Andrea Melle, Walter Richtering

Jack Of All Trades, Microgel

Special research field is dealing with versatile usable materials

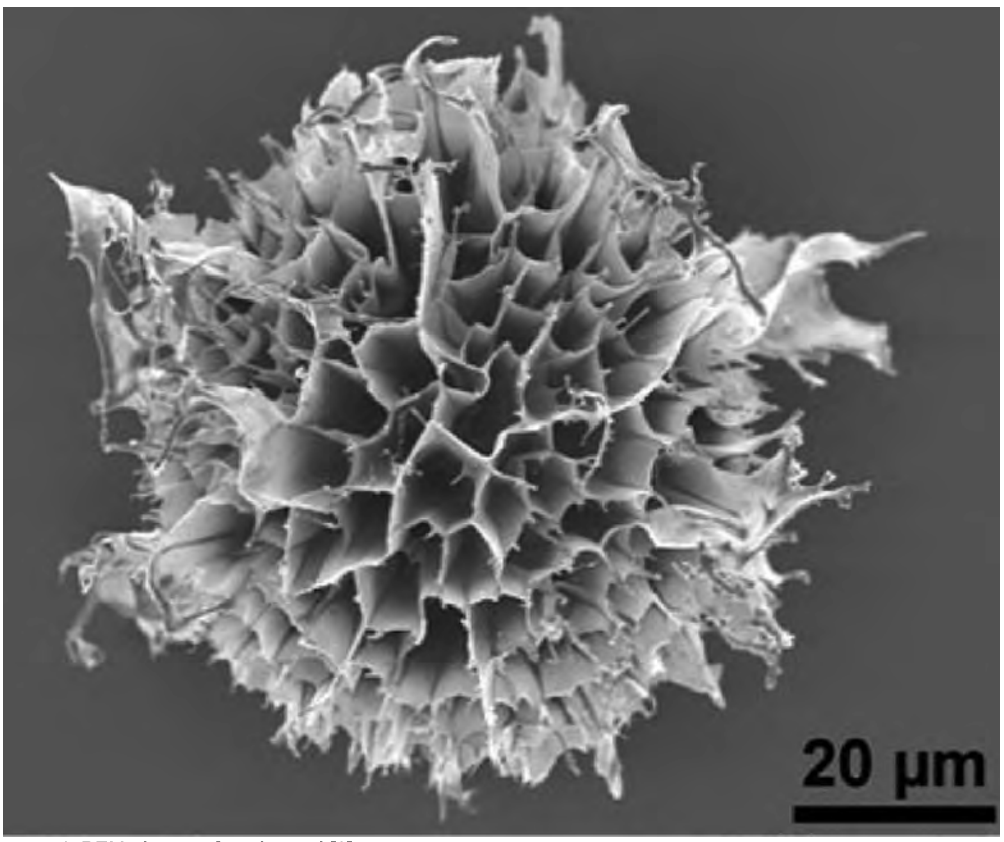

Image 1: REM picture of a microgel [1]

Since 2012, scientists from different disciplines have worked together within the Collaborative Research Centre "Functional Microgels and Microgel Systems" (CRC 985) to investigate the unique properties of "microsponges", so called microgels. Natural scientists, engineers and medical scientists from RWTH, the University Hospital Aachen, the DWI-Leibniz-Institute for Interactive Materials and Forschungszentrum Jülich are cooperating within 15 individual research projects to make use of the outstanding potential of functional microgels. The focus of CRC 985 is to understand and design complex microgels with novel functionalities, to develop high-precision synthesis routes and formulation processes, as well as to find innovative applications for microgels.

The special characteristics of "micro-sponges", so-called microgels, are in the focus of the Collaborative Research Centre "Functional microgels and microgel systems" (SFB 985). In order to be able to make use of the outstanding potential of functional microgels, natural scientists, engineers and medical scientists from RWTH Aachen, the University Hospital Aachen, the DWI - Leibniz-Institute for Interactive Materials and Forschungszentrum Jülich have been working together within 15 individual interdisciplinary projects since 2012. The focus is to design complex microgels with novel functionalities, to develop high-precision synthesis routes and formulation processes as well as to find innovative applications for microgels.

What are microgels?
Microgels are soft three-dimensional polymer networks with a diameter of a few nano- to micrometers which primarily exist "swollen" in water or other solvents. By changing the environmental conditions (e.g. temperature, pH-value, light, ionic strength) microgels (depending on their compound) can be "switched", i.e. they adapt their size and shape to the environmental conditions within milliseconds. Because they can be "switched" and due to their porosity they differ from inflexible nanoparticles. As the mass transport is limited with inflexible nanoparticles, microgels allow multifarious mass transport processes due to their controllable swelling and surface properties. Thus, microgels combine the characteristics of particles and dissolved macromolecules and offer further possibilities for the development of new bio-inspired materials which can be used in therapy, sensor technology, water preparation or catalysis.

Major progress in post-antibiotic era

In a subproject, chemists, biotechnologists and medical scientists are developing a microgel to treat diarrheal diseases. This biocompatible microgel is designed to specifically bind toxins which are released by bacteria. This way it is intended to alleviate disorders as a non-antibiotic therapeutic agent. It could be demonstrated that lectins, similarly constructed as the toxin, are uptaken by the microgels and linked to their specific receptors. The natural balance of the intestinal flora should subsequently decimate the bacteria.

High selective evidence of pesticides possible

In order to prove pesticide residues in environment or nourishment, a fast, sensitive and specific detection plus quantification is needed. For the evidence of so-called organophosphates enclosed in highly toxic environmental pollutants like pesticides, a biosensor made of microgel loaded with an enzyme has turned out to be appropriate. This newly developed biosensor is easy to produce, stable over a long time period and it has a very low detection threshold (pico-molar). It is far below the maximum permissible concentration of pesticides in drinking water. Previous enzymatic biosensors haven't been able to fulfil these criteria so far. As the enzyme is on the surface of the microgel, it is easily accessible and enables a highly sensitive and fast detection of organophosphates in hydrous medium.

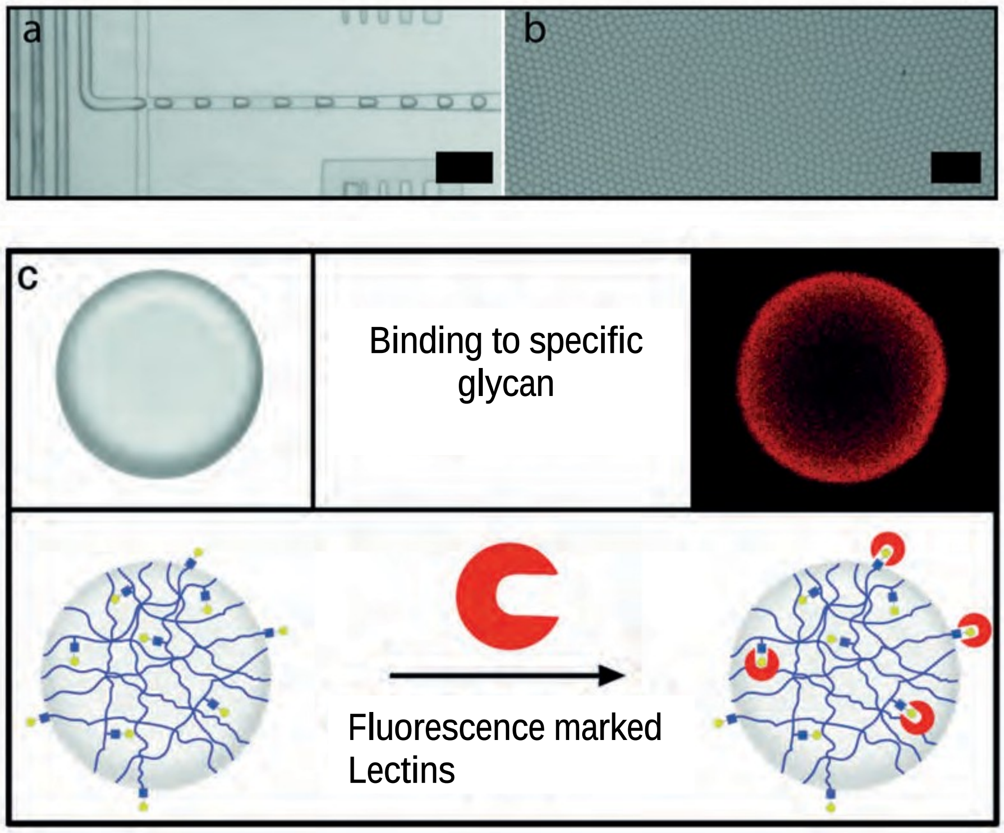

Image 2: a) Synthesis of the microgel by microfluidics b) Microscopy image of the produced microgel c) Schematic representation of the binding of lectins to the receptors (glycan) in microgel. Scale bar is 20 µm [2].

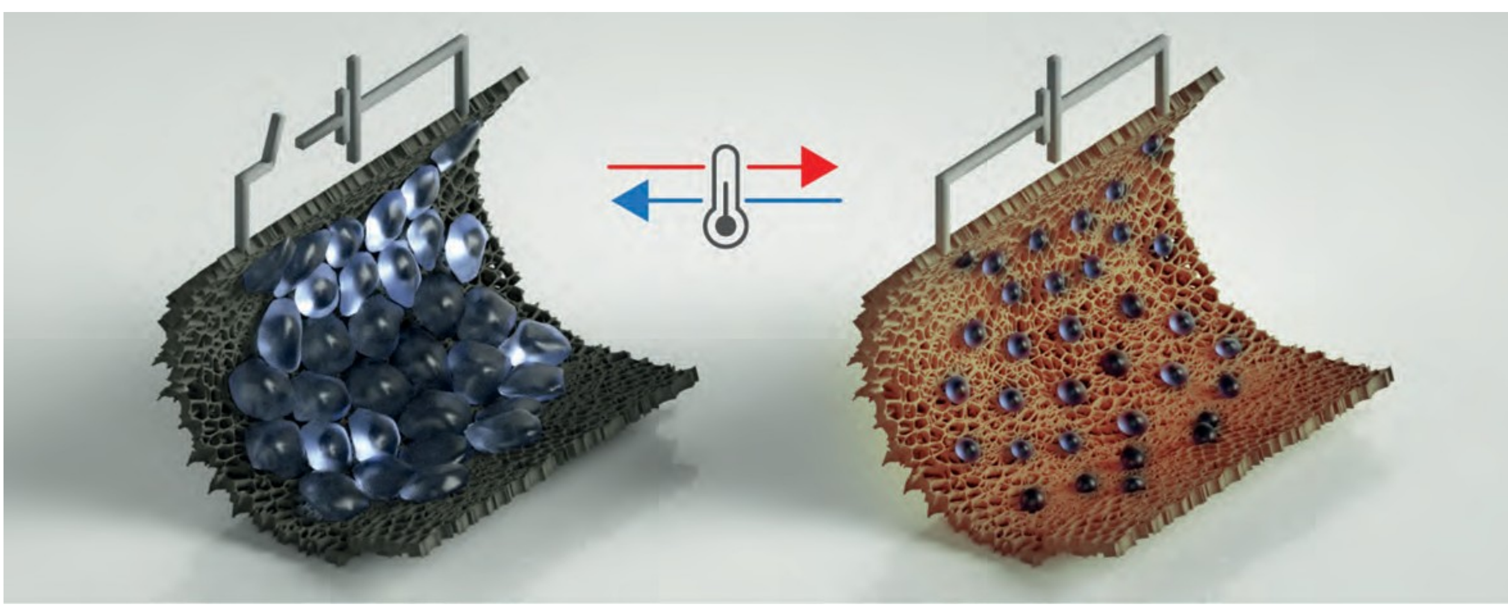

Image 3: Schematic representation of microgel-coated membrane at room temperature in a swollen state (left) and with an applied voltage (right), which is leading to a temperature raise and therefore to the collapse of the microgel structure.

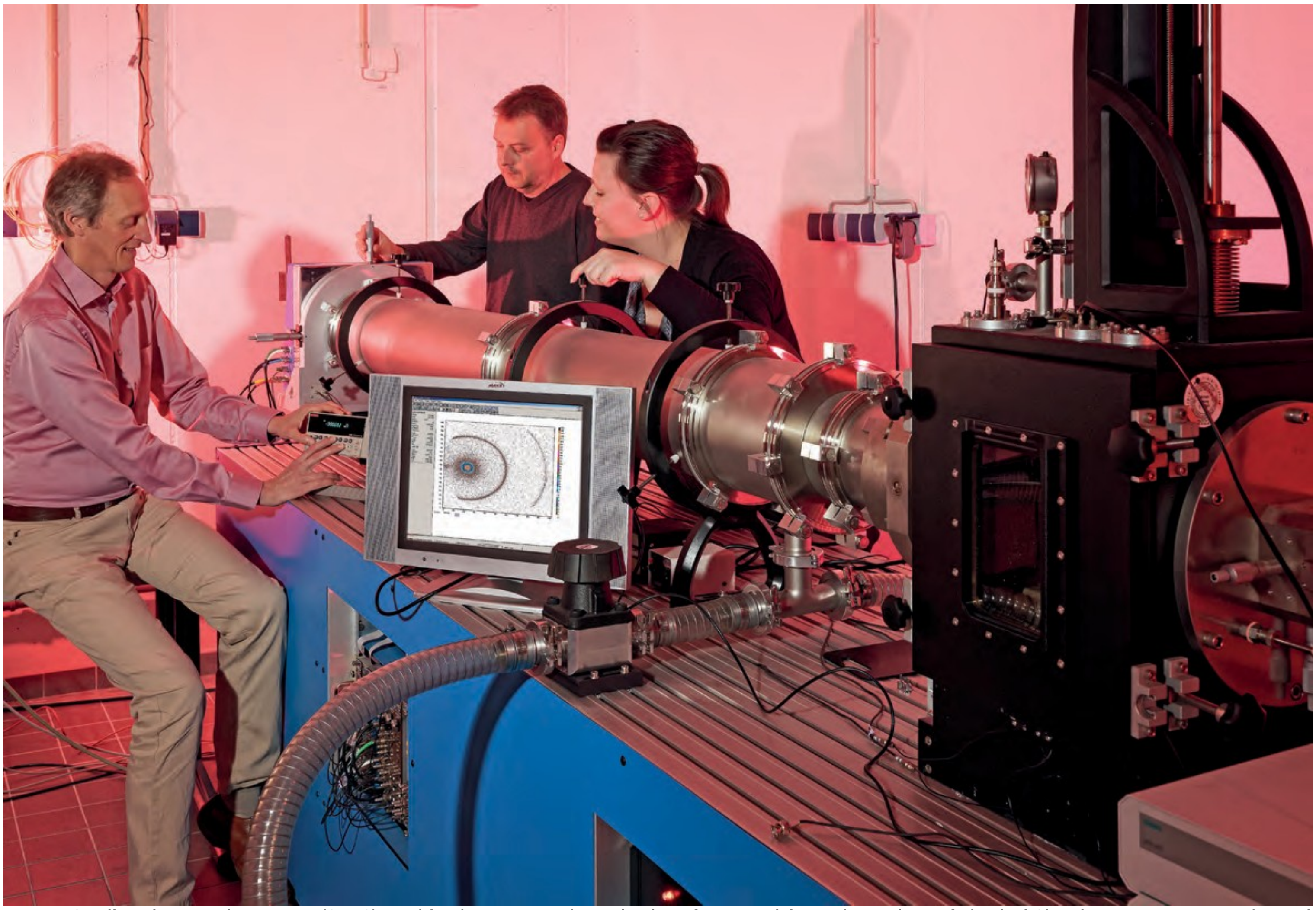

Image 4: Small angle scattering system (SAXS) used for the structure determination of nanoparticles at the Institute of Physical Chemistry II at RWTH Aachen; Middle part of graph: applying a model and fitting or model free inversion.

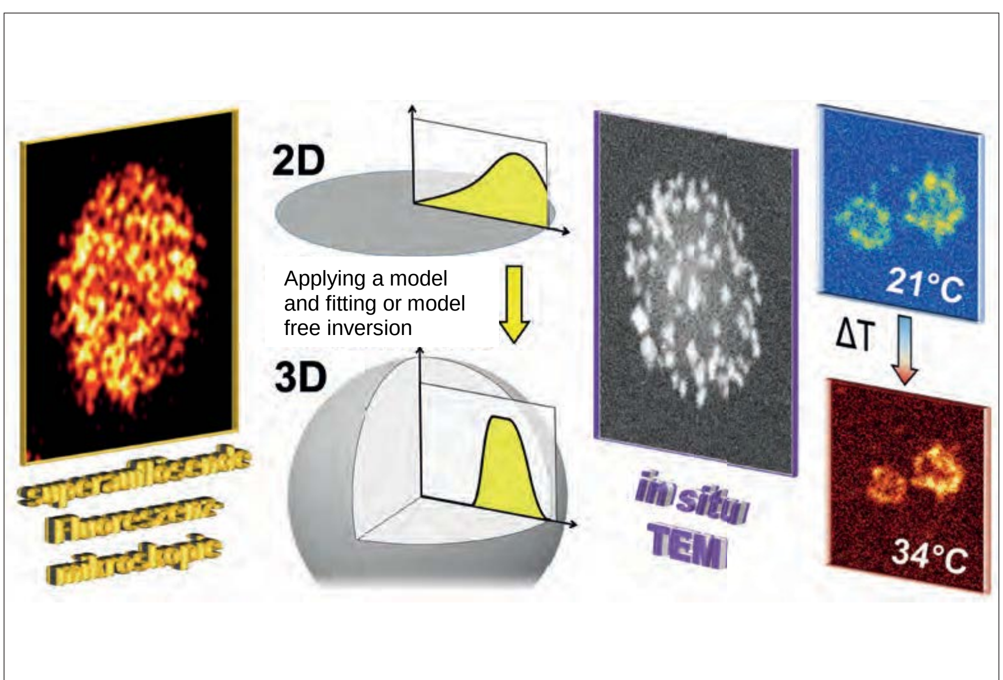

Image 5: The combination of high resolution fluorescence microscopy and *in-situ* transmission electron microscopy (TEM) makes it possible to reconstruct the 3D-structure of microgel. It also visualizes the thermal induced collapse of the microgel in water [5]

Switchable membrane by microgel covering

If you cover membranes with microgels their transmissibility and selectivity can be operated by change in temperature. At room temperature the microgel is swollen in the membrane and seals the pores. If the coated heatable membrane is heated by using its electric resistance the temperature-sensitive microgel collapses and opens its pores. Due to these enlarged pores bigger molecules can get through the membrane. The reversible operating of the membrane enables a precise adjustment of the detention by what molecules of varying size can be selectively separated from each other. These switchable membranes may be applied in water preparation and biotechnology where they can react with a modified process condition.

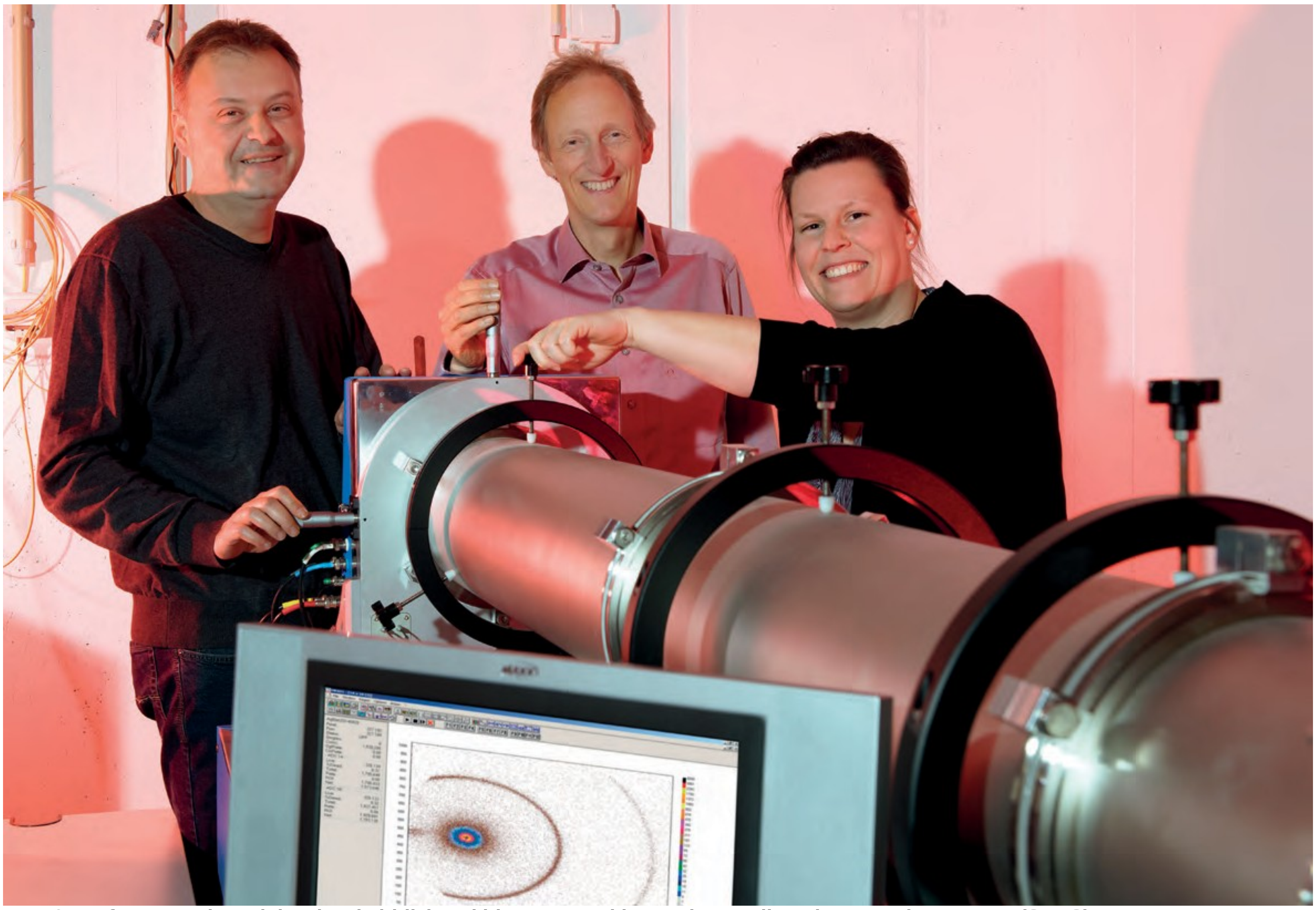

Image 6: **Professor Walter Richtering (middle) and his team working at the small angle scattering system (SAXS)**

How does the 3D-structure of microgel look like?

Even further progress occurred by visualizing the 3D-structure of microgels (core and/or shell). A combination of *in-situ* electron microscopy and super-resolved fluorescence microscopy are used for that. By means of these microscopy methods the functional groups, dyes, ingredients or nanoparticles incooperated in the microgel can be located. Besides, the in-situ electron microscopy is a tool to trace the thermally- initialized collapse of a single microgel in real-time, e.g. water. For the future, these methods of characterization are supposed to be applicable to more complex structures of soft material.

Literature

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