



Sylvie Roke cycles in the foyer of the Max Planck Institute for Metals Research for demonstration purposes only, but she loves cycling in the Swabian hills and dales around Stuttgart.

Diving into Surfaces

The experiments for her doctoral studies did not work out quite as planned the first time around. After switching gears and continued work, however, **Sylvie Roke** opened up a completely new perspective on soft matter. At the **Max Planck Institute for Metals Research**, she also uses this method to investigate potential new drugs and biological materials.

A PORTRAIT BY **UTA DEFFKE**

Sometimes it is the small, everyday things that still hide big secrets. Take some oil, for example, and pour it into a bowl of water. The two liquids won't mix, as everyone knows from an oil and vinegar vinaigrette. Only a vigorous shake makes the oil floating on top disperse into the water in the form of fine droplets. Chemists call this an emulsion. We encounter these everywhere in daily life, for example in the form of milk, butter, shampoo and vaccines. But what determines the size of the droplets, their stability, or their interaction with the surrounding liquid? Why does everything change if certain substances are added? And how can this be influenced for a specific purpose?

The answers to these questions are hidden at the interface of the droplets. Sylvie Roke draws a black circle on the whiteboard and another one around it. "This interface is only about one nanometer thick, but it is fundamentally different from the rest of the liquid," explains the physicist. The liquid there is rather viscous and contains

many more charges, which have an attractive or repulsive effect on each other and on their surroundings. But what exactly do these molecules look like? How are they arranged and why? Is there a difference between a curved surface and a planar interface?

CHALLENGING TEXTBOOK WISDOM IS FUN

Initial speculations about this were already circulating in specialist literature a century ago. "There are lots of theories on droplet interfaces," says Roke, "but so far there have not been any direct measurements." There were simply no suitable methods that would have enabled the researchers to access the interfaces of tiny droplets. Sylvie Roke has developed an optical method that makes this possible for the first time. "We can now jettison a large number of old ideas," she says. "This is fun, of course; but it is also quite difficult to carry out research that goes against textbook wisdom, because we are viewed with a particularly critical eye, of course."

In spite of her delicate appearance and her mere 32 years, it does not sound as if Sylvie Roke is intimidated by this. On the contrary. The young researcher loves such challenges and knows what she can do and what she wants. When she talks about her work and her plans, she makes vivid gestures, demonstrates the motion of molecules with the aid of a slinky and sketches formulas and pictures on the board. She also demonstrates comic talent when talking, as she imitates other people's intonation and facial expressions.

Sylvie Roke sits in her office on the sixth floor of a new building on the outskirts of Stuttgart. Glass facade, concrete core – the Max Planck Institute for Metals Research. Since 2005, she has been heading her own, open-topic Max Planck Research Group, which now comprises seven scientists from Brazil, Spain, the US, France, the Netherlands and Germany. She is often asked just how she came to be at an institute for metals research, of all places. Historically, the institute was indeed dedicated strictly to research on metals, but nowadays one finds behind the doors of the

»» The curved surfaces of small particles scatter light in different directions. Sylvie Roke pursues the idea that these scattering effects can be used specifically to gain insight into the surface properties of the particles.

institute offices and laboratories where researchers work on a broad spectrum of materials and topics. And soft matter, which cannot unequivocally be assigned to solid or liquid matter, is also the latest trend here – including biological materials.

Interfaces play a key role in many processes. They determine the electronic properties of computer chips and the mechanical stability of solid bodies. They affect transport processes through cells, when medication is administered, for example, and the interaction of particles with their environment. The physical and chemical properties of nanomaterials are based almost exclusively on the properties of their surfaces, because the smaller the dimensions of a body are, the more dominant is the contribution of its surface, and the more important it is to understand it.

CELL WALLS AND DROPLETS IN A NEW LIGHT

There are several established methods for investigating planar surfaces, ranging from scanning probe techniques to imaging with electrons to optical spectroscopic methods. These methods have contributed decisively to the continuous miniaturization of microelectronics. However, these techniques are of very limited use in investigating the surfaces of soft matter, such as cells and emulsions. There are several problems at once: quite a few of the methods require vacuum conditions, where liquids immediately evaporate; and the interesting surfaces are often hidden in liquids or in solid materials so

that electrons cannot reach them. Moreover, the particles are very small and their surfaces are thus curved, with the result that reflection experiments are impossible.

The most promising tool for investigating soft matter is light, because it can penetrate liquids and solid bodies. Furthermore, light is already being used to investigate surface structures, specifically in the form of second-order nonlinear optical spectroscopy. In a nutshell, this method shows how the molecules vibrate at surfaces, which in turn can be used to derive their structure.

But the sophisticated method works in this form only with planar surfaces, because a reflected light beam is necessary for detection and analysis. However, the curved surfaces of small particles scatter light in different directions, so that no reflected beam can be measured. Sylvie Roke uses the idea that one can nevertheless use the scattered light to gain information about the surface molecules. She uses the scattering effect for the specific purpose of gaining insight into, for example, the molecular surface composition, chirality or charge that is present in the interfacial region.

In order to realize nonlinear light-scattering spectroscopy, Sylvie requires a sound knowledge of the particle scattering processes. Only then can she correctly interpret the data. In the laboratory, lasers are set up on a large table with many mirrors and lenses that shape the variously colored light beams. Ultrashort intense flashes of light are required for the oscillations of the surface molecules to generate suffi-

ciently strong signals. And because they are so short, they are also suitable for observing the temporal behavior of the excited molecular oscillations in a quick sequence of snapshots, as in a stroboscope.

MAJOR AWARDS FOLLOW THE FIRST PUBLICATIONS

The researchers headed by Sylvie Roke have used this method to prove, for example, that a suspension of colloidal glass particles – small spheres in a liquid – takes on a gel-like consistency if the molecular chains, which sit like hairs on the colloidal surface, arrange themselves alternately with molecules of the liquid. The molecular hairs thus influence the properties of the material, in this case the material to gel. The researchers also showed that the surface of soap sitting on small oil droplets in water is fundamentally different from soap sitting on the planar interface between bulk oil and bulk water. Moreover, the Max Planck scientists are continuously working on improving the sensitivity of their apparatus and integrating new optical effects.

In 2008, Sylvie Roke was awarded the Hertha Sponer Prize of the German Physical Society (DPG) for her development. And back in 2006, she received the Dutch Minerva Prijs, which is a biannual prize for a scientific paper. “This is something quite special for me,” says Roke with some pride. “Some researchers have been honored for their lifetime achievements with this award, and I received it after only a few publications.”



Sylvie Roke was already in a bit of a hurry at the very beginning of her life. Maybe in slightly too much of a hurry, because she was born three months premature, and initially had to fight for survival. Even later in life, she was more occupied than other children with growing up and getting stronger. Luckily she had her sister, who was one year older and served as a great example. “Being one year older, she was always taller and better than I was, but she took me along nevertheless. She learned how to play soccer, so I had to learn, too. When she wanted us to run through the forest, I ran with her. And when she wanted to climb trees, we climbed trees. Following her around was very important for my development. And it was fun.”

At some point, when she was 15 or 16, Sylvie Roke found her own way in life. And it was at this time that she also became interested in science. Mathematics appeared to her to be a very natural way of thinking, and she also found physics and chemistry easy. She began to read trade journals and enjoyed the idea of ending up doing something like that. So it was that she found her niche – in her family, as well, as both of her parents are in the legal profession. And her sister? “She became a psychiatrist and is responsible for the social side,” says Roke with a wink of an eye.

At the university in Utrecht, close to her little home town, she started to study chemistry. But when her questions as to why things happened got on the nerves of the university lecturers time and again during the lectures



When Sylvie Roke explains nonlinear scattering spectroscopy, she uses her hands, simple models and, of course, a whiteboard. The method she developed provides vibrational spectroscopic information on the surfaces of cells and emulsion droplets. The scattering of light discloses the surface structure and the size and shape of the particles.

for her bachelor’s degree, one of them simply recommended that she switch to physics. So that is what she did. After another two and a half years, Roke not only completed her physics degree, but also her chemistry degree, both with highest honors. While working on her master’s thesis at the Institute for Atomic and Molecular Physics in Amsterdam, she became engrossed for the first time in the investigation of surfaces – a classic interface between

physics and chemistry. When the research group moved to Leiden University and the chance was offered to enter the discipline of laser physics, Roke moved with them to write her doctoral thesis.

At first, this didn’t work out quite as planned – the experiments weren’t successful. Sylvie Roke started brooding and thought of three possible causes: “One: I am a lousy scientist; two: the whole idea is wrong; or three: the cause

» The overall view of something was important to her, even as a student. That is why she participated in the “Universiteit Vrij van Nut”, the “University of Uselessness”.



Stuttgart offers no opportunity to skate on ice, but with inline skates, she can train without it.

is the bad signal-to-noise ratio.” In order to find out whether the only really alarming hypothesis – the first one – was correct or not, she decided to simply start a new project. And she already had one in mind.

“IF YOU WANT SOMETHING, THERE IS ALWAYS A WAY”

During the third year of her doctoral studies, she spent a few weeks at Columbia University in New York. There she met people who combined nonlinear optics in the visible spectrum with light scattering. So why not combine light scattering with spectroscopy in the infrared range, which is particularly suited to the analysis of molecular structures?

Within a few months, she had constructed a laser system on the basis of this idea, and showed that it was possible, in principle, to use it to determine the surface properties of particles. “In retrospect, I was very lucky there,” she says, “because my test particles were of just the right size to enable me to measure them with relative ease.”

She had thus restored her “scientific honor,” and after completing her doctoral studies, again with highest honors, she left Holland to take up a postdoc position. “As these things happen, I met Michael Grunze at a conference. We had a nice conversation, he had an interesting position in physical chemistry available, and I ended up in Heidelberg with an Alexander von Humboldt fellowship.” The hosting professor also drew her attention to the

open-topic Max Planck Research Group program and encouraged the young researcher to apply.

Sylvie Roke confesses that, at that time, she didn’t really know very much about the Max Planck Society and its possibilities. While in Heidelberg, however, she got to know Joachim Spatz, who was in the process of joining the Max Planck Institute for Metals Research. He was working with nanostructured surfaces and with biological materials, and he advised her to apply there as well. She was successful: her idea and the initial results of her new method convinced not only the jurors of the Max Planck Society, but also the Board of Directors in Stuttgart.

This promised her a great opportunity, not only in scientific terms. Her boyfriend had declared that he was prepared to move from the Netherlands to Stuttgart if she got the job with the research group. “It is very important to me that we don’t have to have a long-distance relationship,” says Roke. “I know that many people do this, but I could not and did not want to. And if you want something, there is always a way”

And how does it feel being Dutch in Germany? And even more so in the heart of Swabia, the almost mountainous, model region of German orderliness? “Well,” she groans slightly, “it’s different. And this takes some getting used to at first.” She has since grown somewhat apart from her home country, however: “When I go back to the Netherlands now, I often get irritated and think: Can’t this work ‘normally’ for once? I don’t really belong here



anymore.” The biggest difference, she says, is probably that the Germans live a much more orderly life and also keep to the rules: “If it says: ‘No bicycle parking,’ you won’t see any bikes parked there.”

COMPETITIVE ON THE BIKE, AS WELL

The fact that Sylvie Roke is from the Netherlands becomes obvious, if it wasn’t already, when she talks about her favorite sports: cycling and speed skating. “I love the speed on ice, it’s almost like flying,” she gushes. Unfortunately, the ice rink in the neighboring town of Kornwestheim burned down last year, and alternative speed skating rinks are few and far between. Frozen canals are rather rare, even in Holland. But when people can skate from town to town and be enchanted by the icy landscape and the fantastic views of the old towns, there is, of course, a very special atmosphere and a big national party.

Sylvie Roke enjoys cycling in the hills and dales around Stuttgart. “I like cycling uphill,” she confesses. A fighter by nature, she also enjoys a classic ride: she has already conquered Mont Ventoux, the notorious, bleak mountain of the Tour de France, eleven times. And when the weather outside is nasty, or a proper mountain is not within reach, there is always the home-trainer with DVD and computer. “I can simply put on Alpes d’Huez and the trainer translates this for my eyes and legs.”

The physicist is also not averse to using the latest technology for reading. While drinking her cup of tea at break-



The physicist constructed her first laser system during her doctoral studies. But she and her coworkers continue to build better devices.



When Roke first came to Stuttgart, she was keenly aware of the differences between the Netherlands and her new home. Since then, however, her home country has become almost foreign to her.

want to extend the theory to differently shaped particles as well, to enable the study of deformations (of cells) or of viruses. The theory makes a significant contribution to interpreting the measurement results correctly, and to further optimizing the experimental setup.

IMPORTANT CLUES FOR THE DRUGS OF THE FUTURE

A medical project with the University of Utrecht has just been completed. "I literally met the researcher in the elevator and he told me about the problem he had," remembers Sylvie Roke. The medical researchers had developed tiny spheres of biodegradable plastic to possibly fight secondary liver cancer. These microspheres contain small quantities of holmium that is radioactivated to emit beta radiation to destroy tumors. In order to optimize the therapy, they wanted to find out more about the biodegradable plastic microspheres: where exactly the holmium was located in them and how they were interacting with the body fluids.

The Max Planck researchers were initially confused by the results of their measurements on the particles. The scattering phenomena they observed could not be explained by the surfaces of the plastic spheres. Instead, all indications suggested that the plastic molecules within the sphere formed crystalline regions. Roke found that the holmium located inside these regions is in a configuration that is so stable that it doesn't get released even after an activation process of several hours. Sylvie Roke believes that this is an important finding for the design of future drugs. "It is very satisfying to discover something fundamental that, at the same time, is also very useful, isn't it?" The holmium-loaded microspheres are now being tested in clinical studies.

Sylvie Roke does not spend much time in the lab these days. She is writing publications and planning for the future – planning to publish her ideas and results further, also in talks, because her group is the only one in the world taking this approach to particle and droplet surfaces. And you cannot bump into everyone who could be interested in that in an elevator.

fast, she likes to use her e-book reader. It has the feel of a real book and is very practical, she says – it saves a lot of baggage, especially when traveling. In terms of content, however, she prefers history: *Persian Fire* by Tom Holland, for example, on the war between the Persians and the Greeks. She also thinks Bill Bryson's *"A Short History of Nearly Everything"* is particularly good. What she values about this sweeping broadside of popular science is that it makes the bigger picture clear.

Bryson does not simply list discoveries chronologically. He thus does much more justice to the course of science, Roke thinks. The overall view of something was important to her even as a student. That is why she participated in the "Universiteit Vrij van Nut," the "University of Uselessness," which was founded by biology profes-

sor Frits Bienfait. In two-week summer camps without television or computer, she met students from all faculties who came together to discuss diverse and controversial subjects. A boxers' responsibility for his (or her) own brain, for example. "These were very important experiences for me, opportunities to consider things so intensely and from very different perspectives," sums up Roke.

She also tries to implement this integrated approach in her Max Planck Group. Here, chemists and physicists work together on both the experiment and the corresponding theories. Just recently they published a complete theory for their scattering method, the so-called nonlinear Mie theory. This enables them to describe the scattering process on spherical particles for any type of medium. In the future, they

And her personal future? There are no plans for any children, Sylvie Roke and her partner agree on that. "I like being an aunt and I Skype a lot with my nephew and niece. But children demand a lot of energy, I can see this with my sister. I enjoy what I do very much. Not many people have such an opportunity, and I think I should take advantage of it."

The next big project has already begun anyway: In 2009 she was awarded one of the coveted ERC grants from EU research support in the amount of 1.1 million euros to study emulsions. This will keep her busy until the end of 2014. Sylvie Roke is not worried about her long-term future: "There was a certain risk involved in starting work on my idea here." But now, since all ideas she start-

ed with work, she and her fellow scientists can investigate the smallest structures of soft matter and resolve the processes very well as a function of time and thus contribute to developing materials with new properties. "There are so many questions to be answered that we will certainly be occupied with this for the next 20 years. The Max Planck Society offers ideal conditions for that." ◀

GLOSSARY

Soft matter

Matter that is neither unequivocally solid nor liquid. Soft matter undergoes changes easily. It is characterized by the fact that small temperature changes in the vicinity of a system produce major changes in the system itself. Biological materials are soft. Milk, for example: without a refrigerator, it quickly turns sour. In solid materials, the associated temperature increase has no such effect.

Colloids

Small particles with a diameter in the size range of nanometers to microns.

Nonlinear vibrational spectroscopy

In contrast to linear spectroscopy, this is operated with not one, but two lasers for irradiation. The first one excites a molecule to vibrate. The molecules react to different frequencies depending on their structure. The second laser excites the molecule to emit a photon itself. This method works only with molecules in an asymmetrical environment, so for example on surfaces.

Light scattering

Light that strikes a particle from one direction is scattered in different directions. The incident light then temporarily converts the particle into an electric dipole, which oscillates and thus emits light. The direction of the scattered light depends on the size and shape of the particles. In the case of nonlinear light scattering, the molecular surface structure also determines the direction of light.