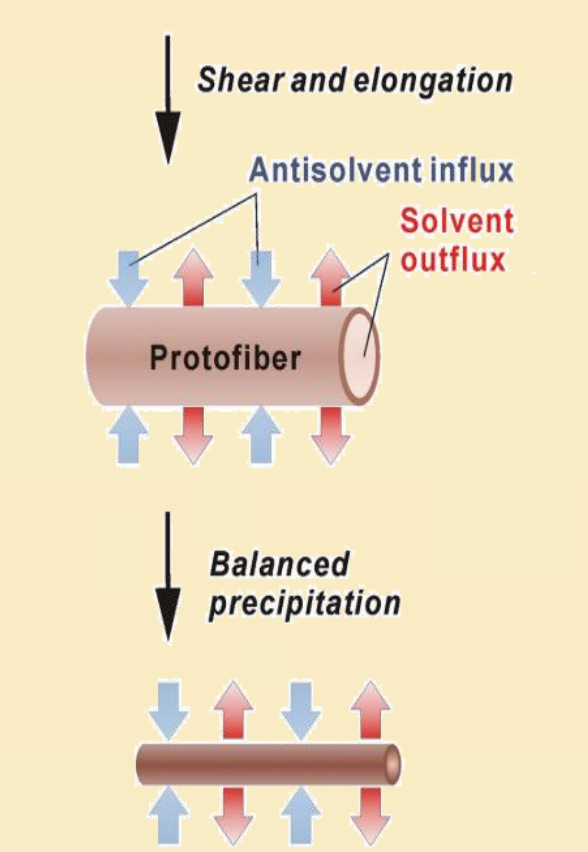


Coffee-ring evolution as a tool to understand water-resistance of polymer nanofilms
Islam et al. *Soft Matter* (2018)

Liquid-shear fabrication of nanofibrous polymer materials



Laminar Nonsolvent Flow

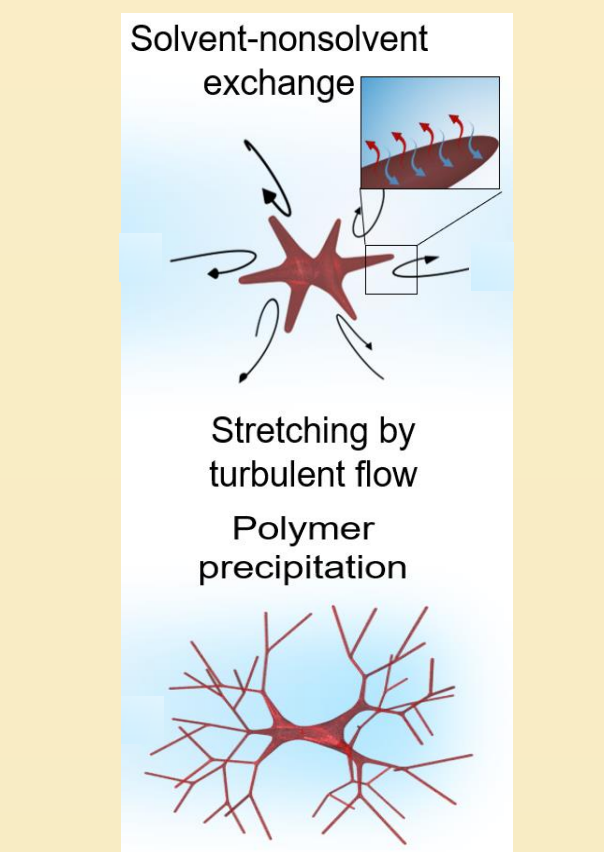


Nanofibers

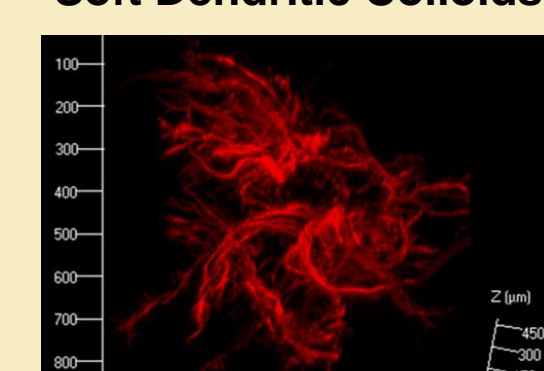


Smukov et al. *Adv. Mater.* 2015
Velev and Roh, US Patents

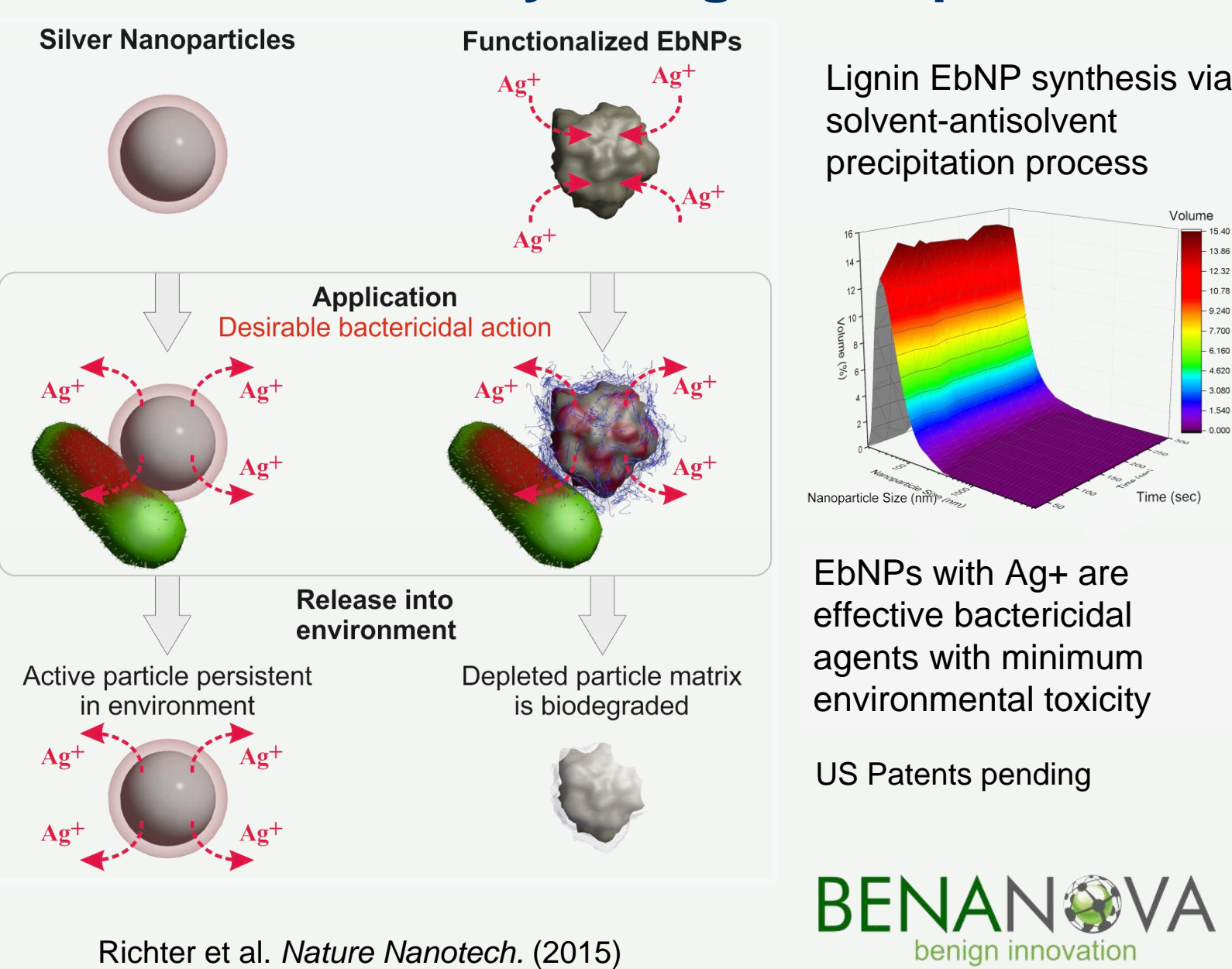
Turbulent Nonsolvent Flow



Soft Dendritic Colloids



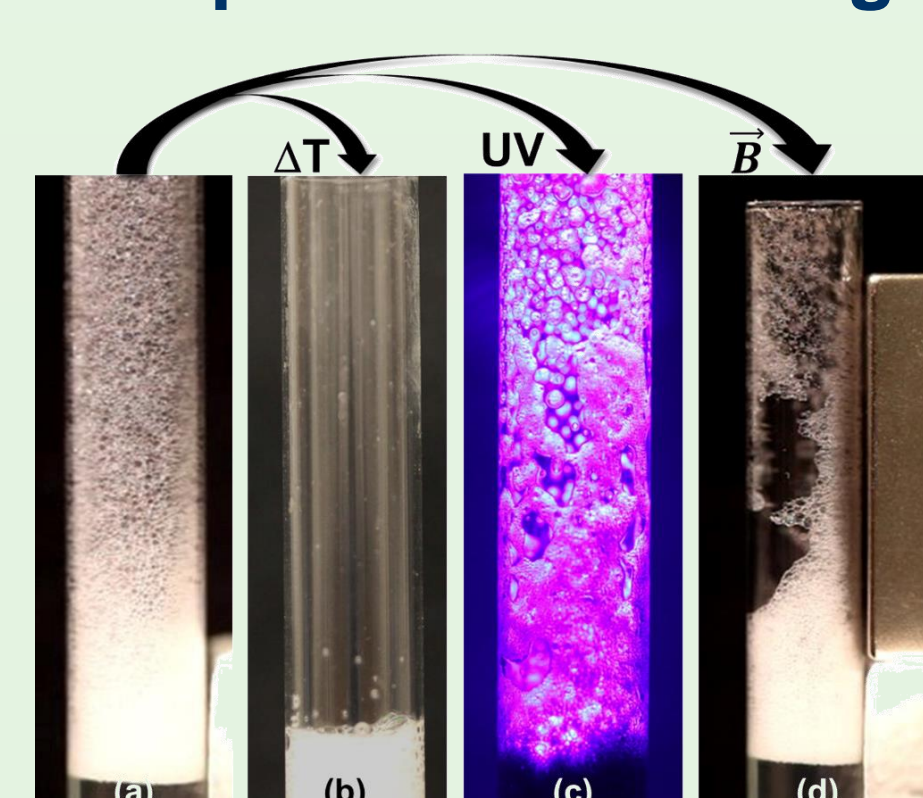
Environmentally-benign nanoparticles



Richter et al. *Nature Nanotech.* (2015)

BENANOVA
benign innovation

Multiresponsive Pickering foam

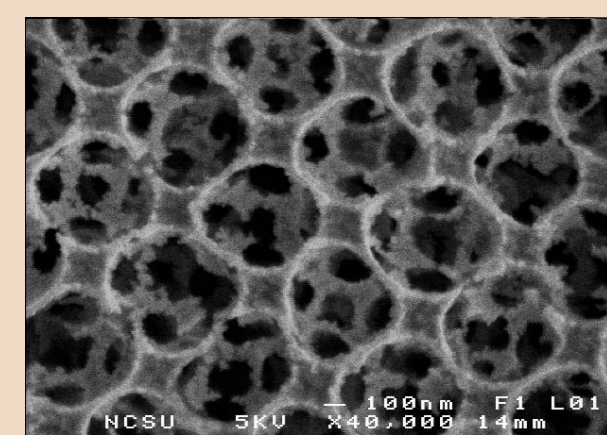


Multi-stimuli responsive foams combining particles and self-assembling fatty acids

Lam et al. *J. Am. Chem. Soc.* (2011)
Fameau et al. *Chem. Sci.* (2013)

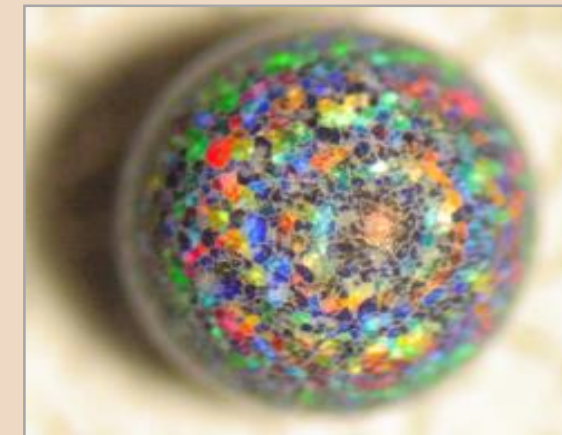
Advanced microparticles and microcapsules

SERS bio- and chemical sensors



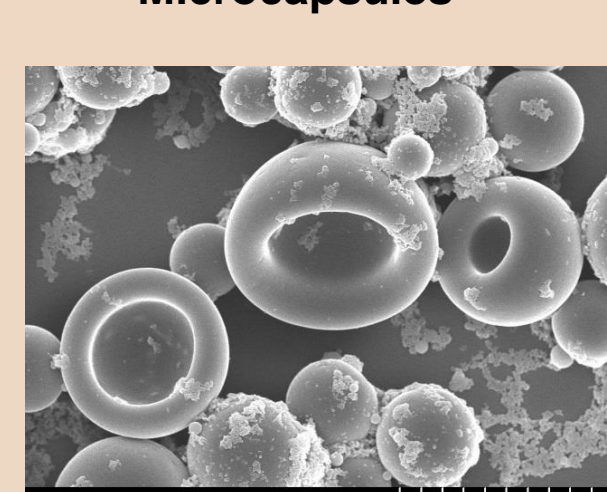
Kuncicky et al., *J. Mater. Chem.* (2006)

Light-diffracting supraparticles



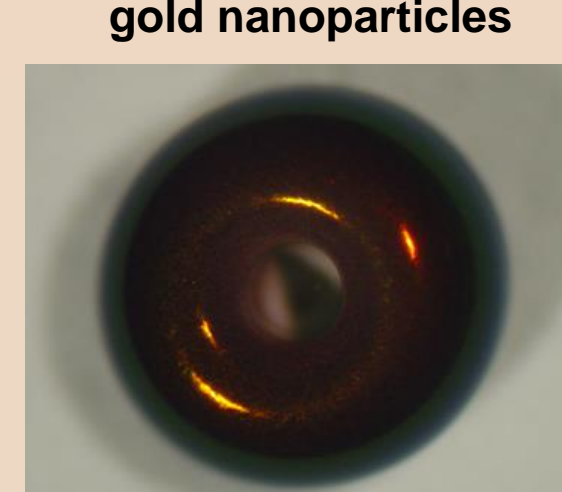
Rastogi et al., *Adv. Mater.* (2008)

Microcapsules



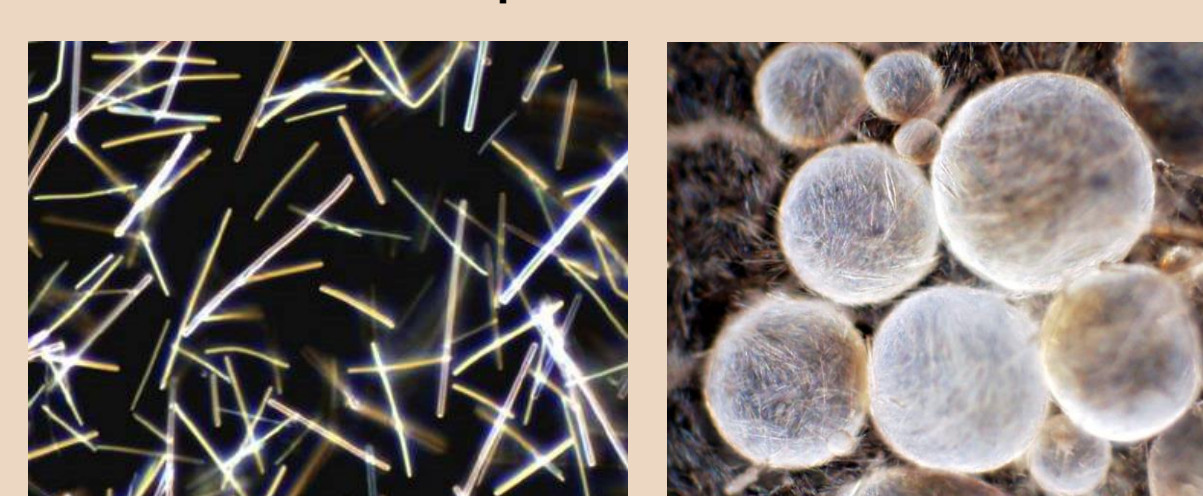
Koo et al. *Chem. Mater.* (2006)

Doughnuts from silica and gold nanoparticles



Rastogi et al., *Macromol. Rapid Commun.* (2010)

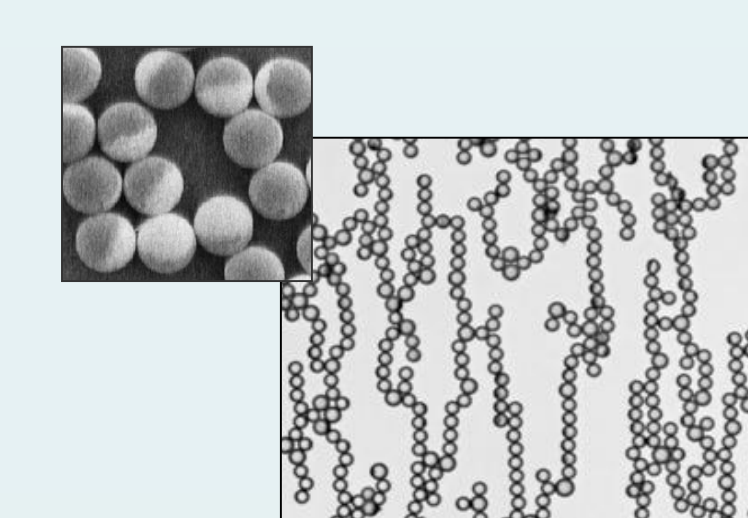
Polymer microrods, foam and emulsion superstabilization



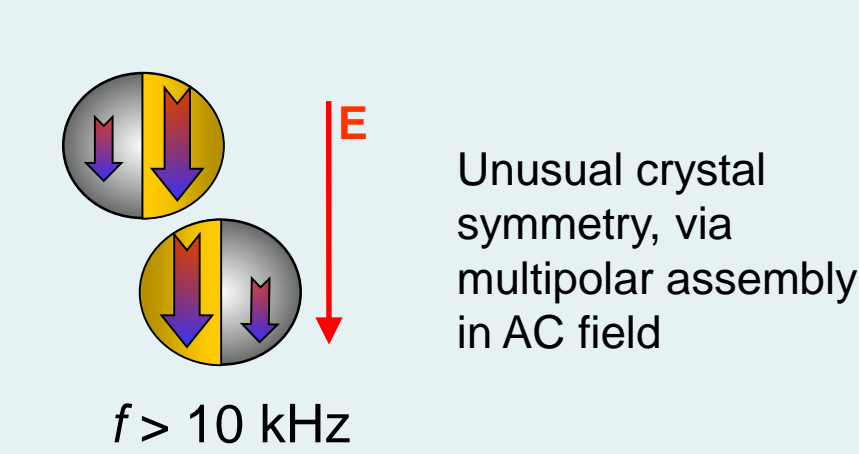
Alargova et al., *Adv. Mater.* (2004)
Alargova et al., *Langmuir* (2004), *Langmuir* (2006)

Functional active nanosystems

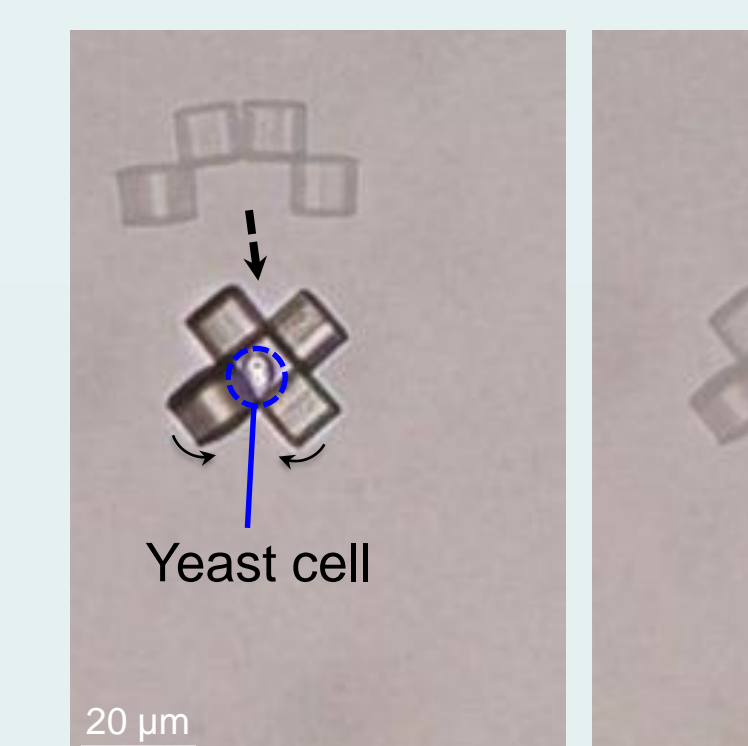
Anisotropic particles in external fields



Janus particles in high frequency AC electric field



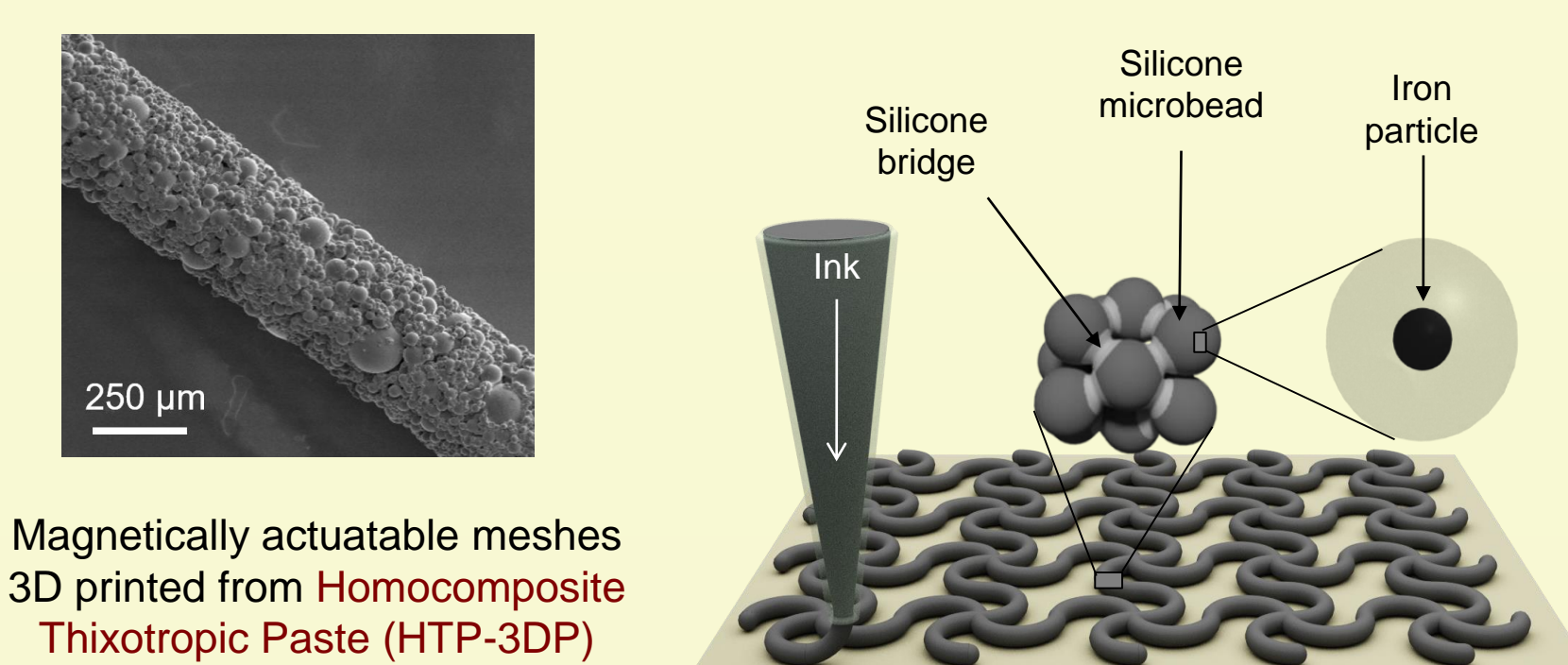
Unusual crystal symmetry, via multipolar assembly in AC field
 $f > 10 \text{ kHz}$
Smukov et al. *Soft Matter* (2009)
Gangwal et al. *Soft Matter* (2010)
Gangwal et al. *Langmuir* (2008)
Soft Mater., (2014, 2016, 2017)



Patchy microcube as a building block for magnetic microbot

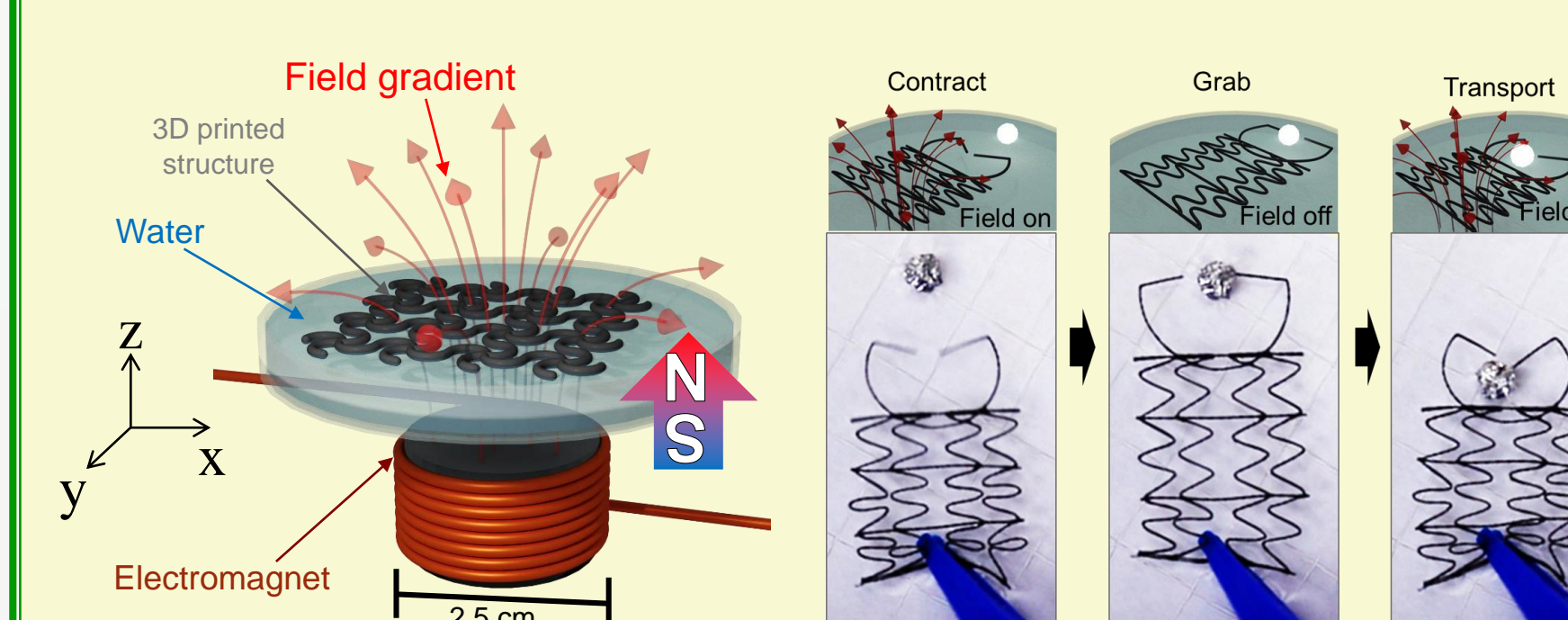
Han et al. *Adv. Funct. Mater.* (2018)

3D printing for soft robotics



Magnetically actuable meshes 3D printed from Homocomposite Thixotropic Paste (HTP-3DP)

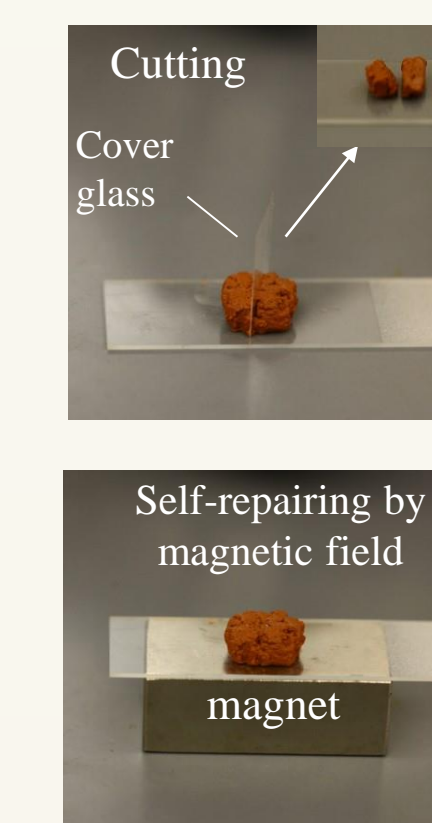
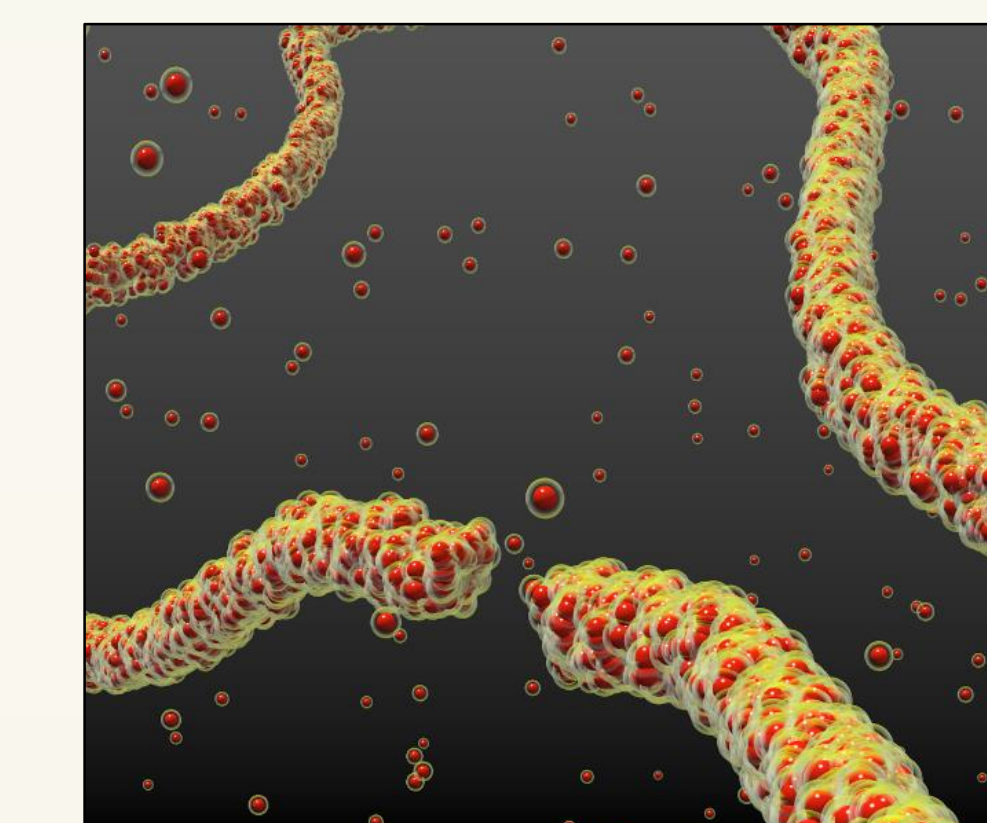
Roh et al. *Adv. Mater.* (2017)



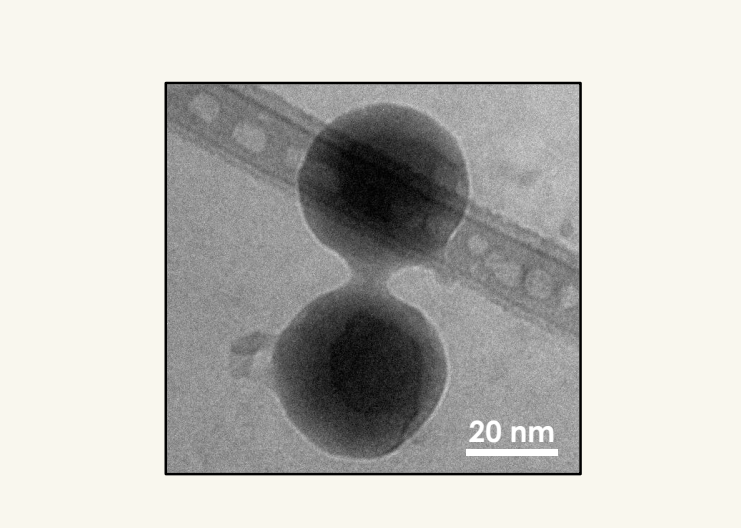
An extendable soft robotic grabber, operated by magnetic field

Roh et al. *Adv. Mater. Technol.* (2019)

Nanocapillary binding of magnetic particles

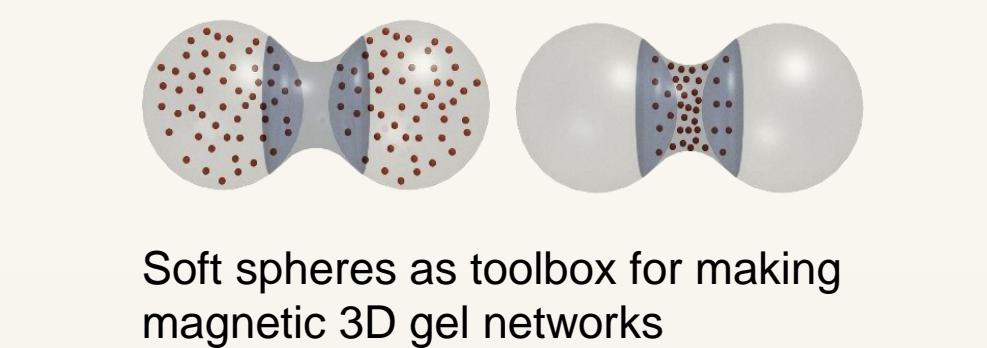


Particles assembled into ultra-flexible self-healing filaments and 2D networks

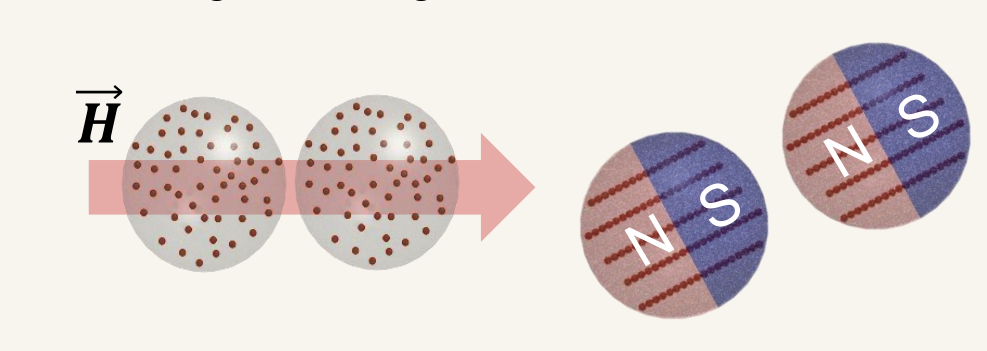
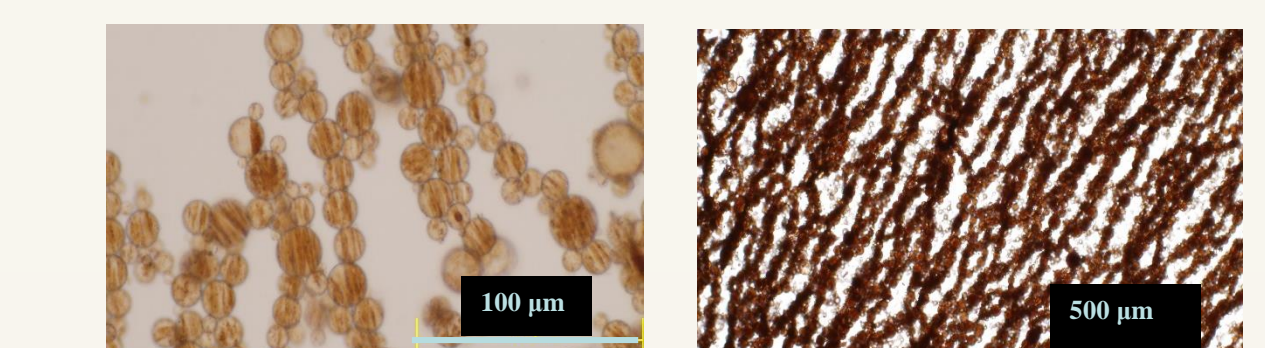


Bharti et al. *Nature Mater.* (2015)
Bharti et al. *Faraday Discuss.* (2015)
Bharti et al. *Langmuir* (2015)
Roh et al. *AICHE J.* (2018)

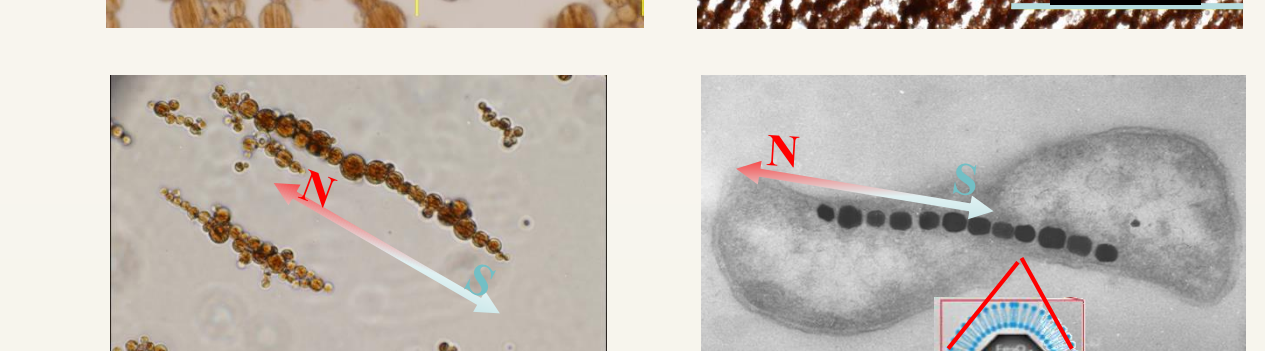
Nanocapillary-mediated assembly of nanoparticles into magnetic filaments and reconfigurable micro-networks



Soft spheres as toolbox for making magnetic 3D gel networks



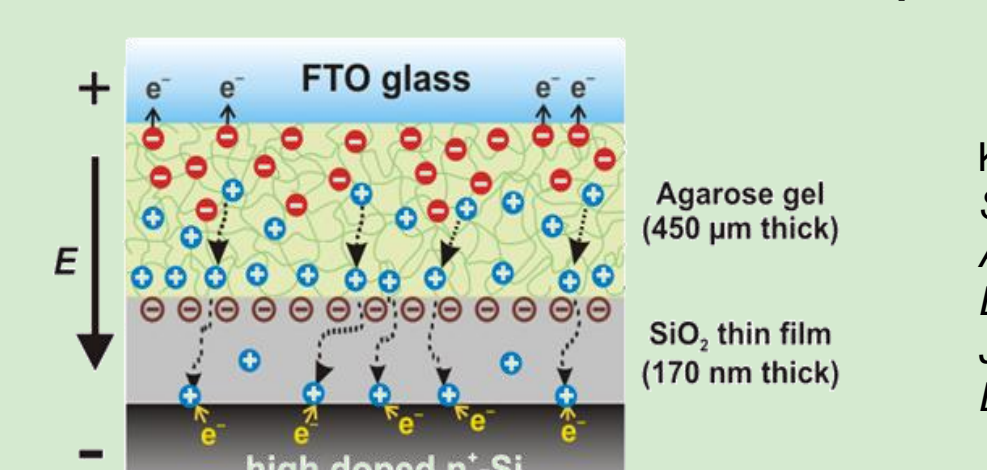
Field-induced dipole moment
Chaining by residual magnetization



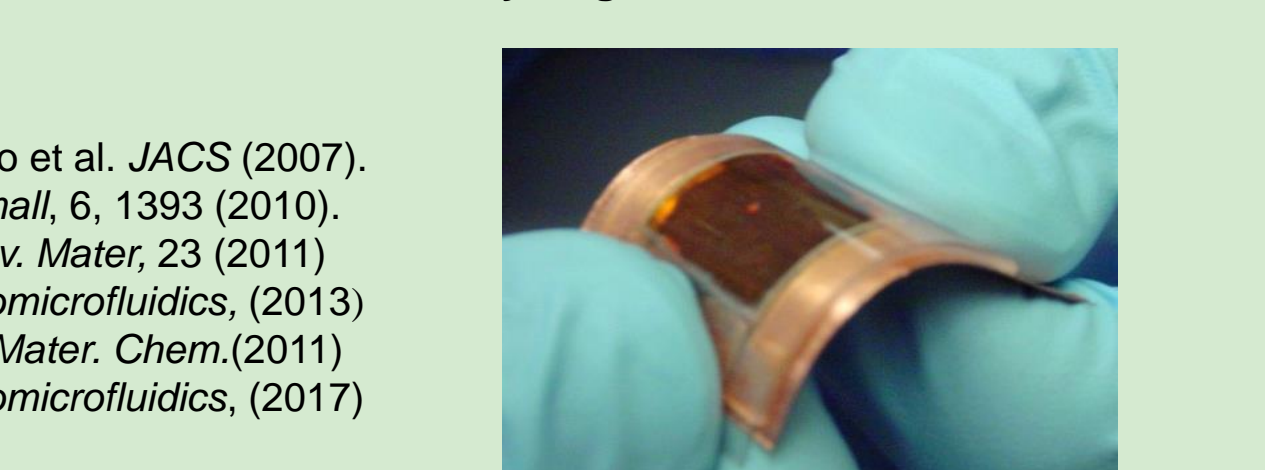
Mimic magnetotactic bacteria

Hydrogel circuits and soft robotic actuators

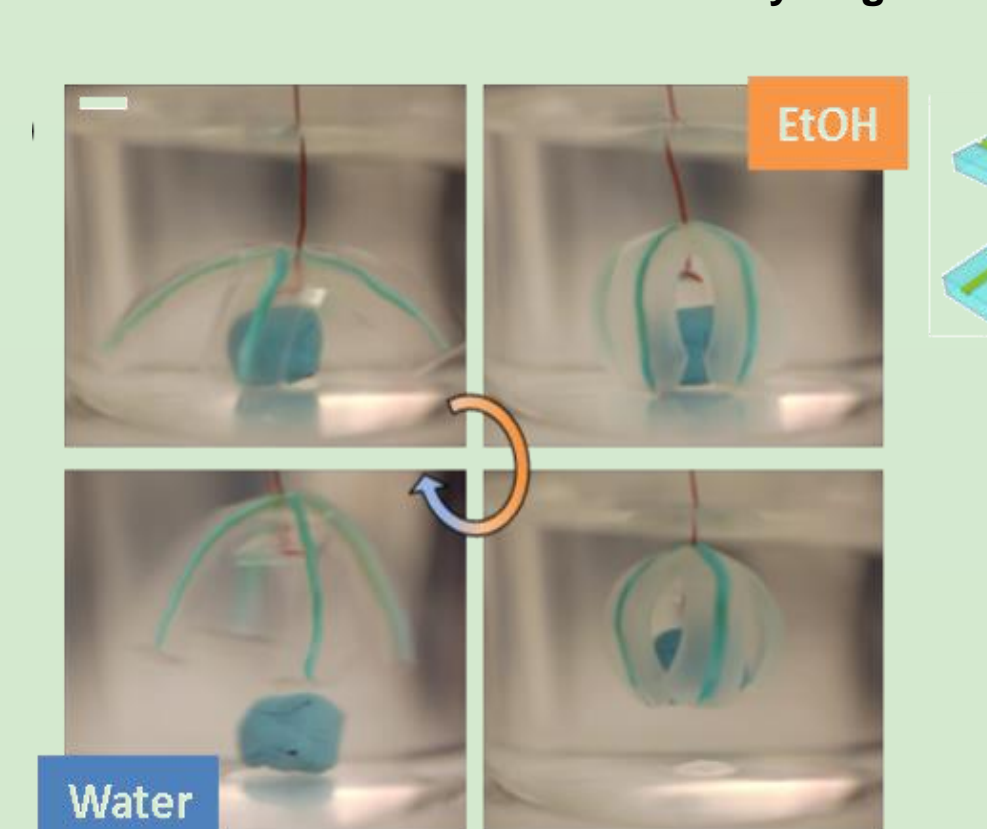
Electronic and photovoltaic devices made of hydrogel



Koo et al. *JACS* (2007), *Small*, 6, 1393 (2010), *Adv. Mater.* 23 (2011), *Biomicrofluidics*, (2013), *J. Mater. Chem.* (2011), *Biomicrofluidics*, (2017)



Hydrogel actuators, grabbers and walkers

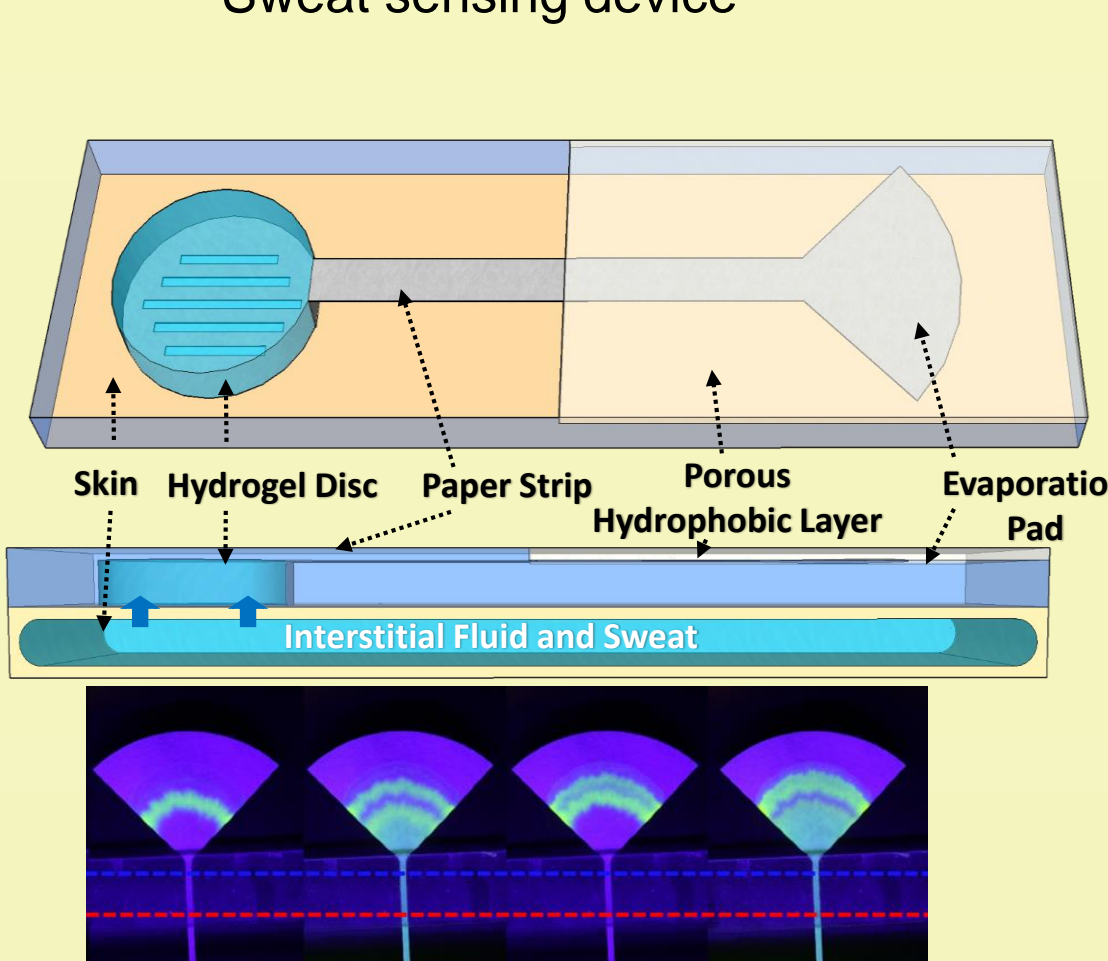


Morales et al. *Small* (2016)
Morales et al. *Soft Matter* (2014)
Palleau et al. *Nature Commun.* (2013)

μ-fluidics & self-propelling particles

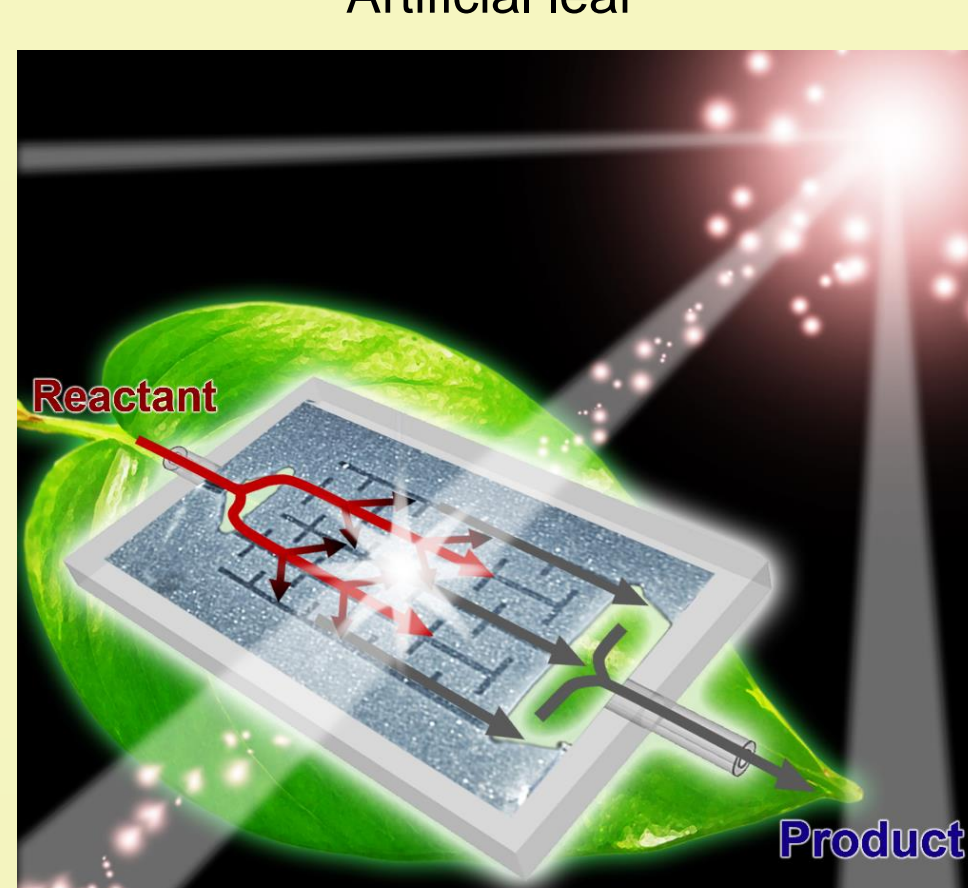
Microfluidic materials and skin interfaces

Sweat sensing device



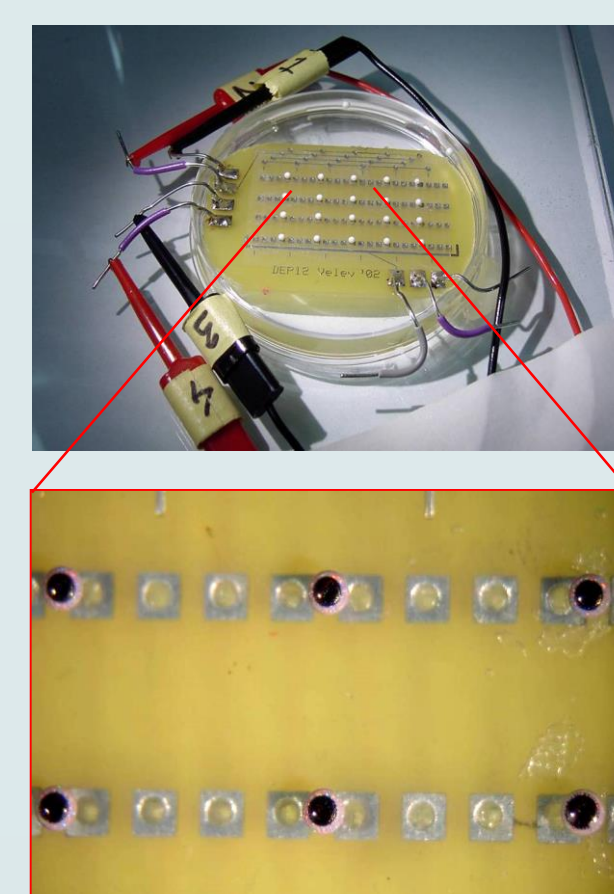
Shay et al. *Lab Chip* (2017)
Shay et al. *Soft Matter* (2017)

Artificial leaf

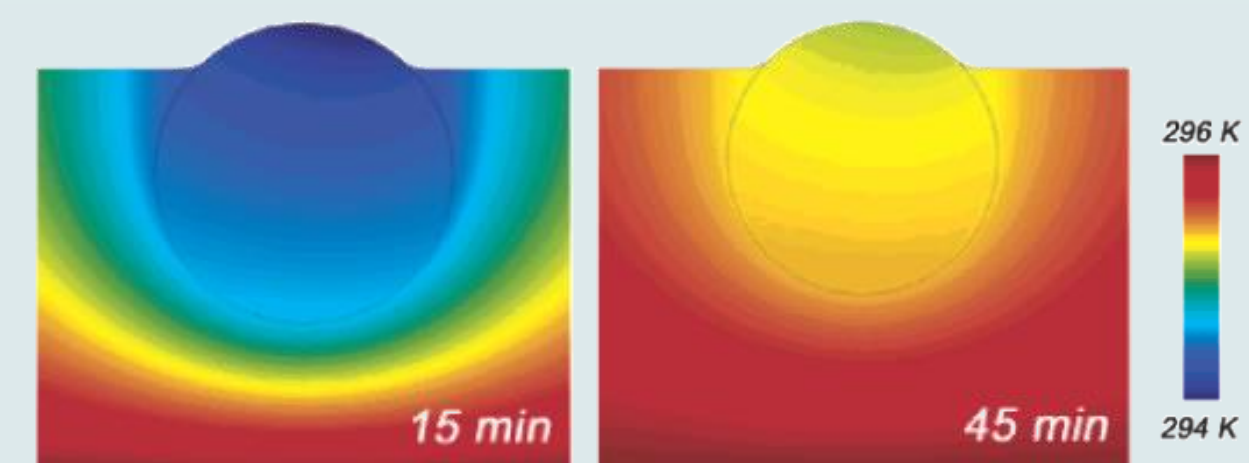


Biomimetic photocatalytic reactor with a hydrogel-embedded microfluidic network
Koo et al. *J. Mater. Chem. A* (2013)
Ucar et al. *Soft Matter* (2012)
Koo et al. *Sci. Rep.* (2013)

Manipulation of microdroplets using dielectrophoresis

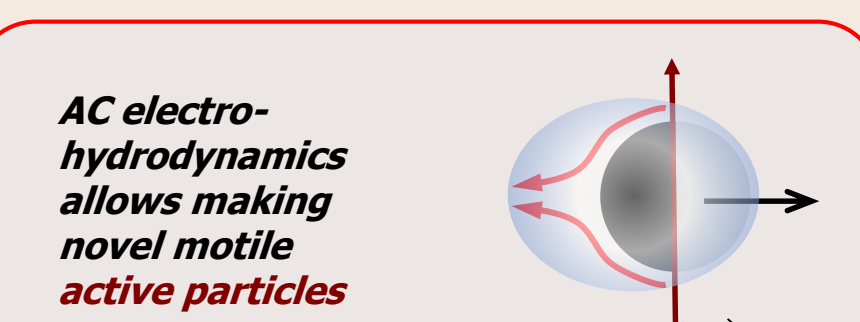
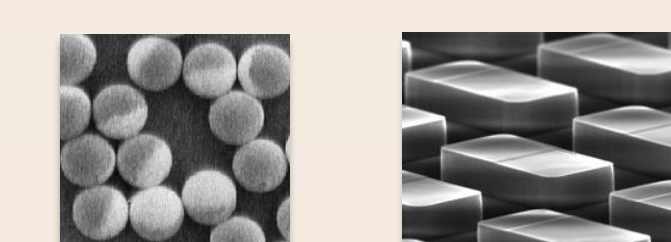


Simultaneous production of "eyeballs" using a DEP chip
Velev et al. *Nature* (2003)
Millman et al. *Nature Mater.* (2005)



Temperature profile in a drying droplet freely suspended on DEP chip to understand particle microseparations inside droplets
Chang et al. *Langmuir* (2006)

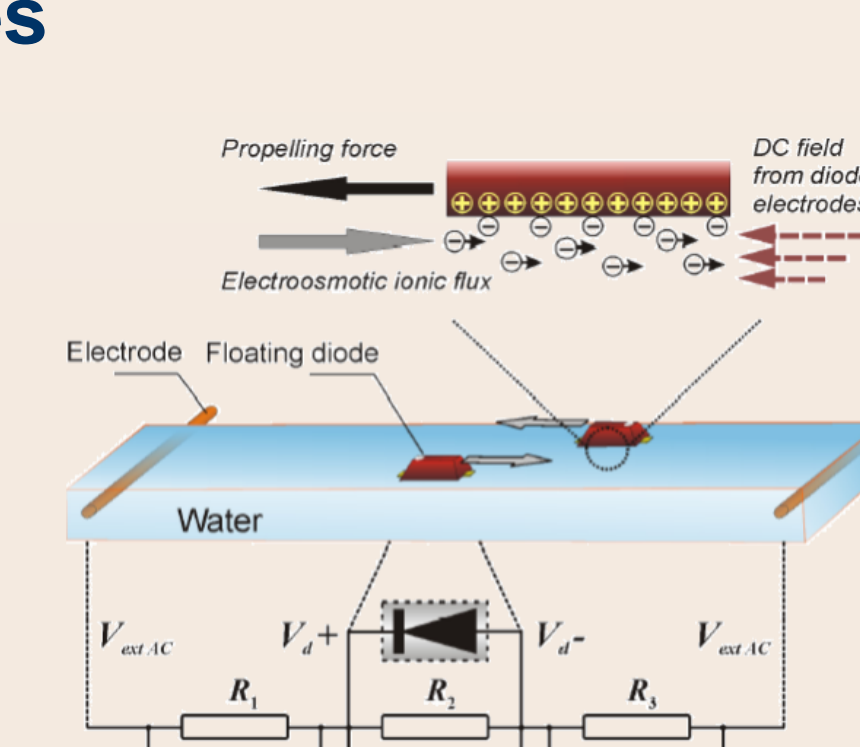
Background: self-propelling particles



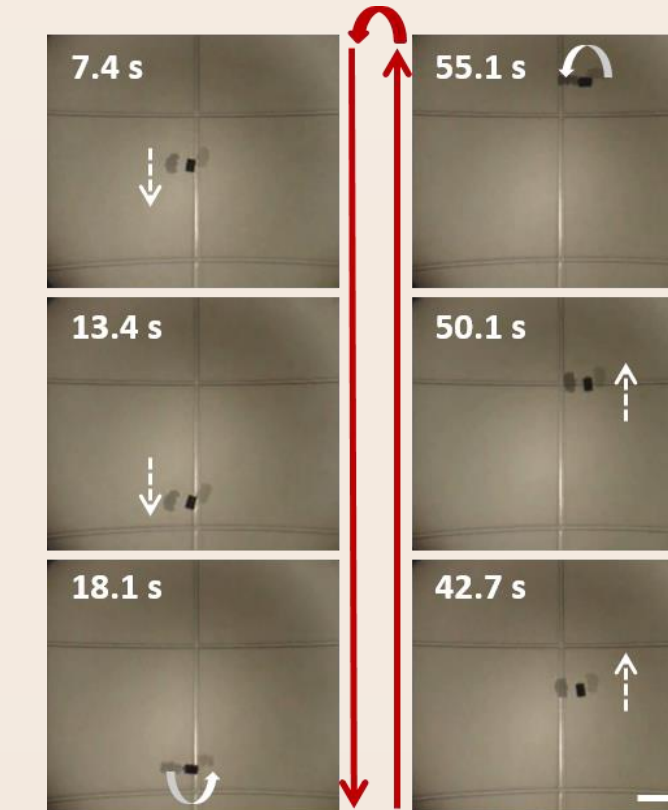
Gangwal et al. *PRL*. (2008)

Potential applications -
• Pumping/mixing fluids in lab-on-chip
• Drug delivery
• Sensors for toxicity detection
• Cargo pick-up/transportation
• Microrobotics

Remote powering/steering of self-propelling circuits

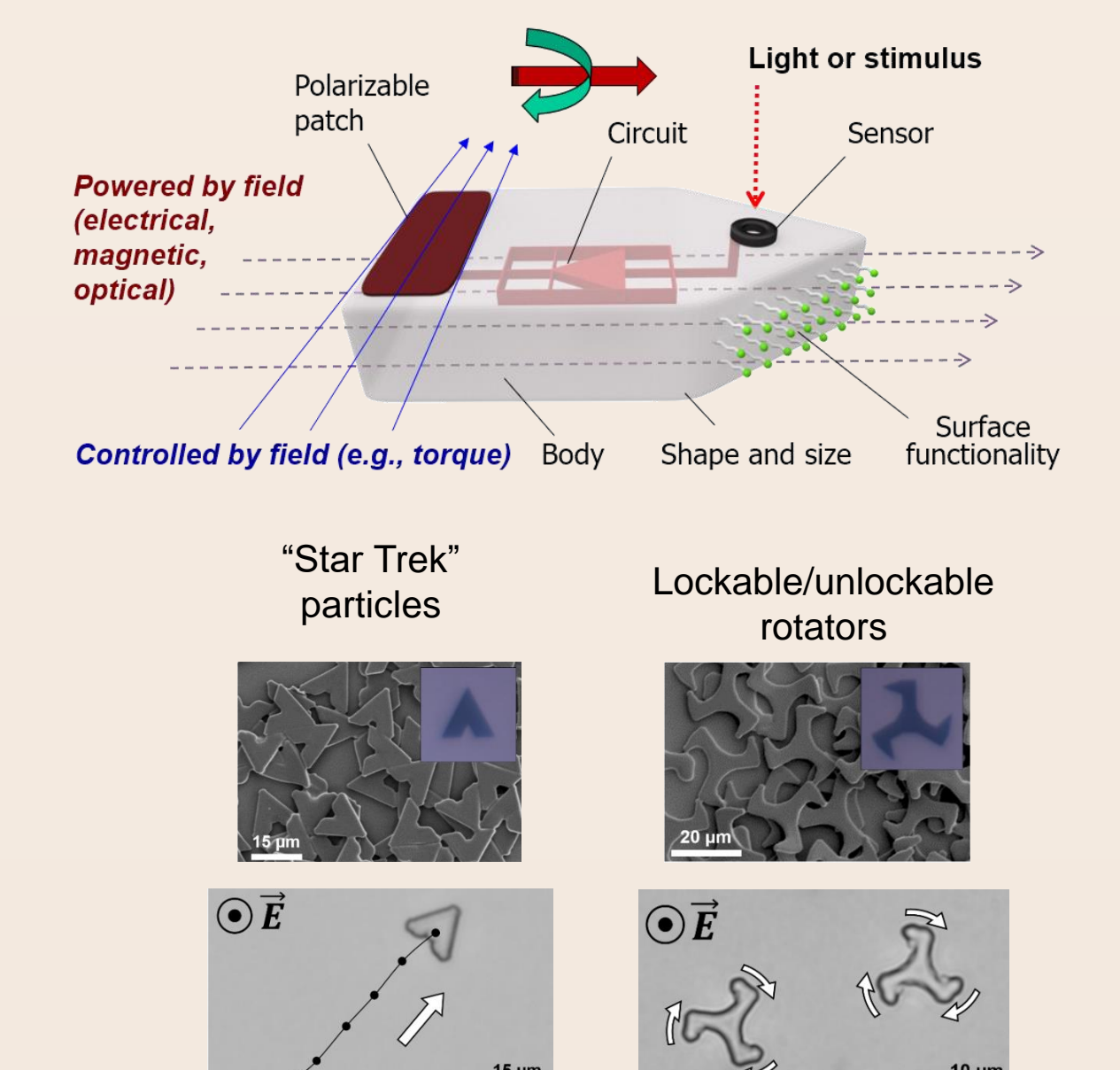


Principles of AC field driven diode propulsion
Chang et al. *Nature Mater.* (2007)



External signal controlled shuffling and steering
Sharma et al. *Adv. Funct. Mater.* (2015)
Sharma et al. *Langmuir* (2012)

Vision: Autonomous microdevices



"Star Trek" particles
Lockable/unlockable rotators
Shields et al. *Adv. Funct. Mater.* (2018)
Ohin et al. *Nature Comm.* (2018)