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SPECIAL ISSUE

Special Issue

APPLIED PLASMA RESEARCH

COMBINING BIOCATALYSIS AND PLASMAS

TRANSFORMING CLIMATE KILLERS INTO RAW MATERIALS

LIVE MONITORING OF THE INNER PLASMA PROCESS

Plasma physics

A REFERENCE SOURCE FOR PLASMA RESEARCH

Generating a plasma is not that difficult. Therefore, there are countless different plasma sources in the world. As far as research is concerned, this is a problem.

The areas of application for plasmas seem inexhaustible. In biomedicine, for example, the technology promises to heal chronic wounds better, kill antibiotic-resistant germs or treat cancer cells selectively. "There are many studies that show that plasmas could be useful for these applications," says Professor Judith Golda, research physicist in Collaborative Research Centre 1316. "But in order to use plasmas for these purposes, we need to understand their underlying mechanisms."

One problem is that while many studies have been done over the years, the techniques have not been comparable. "Making a plasma at atmospheric pressure is easy," Golda explains. "All you really need are two wires to which you apply a voltage so that an electric field is created that ionises the gas between the wires." Because it's so easy, many research groups have built their own plasma sources. But not all plasma is the same. There are many properties that determine how suitable a plasma is for a particular purpose, such as the strength of the electric fields or the type and quantity of reactive particles it contains.

Since both plasma physics and the biological processes that researchers want to manipulate with plasmas are very complex, it is difficult to explain the observed effects of plasma treatments mechanistically given the large number of variable parameters in plasma. In the early 2010s, therefore, the idea arose to develop a reference source, i.e. a plasma whose properties are precisely characterised and which can be reproduced with exactly these properties. The hope was that if different research groups used this plasma, they would know exactly which plasma parameters were responsible for certain effects. "Such a reference source already existed for low-pressure plasmas. We now wanted to transfer the concept to atmospheric-pressure plasmas," recalls Judith Golda, who already worked on this issue while doing her PhD at RUB.

Together with partners from Greifswald, Eindhoven, Milton Keynes, York and Dublin, the Bochum group selected a plasma source that RUB physicist Dr. Volker Schulz-von der Gathen had already studied in-depth. "An important argument in our selection process was that many other groups worldwide have already worked with similar sources. So, we were looking for a plasma that could be used by the majority, so ▸

The COST-jet is deployed at many plasma research sites. The map lists all locations known to RUB, but does not claim to be exhaustive.

The COST-jet, i.e. the reference plasma source developed in Bochum, is about the size of an index finger.

1

2

“We were looking for a plasma that could be used by the majority, so to speak.”

Judith Golda

to speak,” explains Golda. The international research team characterised the plasma source in detail. In the first step, the RUB researchers built five identical sources so that each cooperation partner could examine the plasma at their own location to ensure that it always had the same properties – which worked out well right away. The work took place within the framework of a funding programme of the European Cooperation in Science and Technology (COST). Thus, the researchers eventually dubbed their source COST-jet. Jet, because the plasma emerges from an opening in the form of a jet.

To make the plasma source available to all research groups worldwide, the team wrote detailed assembly instructions and published them online at cost-jet.eu, where they can be freely accessed. “However, because it is sometimes not so easy for researchers without prior experience to implement such instructions, we also made sure that the COST-jet could be purchased ready-built at cost price,” points out Golda. Sales are handled by Plasma Applications Consulting, a RUB spin-off.

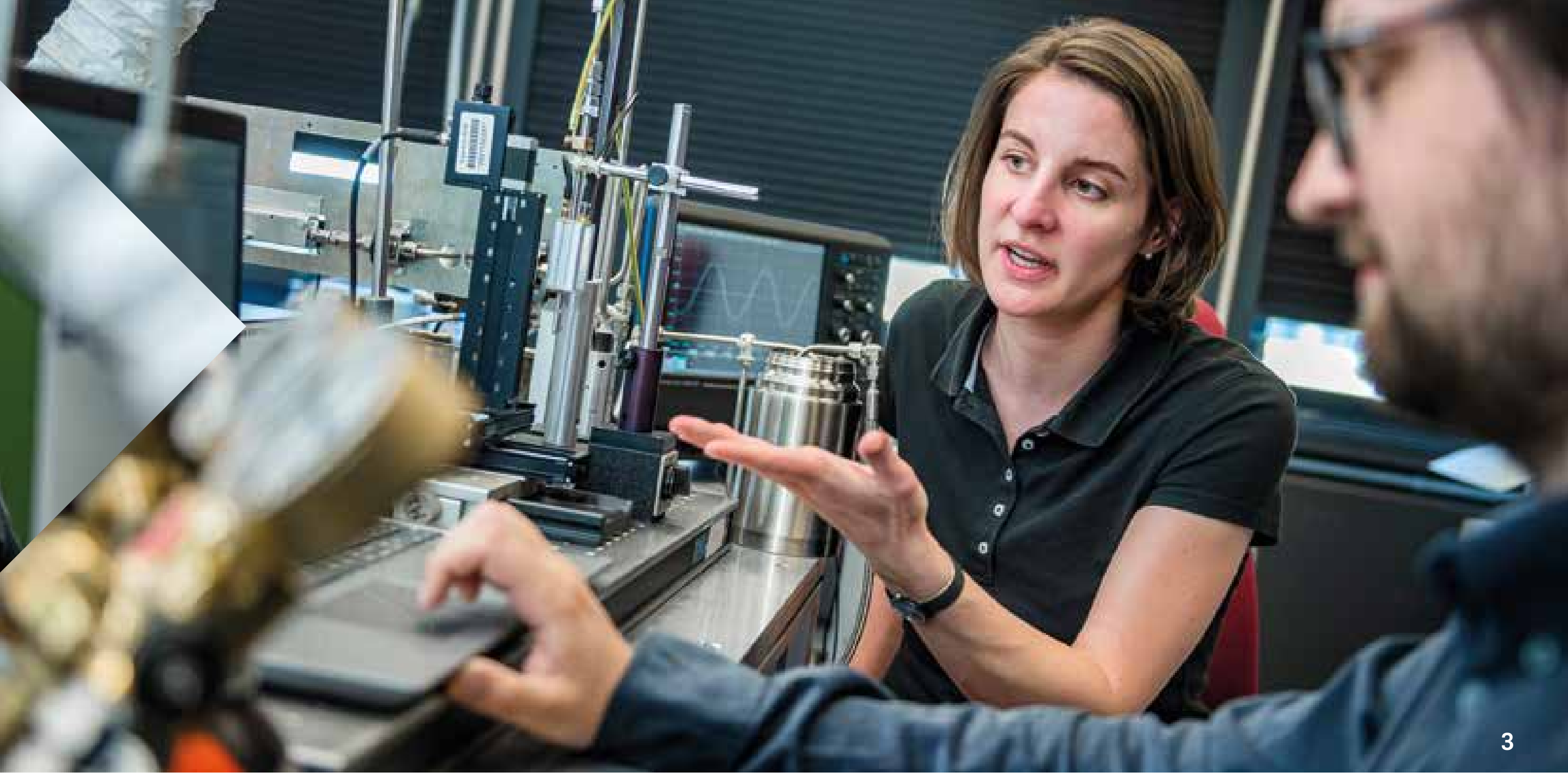
Many groups worldwide are now using the COST-jet, so the research done by all these groups is comparable. Theoretically working groups complement this research.

“There are, of course, alternative sources,” says Judith Golda. “And they also have their justification, because you need different plasmas depending on the application.” Nevertheless, the research physicist is pleased that the reference plasma developed in Bochum is deployed at many plasma research locations around the world.

At RUB, too, research is ongoing in this field under the umbrella of the plasma Collaborative Research Centres. Groups from the fields of physics and electrical engineering are cooperating, for example, to understand in detail which reactive species form in the COST-jet and how their quantity changes with increasing distance from the source. “Depending on which gas you use, up to 1,000 different reactions can take place in a plasma in quick succession, because the reactive species interact in many combinations,” outlines Golda. The COST-jet is based on the noble gases helium and argon with small admixtures of other gases, for example oxygen and nitrogen. If these are dissociated and ionised in the electric fields, the atoms can take on all kinds of reactive forms: oxygen, for example, can exist as a positively (O^+) or negatively charged ion (O^-), as a neutral atom (O), as molecular oxygen (O_2) or ozone (O_3). If nitrogen (N) is added to the mixture, numerous other combinations quickly emerge, for example NO, N_2O, NO_2 and others. “The reaction chemistry literally explodes,” as Golda describes the process.

The Bochum-based researchers were interested, for example, in how many reactive oxygen atoms are produced in the COST-jet and how their quantity decreases with increasing distance from the source. “Since many biological systems need a certain volume of atomic oxygen, plasma treatments with reactive oxygen species can have positive effects,” elaborates Judith Golda. “But sometimes it can be too much oxygen.” According to her, it is therefore important to know exactly how much reactive oxygen is present in the plasma and what the optimal distance from the target surface to the plasma would be. “This is the only way to later develop applications that are also safe for patients,” says the researcher.

Spectroscopy was used to make the necessary measurements. In the process, the researchers transmit laser light of a specific wavelength into the plasma. This light is absorbed by the oxygen particles, raising them to a higher energy level. After a while, they return to their ground state, emitting light of a certain wavelength, which the researchers can measure.



The emitted wavelength depends on the particle that emits the light; a neutral oxygen atom, for example, sends back different light than a positively charged oxygen ion. Based on the amount of light emitted at certain wavelengths, the researchers can thus deduce the amount of different oxygen species.

This is how the team found that the amount of oxygen atoms in the plasma decreases exponentially as the distance from the source increases. Using analytical models, they also showed why this is the case. "Because the particles are so reactive, they quickly react further to form other compounds, such as molecular oxygen or ozone," explains Judith Golda. The team is also researching the reactive species that result from adding nitrogen to the source, for example nitrogen monoxide (NO). This is particularly interesting for the researchers, because NO also occurs in the human body as a messenger substance and is important for wound healing. For example, they determine the flow pattern of NO molecules when they hit a surface from the plasma source.

Overall, the COST-jet is already very well characterised, according to Judith Golda. "We know pretty much what comes out of the source – that is only the case with a few sources," she says.

text: jwe, photos: dg

1 In order to characterise the COST-jet, lots of measuring equipment is necessary. The plasma itself is the purple light source, visible below the box with the RUB sticker.

2 PhD student David Steuer conducted the measurements of the reactive oxygen species in the COST-jet.

3 Judith Golda holds the assistant professorship for Plasma Interface Physics at RUB.

4 Volker Schulz-von der Gathen and Judith Golda are discussing the data analysis.

EDITOR'S DEADLINE

A glowing cup – easily done thanks to plasmas. The SFB team came across this object by chance and quickly integrated it into its experiments for students. The cup's coaster contains a coil to which alternating voltage is applied. This induces an electric field that accelerates the free electrons in the gas layer between the glass walls. They collide with gas atoms, which are excited and ionised. As a result, positive and negative charges of the gas particles are separated for a short time. When the atoms de-excite a light particle is released – the cup appears to glow.

photo: dg

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