Interview with Professor Andreas Gross and Anne-Laureen Lauven

"Even in the 21st Century Products Will Be Multi-Material Composites"

Making products from a uniform material to facilitate recycling at the end of their life – is that realistic in our modern world? And is this even the right approach? In an interview with **Plastics Insights**, Professor Andreas Gross, Head of Training and Technology Transfer at Fraunhofer IFAM, and Anne-Laureen Lauven, Head of Marketing at Plasmatreat GmbH, take a different view. An often underestimated joining technology plays a key role here.

The idea for this interview came about after a presentation that Prof. Gross gave at the International Sales and Technical Conference (ISTC) at Plasmatreat. The presentation essentially summarized the results of a 300-page study by the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, which was published in 2020. Title: "Circular economy and adhesive bonding technology". We want to know more about this connection. So the screens are switched on together.

Plastics Insights: *Professor Gross, it is only gradually becoming accepted that we are falling short when we consider recycling to be the core objective of the circular economy. There are two aspects to this: why and in what way is this the case?*
Andreas Gross: With regard to the first part of the question, it is simply the case that decades of preparatory work by collection systems such as the Yellow Bag (a German collection system for recycling, *editor's note*) have given the topic of recycling considerable importance and a positive image among the public and at political decision-making level. The core idea based on natural processes – if you recycle everything, you automatically get a circular economy – is certainly correct, but also very simplistic and at odds with reality. The figures speak for themselves: only just under ten percent of plastics are actually recycled. The figure published by Plastics Europe is from 2021, but nothing fundamental has changed to date.

Plastics Insights: *The rest?*
Gross: The rest is either downcycled, incinerated or thrown into landfill. Today, we can even see how recycling is sometimes degenerating into a marketing tool. One example: If it says on packaging that it is made of recyclable material, the consumer associates this with the fact that it is also recycled. Unfortunately, this is not true.

Plastics Insights: *And in what way has the focus on recycling fallen short?*
Gross: We can illustrate this by considering the following scenario. If we make recycling the sole decision criterion for a circular economy, wind energy will be dead tomorrow. The rotor blades of wind turbines consist of half-shells that are bonded together. However, according to the current state of science and technology, the matrix resins used to manufacture these rotor blades cannot be recycled. They are thermosetting plastics – although work is being done to recycle these materials, too, there is still no solution. Plastics are very complex materials and recyclates must ultimately be of a quality that allows them to be reused as secondary raw materials. Adhesive bonding has nothing to do with this.

Plastics Insights: *How does the circular economy work?*
Gross: A central component of the circular economy action plan is the EU Waste Framework Directive. It contains three key points – we all like to grumble about Brussels, but they have really put some thought into this and the whole thing has also been defined from a technically correct point of view. Logically, the primary aim must be to produce as little waste as possible. Point one.

Guiding Principles of the Circular Economy

Circular economy means more than just recycling. Rather, a holistic approach to the circular economy must include all aspects from product design and raw material production through to recovery after use. In this context, people often talk about so-called R-strategies. These form the framework for transformation and are intended to open up new options for action for circular value creation. According to the basic principle of "Reduce, Reuse, Recycle", the product life cycle should be extended and a linear economic system should be transformed into a circular one.

- Guiding principle 1: refuse, rethink, reduce
- Guiding principle 2: reuse, repair, refurbish, remanufacture, repurpose
- Guiding principle 3: recycle

According to this concept, eight R strategies are therefore at a higher circularity level than recycling.

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The study "Circular economy and adhesive bonding technology" cited at the beginning is available at:
www.re-form-material.ifam.fraunhofer.de/en/projects/circular-economy-adhesive-bonding.html

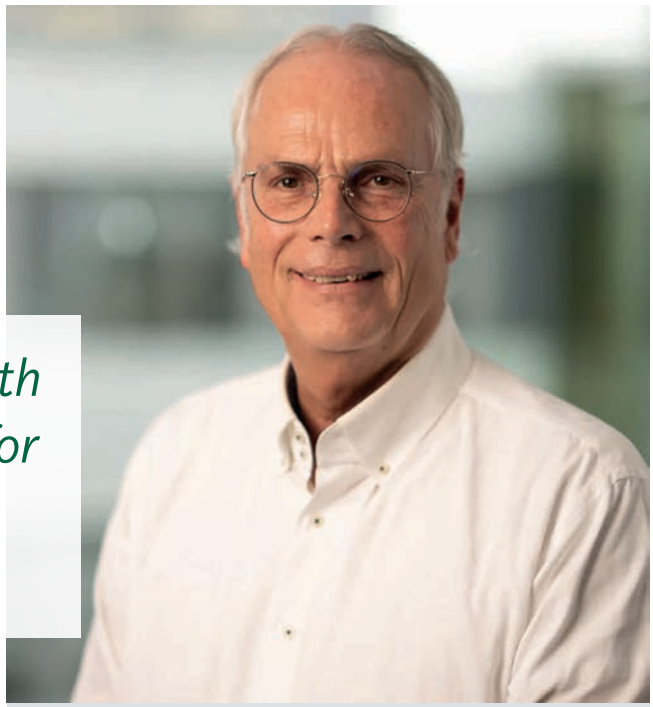
Plastics Insights: *This tends not to be perceived in this way by the public.*
Gross: Not at all! But from an ecological point of view, the most important thing is to avoid waste. The second is the recycling of waste. Here, recycling is in the middle of the pack in terms of importance. And at the very end of this, figuratively speaking, inverted pyramid comes the disposal of waste. All in all, this is a very clever and sensible definition by the EU Commission, but it contradicts the role that is often assigned to recycling.

> *„Future design must enable both repairability and separability for potential recycling."*
>
> Prof. Andreas Gross

Plastics Insights: *Three guiding principles are derived from this, which give life to the whole thing. What are they and how can they work in practice?*
Gross: We are talking about the so-called R-strategies, which are all derived from the first letter of the English verbs in question (**see Box,** *editor's note*). This is nothing other than a refinement of the Waste Framework Directive. Guiding principle one addresses the need for more intelligent product manufacture and use in order to reduce the consumption of raw materials. The second guiding principle is primarily about extending the life of the product and its individual parts in order to keep raw materials in the economic system. Only then, in third place, comes the useful recycling of materials in order to obtain secondary raw materials.

Plastics Insights: *So being able to repair products is an important factor. However, design for recycling is being preached everywhere. Where is the design for repairability?*
Gross: Some sectors are a little more advanced in this respect, such as rail vehicle construction – where the repairability of all connections is the subject of every tender. In the public eye, however, recycling is, as I said, more prominent than repairing. But there is another overriding aspect: what must never be called into question is product safety. This is stipulated by the Product Safety Act and is paramount. Only then can we think about everything else. But for me it is clear that future design must enable both repairability and separability for potential recycling.

Plastics Insights: *Repairability means that, when there is doubt, a product must be able to be dismantled. Strangely enough, one of the high-performance joining techniques, bonding, is often viewed rather critically, almost as an obstacle to recycling. With a holistic view of the circular economy, one has to say: what nonsense. Or is it?*
Gross: Yes, even the relevant professional associations are struggling to straighten out this skewed impression, which is also prevalent at a political level. You have to know: no matter what joining technology is used – every soldered joint, every welded joint, every nailed joint – there is no joint that cannot be undone.



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About the Interviewee

Prof. Dr. Andreas Gross has worked at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM for over 35 years and heads the "Continuing Education and Technology Transfer" department. He also works on various committees and working groups, including as Director of the Fraunhofer Academy, chairman of working group V8 "Adhesive Bonding Technology" of the DVS – Deutscher Verband für Schweissen und verwandte Verfahren e.V. (German Association for Welding and Related Processes), chairman of the working group "Adhesive Bonding DIN 6701" and member of the Technical Committee (TA) of the Industrieverband Klebstoffe e.V. (German Adhesives Association).

This also applies to bonding technology. However, there is a difference in technical definition between detachable and non-detachable joints: in the one case, the joining parts are not damaged by the separation process and can be reused afterwards; in the other, they are deformed or destroyed. However, none of this has anything to do with recyclability; only the individual materials themselves count. I assume that this will be published as an international standard in 2025; the corresponding ISO project ("Adhesives – Guideline for separating adhesively bonded joints, enabling repair, and improving recycling", *editor's note*) is already in progress.

Plastics Insights: *How can bonded joints be released?*
Gross: In the simplest case, for example between the car window and chassis, the thick-film adhesive is simply cut open. Another option is to heat the bond. Adhesives are plastics – once they have passed their glass transition zone, they become soft. Or you can cool the whole thing to below the glass transition zone, then they become brittle. This is also a typical property of plastics – the brittle joint can be separated. In summary, adhesives are the key to separability, repair, and recycling. »

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About the Interviewee

Anne-Laureen Lauven is Head of Marketing at Plasmatreat GmbH in Steinhagen, Germany. She studied business administration in Magdeburg and Bielefeld, Germany. Since then, the business studies graduate can look back on 15 years' experience in B2B marketing. She is at home both in strategic marketing and in an international environment and sees herself as a bridge between technology and customer benefit.

Plastics Insights: *What role will joining technology in general play in the future?*
Gross: In order to remain economically viable on the market, today's products have to meet ever-increasing requirements. This must be achieved technologically, economically, and ecologically – but the requirements are becoming so complex that one material alone, the mono-material, can no longer fulfill them. Consequently, materials must be combined with others. In the 21st century, too, products will be multi-material composites. And the more highly developed a material is, the more sensitive it becomes to production requirements. It is precisely in this area of tension that adhesive bonding technology comes into play.

Plastics Insights: *What advantages do you see in adhesive bonding technology in general compared to other joining processes?*
Gross: Adhesive bonding technology is the only joining technology that can securely join the same or different materials over the long term without impairing the material properties of the joining partners. I don't drill any holes that lead to stress peaks under load, and I don't have a heat-affected zone as with welding and hot soldering. In addition, adhesive bonding technology enables new construction methods – lightweight construction is a classic example of this. And the fourth point: I can develop adhesives in such a way that they go beyond the main functions of adhesive bonding technology – force transmission and deformation compensation between the parts to be joined – and integrate additional functions such as sealing, vibration damping, thermal conductivity, separability and, in microelectronics, electrical conductivity.

Plastics Insights: *At this point, we turn our attention to the application side – with a discussion partner who brings a different perspective to the table. Namely, that plasma treatment can significantly expand the range of applications for bonding. Ms. Lauven, what is behind this?*

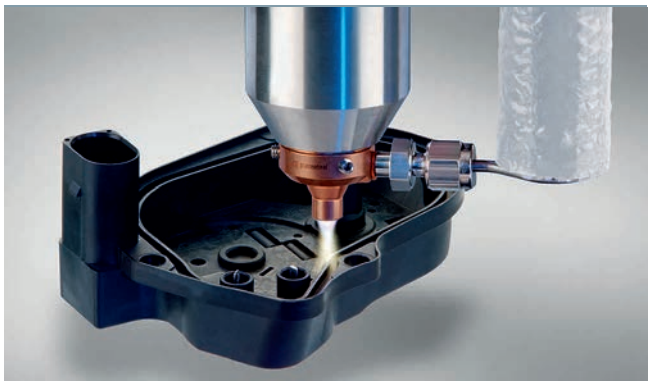
„Plasma treatment leads to long-term adhesive strength stability of adhesives, inks, and varnishes."

Anne-Laureen Lauven

Anne-Laureen Lauven: Plastics as such do not actually bond very well. However, if their surface is activated with a plasma treatment, they are easier to bond with adhesives. This is due to the fact that during the treatment of mostly non-polar plastics, oxygen- and nitrogen-containing groups are introduced into the surface, which cause a significant increase in adhesion. This in turn leads to long-term adhesive strength stability of adhesives, paints, and varnishes – we are more broadly positioned in our range of applications. But to stay with bonding: A well-known example, which Professor Gross has already mentioned, is wind turbines, where the rotor blades can be bonded together to a high quality using our plasma technology.

Plastics Insights: *How would you categorize plasma technology according to the mentioned guidelines?*
Lauven: I also believe that future products will want to combine more and more different materials. That's why we absolutely need well thought-out design solutions. Plasma technology supports the three key principles – reduce, reuse, recycle – by contributing to more efficient use of resources, longer product life, and improved and more versatile use of recycled plastics. What's more, applications with atmospheric pressure plasma are clean processes. Only compressed air and electricity are required to operate the plasma nozzles, and no waste is produced. In addition, the use of plasma can save considerable CO_2 emissions, especially if green energy sources are used. Another advantage is that the use of environmentally harmful chemicals is no longer necessary in subsequent processes such as bonding, painting or printing. This significantly improves the environmental balance of many processes.

Plastics Insights: *Let's stick with the three "Rs" I just mentioned. Can you give us specific examples?*
Lauven: The improved adhesion opens up a wider range of materials for users. Under certain conditions, expensive and energy-intensive engineering plastics can be replaced by cheaper standard plastics. For example, one user was able to replace the previously used PC+ABS material with simple PP when bonding headlight housings, thus saving 3100 tons of CO_2 per year. Or the topic of durability: Plasmatreat's PlasmaPlus technology comes



PlasmaPlus technology solves adhesion problems, for example, by applying a PT-Bond plasma polymer layer to plastics that are difficult to bond. The bifunctional layer promotes adhesion both to the plastic and to the adhesive. © Plasmatreat

into play for particularly stubborn cases. A so-called precursor is added to the plasma nozzle, which creates a nanolayer on the plastic surface. This optimizes the adhesion of the adhesive and the long-term stability of the material bond. One car manufacturer uses the process to achieve a durable "plastic to metal" tailgate bond.

Plastics Insights: *And the third point – to what extent does plasma simplify the processing of recycled plastics?*
Lauven: Compared to virgin material, recyclates have altered surface properties that make processing more difficult. Plasma technology is establishing itself as a real game changer here, because in many cases it not only improves the processing of recycled plastics, but actually makes it possible for the first time. At K fair 2022, for example, we showed how automotive dashboards containing a high proportion of recycled material can be successfully laminated with so-called molded skins. An end customer rarely thinks about how the leather-like feel is applied to the dashboard.

Plastics Insights: *I also remember an exhibit with an Arburg machine where freshly injection-molded cups were UV printed.*
Lauven: That's right, they were drinking cups made from recycled PP. After an Openair-Plasma pretreatment, excellent adhesion of solvent-free printing inks was achieved without the use of additional adhesion promoters. In this way, the cups were printed with a recycling code in addition to the main image, which later assists a correct recycling process.

Plastics Insights: *What is the strongest growth area at Plasmatreat?*
Lauven: Automotive and electronics. This often involves future technologies. The two sectors also come together in electromobility. An example from battery production: before they are bonded to the next module, either a PET film coating or a layer of paint is used to insulate battery cells. It is important that no bubbles form when the film is applied and that the paint adheres to the cell throughout. Otherwise, faults can occur in the insulation, which can usually only be detected on the finished battery module – ultimately resulting in expensive rejects. Openair-Plasma pre-treatment of the aluminum alloy prevents this production error. Such innovations often put us in pole position in new fields of application.

Plastics Insights: *Where else?*
Lauven: Lightweight construction is an essential part of electromobility. In addition to the consumption of resources, vehicle weight has a direct impact on EV range. This involves, for example, the question of how metal and thermoplastics can best be combined to achieve a certain rigidity and meet sustainability criteria. This is an exciting area of application for Plasmatreat, where we are also involved in various research projects.

Another area of use relating to electromobility is in fuel cell technology. Bipolar plates are central components in fuel cells, as they act as electrical conductors between the cells, distribute the reaction gases, and at the same time transport cooling media to dissipate the reaction heat. Here, plasma treatment can help provide bipolar plates with long-term seal stability and increase the hydrophilicity of the plates. »

Pretreatment with Openair-Plasma extends the choice of materials, for example to recycled plastics. In addition, only very little heat is generated, so the components remain dimensionally stable and can be readily processed. © Plasmatreat

Plastics Insights: *What has been your focus at the Fakuma trade fair last year?*
Lauven: We have shown a broad cross-section of how we can modify plastics so they can be used as flexibly as possible. One theme we presented for the first time at a trade fair was the combination of plasma treatment and subsequent tape application. At the live plasma table, we showed how test specimens made of different plastics such as PP, PE, and ABS are activated using plasma technology. A tape was then applied to the treated test specimens on a special tape demo system to demonstrate the effectiveness of Openair-Plasma pre-treatment in various tests. Nothing new for us, but we believe that there is still a need for explanation here.

Plastics Insights: *Mr. Gross, apart from briefly mentioning the Yellow Bag earlier, we haven't talked about the largest area in terms of volume, that of short-life packaging. How can the R-strategies be applied here?*
Gross: We have to be a little careful because, here too, we need to take a holistic view of the issue. Only then can we arrive at an ecologically sensible assessment of the situation. If we reduce the issue of packaging to recycling, that is too short-sighted. Packaging always has several functions, such as making the transportation of goods as efficient as possible, i.e. with the lowest possible energy consumption ...
Lauven: ... or to extend the shelf life of food ...
Gross: ... this type of ecological impact must also be taken into account. What use is it if the energy and auxiliary materials such as solvents required for recycling are greater than the positive effect of the recycled material? Don't get me wrong: I'm not saying that recycling is nonsense, I just want it to be considered holistically and realistically.

Plastics Insights: *In the interests of balance, you could now mention the negative aspects of bonding ...*
Gross: You wouldn't believe how broadly based adhesive bonding technology is. Its technological performance is outstanding, yet it has a poor image – the opposite is true for recycling. We need to overcome these reservations about adhesive bonding technology, then completely different opportunities will open up for the circular economy. Even if I can't think of anything now, there may be cases where adhesive bonding technology has a negative ecological impact. Then it will be done differently. But, to put it bluntly, the potential of adhesive bonding technology and plasma technology is far, far from exhausted. ■

Interview: Dr. Clemens Doriat, editor