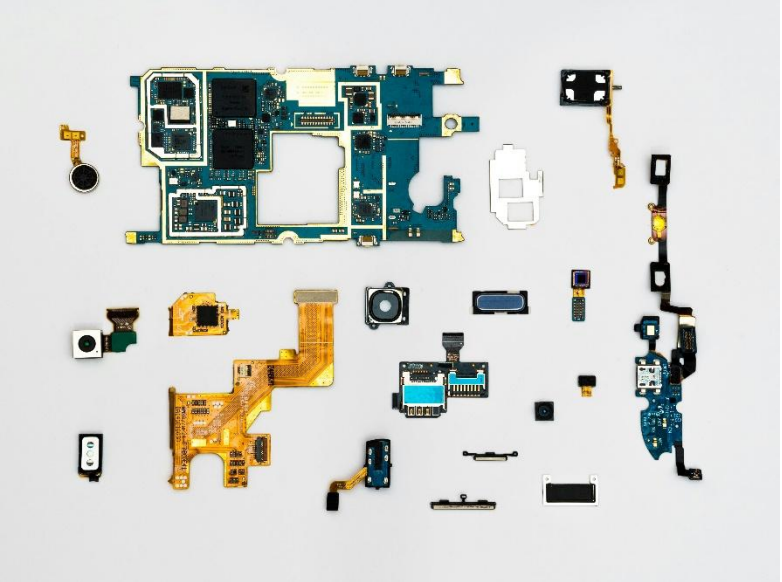
Unlocking sustainable design for repair and recycling with debonding on demand adhesive tapes

Author: Sreeparna Das, Sustainability Communications Consultant, Afera

Adhesive tapes, synonymous with permanence, are undergoing a transformative shift with the advent of debonding-on-demand technologies. This innovation challenges the traditional notion of adhesives as static, non-reversible bonds and paves the way for dynamic applications across industries. With increasing emphasis on **sustainability, ease of application, repairability and end-of-life management**, debonding-on-demand adhesive tapes are emerging as vital tools for modern industry demands.

Debonding-on-demand (DoD) adhesive technologies are revolutionising sustainable product design, closely intertwining with the principles of **'right to repair' and 'design for recycling (DfR)'**. These adhesives enable the controlled separation of bonded components, facilitating efficient disassembly and material recovery.



Transforming adhesives from barriers to enablers

Traditionally, adhesives posed challenges to recycling by creating inseparable bonds that hinder the reuse of materials. However, DoD adhesives have transformed this limitation into an opportunity. By incorporating triggers such as heat, electricity, UV light or specific chemical stimuli, **DoD adhesives allow products to be disassembled cleanly** and without damaging the individual components. This capability is particularly valuable in industries like electronics and automotive manufacturing, where complex assemblies contain diverse materials such as metals, plastics, and glass.

For example, in electronics, where miniaturisation and multifunctionality dominate, DoD adhesives simplify the separation of valuable components like circuit boards and lithium-ion batteries, ensuring **repairability and high material recovery rates**. In the automotive sector, they aid in recycling electric vehicle batteries and reducing waste from other bonded assemblies.

Moreover, the adoption of DoD adhesives aligns perfectly with **circular economy goals**. These technologies encourage manufacturers to design products with repair and recyclability in mind. This shift not only conserves resources but also lowers the environmental footprint of manufacturing.

How debonding-on-demand works

At the heart of debonding-on-demand technology is a mechanism that allows adhesives to switch between bonded and non-bonded states. These adhesives incorporate smart materials or stimuli-responsive chemicals that react predictably to external triggers. Common methods include:

- **Pressure-Sensitive Release**: Adhesive tapes that respond to mechanical pressure offer manual debonding capabilities without the need for external tools or chemicals.
- **Thermal Activation**: Adhesives designed for thermal debonding respond to specific temperature ranges, enabling users to heat the bond and release the tape without damage to the underlying materials.
- **UV Light Activation**: Photodegradable adhesives use ultraviolet light to weaken bonds, making them ideal for electronic components and delicate surfaces.
- **Chemical Activation**: Certain adhesives debond when exposed to specific solvents, offering controlled separation for applications like electronics recycling.
- **Electrical Activation**: Controlled debonding is achieved with low-voltage electric current.

Industry applications

Debonding-on-demand adhesive tapes have gained traction across diverse industries, each harnessing their potential to address unique challenges. Notable example here comes from **Apple,** which introduced **electrically-released tape adhesive** in the iPhone 16 to facilitate **battery replacement**. While the tape maintains a strong bond, it can be easily released by applying a small voltage (between 9 to 12 volts for 60 seconds).[1]

1. Electronics

The electronics sector has embraced debonding technology to **simplify disassembly and recycling of components**. Adhesive tapes used in circuit boards or battery assemblies can now be easily detached, preserving valuable materials like metals and reducing e-waste. For example, smartphone and laptop manufacturers are integrating debonding adhesives into their designs to facilitate efficient repair and recycling processes.

2. Automotive

Automotive manufacturers are leveraging debonding adhesives for modular construction and sustainable assembly practices. These tapes enable quick removal of panels, interiors, and other bonded components, **minimising repair costs and material waste**. Debonding adhesives also support the transition to electric vehicles, allowing better recycling of battery units and high-tech components.

3. Renewable Energy

In the renewable energy sector, debonding-on-demand adhesives are used for constructing and maintaining **solar panels and wind turbines**. These tapes provide reversible bonds for ease of replacement and recycling, ensuring longevity and sustainability in green energy projects.

4. Consumer Goods

Packaging and product design have seen the benefits of debonding adhesives for **reusability and waste reduction**. Brands are incorporating debonding tapes in reusable packaging solutions, allowing consumers to dismantle and recycle items effortlessly.

5. Healthcare and Biomedicine

Medical devices and wearable technologies are beginning to use debonding adhesives for **patient comfort and device reusability**. These tapes allow healthcare providers to remove bonded components without causing discomfort or damage.

Environmental and economic impacts

The environmental benefits of debonding-on-demand adhesives cannot be overstated. By enabling repair and recycling processes, these tapes help **reduce landfill waste and conserve resources**. For industries under scrutiny for their environmental impact, such as electronics and automotive manufacturing, debonding adhesives offer tangible solutions for achieving sustainability goals.

Economically, debonding-on-demand technologies drive cost savings by **reducing the need for labour-intensive disassembly** methods. They also improve the efficiency of repair and recycling processes, allowing businesses to reclaim valuable materials and minimise production expenses.

Despite their promise, debonding-on-demand adhesives face challenges in widespread adoption. Developing adhesives with precise debonding triggers requires advanced research and testing, **increasing production costs**. Additionally, industries accustomed to traditional adhesives may be hesitant to transition to newer technologies without guaranteed performance metrics.

Innovations from adhesive and adhesive tape manufacturers

Efforts are underway to address the above-mentioned challenges. Collaborative research between adhesive & tape manufacturers and industry leaders is fostering innovation and creating standardised solutions for specific applications. Let's take a look at some of the examples in the table below.

Company	Solution	Key Features
Evonik Industries AG	Thermal debonding technology	The new debonding on demand concept from Evonik has low viscosity, enhancing ease of use in various applications. It offers a flexible range of debonding temperatures (80-150°C), compatible with both 1K and 2K adhesive systems, making it suitable for a wide range of applications.
H.B Fuller	H.B. Fuller EV Bond	The EV Bond 2K adhesive product line provides instant green strength during assembly and at end-of-life (EOL) mechanical removal of cells.
Henkel	Debonding technology for carmakers	Henkel's Battery Engineering Centre is working with Automotive OEMs on battery cell debonding, using their prototypes to jointly develop solutions.
Lohmann GmbH & Co.KG	Hook & Loop tape solutions; Adhesive foam tapes with an integrated reinforcing film and more	With the aim to ensure controlled longevity throughout the product lifecycle, Lohmann's debonding on demand solutions enable residue-free removal, repair, recycle, and reuse.
Tesa	"Bond & Detach" adhesive tapes	Used in more than 1.8 billion smartphones worldwide, tesa® Bond & Detach solutions enable mechanical release with residue-free removability. Tesa also aims to make structural adhesive tapes intelligently removable using various mechanisms such as temperature, electricity, laser and electromagnetic induction.

The future of debonding adhesives and tapes

As industries strive for greater sustainability, the future of debonding-on-demand adhesive tapes looks bright. Advances in **nanotechnology and smart materials** are expected to yield even more precise and versatile adhesives. Efforts to reduce production costs and enhance scalability will make debonding-on-demand solutions accessible to smaller businesses and emerging markets.

Furthermore, regulatory policies emphasising sustainable practices such as **EU's Right to Repair and EU Ecodesign Regulation (ESPR)** are likely to accelerate the adoption of these technologies. Governments and organisations worldwide are advocating for reduced waste and improved recycling methods, creating a favourable environment for debonding-on-demand adhesives.

Debonding-on-demand adhesive tapes represent the convergence of innovation, sustainability, and functionality. Their ability to balance permanence with reversibility has unlocked new possibilities for industries and consumers alike. As the world moves towards a more sustainable future, DoD adhesives and tapes are set to become a **pillar of circular product design**—reshaping how we repair, reuse, and recycle.

References:

[1] https://www.prescouter.com/2024/10/apple-makes-iphone-battery-replacement-easy-inside-debonding-on-demand-techs/