Position paper
on the
classification of
adhesives and sealants
as
ADVANCED MATERIALS

Content

0 Preliminary remark: Definition of ‘Advanced Materials’

Neither ISO nor CEN provide a clear definition of ‘Advanced Materials’. In its communication COM/2024/98 ‘Advanced Materials for Industrial Leadership’, the European Commission describes the term precisely in terms of content, but not as a separate definition, and refers to the OECD definition.
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52024DC0098

The OECD defines ‘Advanced Materials’ in a ‘working description on advanced materials’ as follows:

‘*Advanced materials are understood as materials that are rationally designed to have (i) new or enhanced properties, and/or (ii) targeted or enhanced structural features with the objective to achieve specific or improved functional performance. This includes both new emerging manufactured materials (high tech materials), and materials that are manufactured from traditional materials (low tech materials).*‘
https://one.oecd.org/document/ENV/CBC/MONO(2022)29/en/pdf

1 The significance of materials, including advanced materials, in the 21st century

The development and refinement of materials is essential because the demands placed on products in the 21st century are constantly rising. Examples of increasing product requirements include lightweight construction, miniaturisation, extended product life, repairability, quality improvement, design requirements, waste prevention and much more.

As these examples of increasing product requirements illustrate, meeting these requirements is where innovation lies. Consequently, meeting these innovation-driven requirements is the task of the materials used in the product, including advanced materials. More specifically, it is the *properties* of the materials used that meet the innovative product requirements, in particular the properties of advanced materials.

To cope with the new demand, the variety of materials across different classes (such as metals, plastics, glass, ceramics) is steadily growing in recent decades. Consequently, material diversity is a characteristic feature of the 21st century.

2 The significance of material compounds in the 21st century

The products of the 21st century will largely be made of material compounds, i.e. combing materials of different matters. This technology trend reflects the fact that a single material – whether ‘conventional’ or ‘advanced‘, ‘high-tech’ or ‘low-tech’ – is usually not capable of meeting those complex, innovation-driven requirements as described above. This also applies to materials that already have new or improved properties, structural characteristics, and/or functional performance. Realising tangible new products by solely using mono-materials just seems unreasonable as it would also have huge limiting effects on innovation and hence, sustainable economic growth.

3 The significance of joining technology for materials, including advanced materials, in the 21st century

3.1 The predominant systemic fundamental error

Against this background, the development, support and promotion of materials is not an end in itself. Rather, the stated goal is to enable technological, economic and ecological innovations that would not be possible without materials.

At present, however, the systemic error is still being made of focusing solely on materials development. As correct and necessary as the promotion of materials development – and thus, also the development of ‘advanced materials’ – definitely is, it is only one side of the medal.

The other side of the medal, if the actual goal of truly exploiting the ‘advanced material potential’ for product innovations is to be achieved, consists of giving equal consideration to material development and developed materials in direct connection with the appropriate joining technology. To achieve the above-mentioned and desired goal, material developments and suitable joining technology are interdependent. How this ‘suitability’ in terms of joining technology is to be understood is explained and justified below. In any case, it is clear that without this combined thinking about materials and joining technologies, the development, support and promotion of materials, including ‘advanced materials’, would remain a useless end in itself.

3.2 Increasing demands on joining technology: preserving the material properties of the materials to be joined

The necessity of joining materials for a final product means that a material – even an ‘advanced material’ – can only become a productive, economically and ecologically usable and ultimately innovative material if it can be joined with each other materials, including ‘non advanced materials’. This joint must be stable and secure in the long term and, at the same time, ensure that the special properties of the materials used are not lost and that these properties, in their interaction, meet the requirements profile of the respective end-product.

Therefore, the generic task of joining technology is primarily to join materials, which are sometimes different. This leads to two conclusions for joining technologies:

1. Due to the increasing performance requirements for products and thus for the individual materials used, the requirements for joining technologies are also increasing in parallel.
   The development of advanced materials must *fundamentally and always* go hand in hand with the development of joining technologies whose ‘suitability’ includes the preservation of material properties. Without these joining characteristics, the materials cannot meet the requirements of the product profile and the end-product cannot deliver the desired innovation.

3.3 Use of adhesives and sealants: Adhesive bonding technology as a key joining technology of the 21st century

These increased demands on joining technology have led to adhesives and sealants playing a key role: even today, our everyday lives would be unthinkable without adhesives and sealants, as they have long since fulfilled the above conclusions.

In this context, the use of adhesives and sealants offers the innovation potential required for the 21st century. Adhesive bonding technology is the sole, most versatile joining technology that can be used to either assembly ALL materials with themselves and with each other in numerous combinations in a long-lasting, stable and safe manner while at the same time preserving *the properties of the materials to be joined.* In concrete terms, this means that adhesively bonding is the only joining technology that avoids changes in material properties caused by material-damaging fastenings such as drill holes, as is the case with screws, rivets or nails, and structural changes caused by thermal loading, as occurs during welding or brazing.

What's more, adhesives and sealants can be used to integrate additional functions into the product.

It is precisely these unique properties of adhesives and sealants that offer enormous potential for future innovations. From a purely technological point of view, this potential is far from being exhausted. The technology therefore has a bright future ahead of it and is undoubtedly indispensable for the 21st century in terms of technology and innovation. In fact, adhesives and sealants are already ‘advanced materials’ today.

The innovation potential is further enhanced by the chemical diversity and versatility of adhesives and sealants, offering almost unlimited possibilities for integrating additional functions into the adhesive or sealant and thus into the material compound, which often go beyond the mere joining and integrity of the material properties. Such integrated additional functions include, for example, thermal and electrical conductivity or insulation. Adhesives can also serve as barrier materials for water vapour, plasticisers and other media.

The material-fit (in the sense of materially coherent) joining technology of adhesive bonding results in combined property profiles for the material connection that cannot be achieved with any other joining technology.

In addition, adhesive-specific application technology plays an extremely important role in this innovation context. Adhesives can be applied in extremely small quantities, for example in spray or drip applications, but also in considerable quantities, for example in gap fillers or potting compounds. Modern, partly robot-assisted application technologies enable defined application weights with low variation limits and application speeds of up to 1000 m/min in continuous lamination processes.

The physical diversity of adhesive delivery forms and adhesive bonding technologies does not limit the use of adhesives in any way. It is simply a matter of selecting the right adhesive bonding technology to join materials under conditions such as heat, cold, pressure, high humidity, underwater, in a protective atmosphere, etc., in such a way that their properties are fully retained.

The use of adhesives and sealants meets the above requirements and enables innovative, future-oriented design and manufacturing methods for the 21st century from a technological, economic and ecological point of view.

3.4 Examples of the necessary use of adhesives and sealants

3.4.1 Preliminary remark on the following examples

The following examples – which are certainly only a few and do not claim to be exhaustive – illustrate the necessity of always considering ‘materials’ and ‘joining technology’ together if the innovation potential of the end-product is to be optimally exploited: When lightweight materials are used in lightweight construction, the ‘lightweight properties’ of the material must be exploited as far as possible. Otherwise, optimal lightweight innovation is not possible. If, due to increasing functionalities, ever smaller dimensions of an (electronic) component are to be realised, the joining technology must be able to cope with these smallest dimensions. Otherwise, such innovative functional enhancements cannot be optimally achieved. Materials and joining technology must meet the requirements of the energy transition. Without this prerequisite, innovation in the energy transition is not possible to the desired extent. This also applies to energy generation from alternative energy sources.

3.4.2 Adhesives and lightweight construction

Lightweight design involves achieving the same functionality over the long term with less material. This undoubtedly makes it one of the most effective eco-design strategies for avoiding waste and saving energy in the ‘utilization’ phase of a product's life cycle. Due to its unique potential to join all materials – including lightweight materials – to itself and other materials in a long-term stable and safe manner while maintaining the (lightweight) material properties in the product, adhesive bonding technology is one of the most important joining technologies for implementing both structural and material lightweight design. Adhesives and sealants are therefore enablers of innovation in this context.

Adhesive bonding technology is therefore also a key technology for a circular economy.

3.4.3 Adhesives and miniaturization

In electronics manufacturing, where continuously increasing functionality requires smaller dimensions, adhesives are ideally suited for joining a wide variety of materials quickly and securely. In addition, adhesives enable the material-appropriate, high-precision joining of miniature components during miniaturization: fixing coils, sealing housings, use as chip encapsulants in high-reliability applications to protect fine chip structures and wires from mechanical stresses such as vibrations and temperature fluctuations, and environmental influences such as moisture and corrosion. Here, too, it is solely adhesives and sealants that optimally fulfil the desired innovation.

With other joining techniques this can only be achieved at significantly higher effort or not at all.

3.4.4 Adhesives and energy transition

Adhesive bonding is an important enabler for the desired energy transition. The rotor blades of wind turbines are purely adhesively bonded constructions made of glass fibre reinforced plastics, known as GFRP. Given the high mechanical and abrasive loads during the utilisation phase, with rotational speeds of up to 390 km/h, any other joining technology would minimise the energy yield to such an extent that wind energy would no longer be economical. Welding as a joining technology is out of question: the GFRP used is not weldable. Screw connections – ditto rivets or nails – of the rotor blade half-shells are also out of the question. These spot joining technologies would generate high stresses at the connection points during utilization, where the GFRP would have to be destroyed by ‘holes’. The rotor blade’s walls would have to be greatly thickened to reduce these stresses. The construction would thus be far too heavy and inefficient for energy generation. In addition, in order to mitigate the high abrasion loads, a protective layer is already adhesively bonded to the particularly stressed front edges during rotor blade production. The surfaces protected in this way by adhesive bonding create a permanently smooth and therefore aerodynamically favourable surface for the extreme offshore conditions.

The use of adhesive bonding technology not only optimises energy yield. Adhesives and sealants are what make this innovation in ecological energy production economically viable in the first place.

3.4.5 Adhesives and alternative energy sources

The development of alternative energy sources without adhesive bonding technology is inconceivable given the current state of the art. Adhesives and sealants are used in electro-mobility for the assembly of magnetic cores, for sealing battery cells and for the necessary heat management of batteries. Fuel cells must also be hermetically sealed, and the bipolar plates must be joined in a safe and long-term stable manner.

This innovation is done using adhesives and sealants.

3.4.6 Adhesives and circular economy

Adhesive bonding technology, i.e. the use of adhesives and sealants, supports the circular economy and is not its enemy.

The superordinate goal of a circular economy is to decouple economic growth from resource consumption. The EU Action Plan for the Circular Economy describes the transition from a linear economy (also known as a ‘throwaway economy’) to a circular economy. Unfortunately, both in popular opinion and in political assessment, the term ‘circular economy’ is all too often mistakenly reduced to the topic of ‘recycling‘. ‘Circular economy’ is incorrectly understood as ‘recycling economy’. The fundamental error in this incorrect reduction of meaning is that the Circular Economy Action Plan sets out a much broader scope and deliberately does not focus on a single element such as recycling. On the contrary, the Circular Economy Action Plan takes a holistic view of the product life cycle and evaluates it in terms of its overall resource efficiency. In line with this requirement for a holistic assessment, both the EU Waste Framework Directive with its five-stage waste hierarchy and the EU Commission's cataloguing system with its nine R strategies (R9 – recycling is last on the list!) serve as guidelines for the circular economy. The EU Waste Framework Directive and the associated R strategies, whose ranking in order of importance is binding on the Commission, thus establish a link between eco-design and the circular economy.

In this context, adhesive bonding technology makes outstanding, indispensable and innovative contributions that must be taken into account in its technological, social and political classification.

Adhesive bonding technology is not in contradiction with recycling.

Technically accurate, adhesive bonding is classified as a ‘non-detachable’ joining technology. (Sources: M. Bassing, Lösbare Verbindungen. https://www.metallbau-stahlbau.net/loesbareverbindung, access 31.08.2025) / M. Bassing, Lösbare Verbindungen. https://www.metallbau-stahlbau.net/unloesbare-verbindung, access 31.08.2025). However, this technologically correct classification is generally misunderstood in the popular and political assessment of adhesive bonding technology – and especially in ecological considerations. Logically, this misunderstanding leads to the equally incorrect assessment that ‘non-detachable’ joints, such as adhesive bonding, make recycling difficult or impossible due to their seemingly non-detachable nature.

In principle – and therefore also for adhesive bonding technology – any joint produced using either ‘detachable’ or ‘non-detachable’ joining techniques can also be detached again. The only difference between the two joining technologies is that with ‘detachable joining technologies’, the joining partners do not suffer any (usually geometric) damage during the separation process and can be reused as joining parts for new product manufacturing after the separation process. In products manufactured using ‘non-detachable’ joining technologies, one or both joined parts are often damaged or contaminated (usually geometrically) by the separation process. Nevertheless, through targeted product design and the selection of suitable separation processes, repair or recycling is still possible even for adhesively bonded products, despite the use of adhesives and sealants.

The separation processes for adhesively bonded products were published in summary form in DIN/TS 54405:2020-12 (Source: DIN/TS 54405-04, Construction adhesives – Guideline for separation and recycling of adhesives and substrates from bonded joints, DIN Media Berlin, 2021). The document already provides users with guidelines for detaching adhesively bonded joints and is currently being converted into an ISO standard in a current project (Source: ISO/AWI 21037, Adhesives – Guideline for separating adhesively bonded joints enabling repair and improving recycling, current ISO project).

4 Adhesives and sealants: their significance as ‘advanced materials’

Adhesives and sealants in an adhesively bonded joint, in their solidified state, i.e. when they are chemically cured or physically hardened, act as a *‘material between materials’* between the parts to be joined and fulfil their joining function. Their properties and structural characteristics, which develop during the adhesive bonding process between the parts to be joined, enable the specific functional and innovative performance of the end-product.

For this reason, adhesives and sealants are not only just as important as the ‘advanced materials’ themselves. They also fulfil the same level of innovation as ‘advanced materials’ because they preserve the innovation-required properties of the ‘advanced materials’ in the end-product. For this reason, and due to the innovation potential of chemical versatility described in Chapter 3.2, adhesives and sealants must also be classified as ‘advanced materials’.

However, adhesives and sealants must be classified as ‘advanced materials’ in their initial state, i.e. in their chemically uncured or physically unhardened state. It is the solidification of the adhesive during the adhesive bonding process that then leads to the innovation-promoting ‘material between materials’ as a joining element.

Since in material composites ‘advanced materials‘ can only develop their special properties in a product if they are joined with each other and/or with other materials in such a way that the performance-driven combination of material properties corresponds with the overall requirement profile, this is only possible in most cases with the aid of adhesive bonding technology for the reasons mentioned above.

Unlike welding and soldering, which are ‘homogeneous material fit’ (homogeneous materially coherent) joining technologies, adhesive bonding is correctly classified as a ‘heterogeneous material fit’ (heterogeneous materially coherent) joining technology. The ‘heterogeneity’ of the material fit results from the special feature that, after solidification (curing/hardening), the joining elements adhesive and sealant consist of separate and usually polymeric materials that are different from the material to be joined in terms of material technology.

The development and use of so-called ‘material cards’ in FEA (finite element analysis) and CAE (computer-aided engineering) processes is a clear indicator that hardened or cured adhesives have long been regarded by their users as an autonomous ‘advanced material’ and that the modelling and design of the ‘material between materials’ and the resulting interfaces with the substrates are already being taken into account.

Since the adhesives create a heterogeneous material fit joint between the parts to be joined after they have solidified, i.e. after they have cured or hardened, the solidified adhesive fulfils the OECD definition of ‘advanced materials’ mentioned at the beginning as a ‘material between materials’ due to its design, which is specifically tailored to the respective application (‘*…rationally designed to have (i) new or enhanced properties, and/or (ii) targeted or enhanced structural features with the objective to achieve specific or improved functional performance…*‘).

Adhesives and sealants therefore represent the innovative joining element ‘advanced materials’ – preserving material properties and specifically designed with regard to the respective joining materials and their properties, as well as the requirements for the material compound.

5 Summary

- Due to increasing product requirements, the (further) development of materials, including advanced materials, is absolutely necessary.
- Material development only makes sense from a technological, economic and ecological perspective if materials *and their joining* are assessed equally and treated as interdependent.
- The spectrum of requirements for a joining technology is expanding: it is no longer just a matter of joining materials and components. In the 21st century, joining technology must also preserve the properties of the materials and components used in the product and, where possible, create synergies through material combinations.
- The safe and long-term stable joining of materials *while maintaining their often highly specialized properties* is the unique selling point of the joining technology ‘adhesive bonding‘ and sets it apart from other joining technologies. This is the decisive reason for the innovation potential of adhesive bonding and sealing technology, i.e. the use of

adhesives and sealants as innovative materials. Adhesives and sealants are specially developed ‘advanced materials’ in relation to the respective materials to be joined.

- Against this background, when joining technologies are compared, the heterogeneous material fit joining technique of adhesively bonding, with its high-performance materials of adhesive and sealant arising from hardening/curing, occupies the innovative key position for the 21st century in terms of technology, economics and ecology.
- Their classification characteristic as ‘advanced materials’ applies both in their uncured/unhardened initial state, i.e. *before* application to the parts to be joined, and in their cured/hardened form *after* application between the parts to be joined.
- Meeting the increasing complexity of product requirements leads to the inseparable linking of materials *and* joining technology. Due to the unique joining potential of adhesive bonding technology, adhesives and sealants must also be classified as ‘advanced materials’.
- Without the equal status of adhesives and sealants both before and after their application with (or as) ‘advanced materials’, the development of advanced materials makes no sense technologically, economically or ecologically.
- Adhesives and sealants have therefore also been added to the ‘advanced materials’ group!

6 Perspective

Europe still holds the undisputed global leadership position in adhesive bonding technology and sealing technology, i.e. in the use of adhesives and sealants. Innovations involving the use of adhesives and sealants originate largely in Europe. This leading position must be maintained and expanded. This is particularly important in light of the background that there have been and continue to be many areas in which Europe has lost its technological leadership, resulting in economic disadvantages and dependencies**.**

If Europe fails to maintain and, if possible, expand its leading position in adhesive bonding technology, development in this field will take place elsewhere in the world. The USA and China are certainly the first that come to mind in this regard. As in many other areas of technology, Europe would then relinquish its leading role in this field as well and soon lag behind in the development of this future-promising area of adhesive and sealant application.

This danger increases if adhesives and sealants are not treated as ‘advanced materials’ and classified as such. Adhesives and sealants are ‘specially developed materials between the materials in the joint’ and must therefore be classified in the ‘advanced materials’ group. Even in their uncured/unhardened initial state, they must be treated with the same technological and strategic focus as all other ‘advanced materials’.

Without this equality, current and future advanced materials run the risk of only being able to exploit their undisputed great potential in the development of new, innovative products to a limited extent in the future.

7 Sources

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8 Annex

8.1 Fraunhofer Society

With around 32,000 employees at 75 institutes and independent research facilities and an annual budget of €3.6 billion, the Fraunhofer Society is one of the world's leading organisations for application-oriented research. It plays a central role in the innovation process, with a focus on research into key technologies of future relevance and the transfer of research results to industry in order to strengthen the economy. For the benefit of society, it occupies a unique position in the science and innovation system as an 'adapter' between knowledge-oriented basic research and the results-oriented integration of research and development into the economy. The Fraunhofer Society's core business model is therefore contract research. Consequently, the high proportion of commercial income is Fraunhofer's decisive unique selling point and, at the same time, guarantees close cooperation with business and industry and the constant market orientation of Fraunhofer research. (Homepage Fraunhofer-Gesellschaft)

8.2 Fraunhofer Institute for Manufacturing Technology and Advanced Materials – Fraunhofer IFAM

With its areas of expertise in adhesive bonding technology, surfaces, shaping and functional materials, and its approximately 700 employees, Fraunhofer IFAM is the fifth largest institute in the Fraunhofer Society. Fraunhofer is the leading independent research institute in the field of joining technology adhesive bonding. For more than 50 years, highly qualified, multidisciplinary teams have been working independently of suppliers on the further development of this multifaceted joining technology. The many years of experience, the high degree of diversification of the more than 200 employees working in this field and the comprehensive range of equipment enable the rapid and high-quality processing of services and research and development contracts, from one-day consultations to the detailed design and practical implementation of tested manufacturing concepts. As the world's only independent R&D institution for all industries (mobility, energy, aviation, maritime

technologies, medical technology and life sciences, mechanical and plant engineering, electronics and electrical engineering, ship and rail vehicle construction, the packaging industry and construction). Fraunhofer IFAM is able to map the entire adhesive bonding process chain – from the initial idea to functional implementation in production – including polymer development, the development of customised surface treatment processes and quality assurance concepts.
(Fraunhofer IFAM / English / Adhesive Bonding)

Fraunhofer IFAM is also the founder and, for over 30 years now, the global market leader in product-neutral, cross-company, industry-independent, extra-occupational and personnel-certifying qualification of company employees in the field of adhesive bonding technology. At the same time, Fraunhofer IFAM is the leading institute for quality assurance standardisation at ISO, CEN and DIN level and has developed adhesive bonding QA standards into international industry standards. Current standardisation projects focus on the technological and ecological sustainability assessment of adhesively bonded products based on the circular economy and the EU Waste Framework Directive, including the R strategies specified by the Commission.
(www.bremen-bonding.com)

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