2024 | Sustainable Packaging Materials | UV Coating Methods

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TABLE OF CONTENTS

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AD INDEX

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FROM THE EDITOR

Introducing Our Top Features Articles of 2024

Karen Parker
Editor-in-Chief, ASI

In this exclusive print edition of **ASI** we are featuring some of the most popular articles published in 2024. As your main source of news and information for the adhesives and sealants industry, this best-of edition includes three of our most popular and informative articles from 2024.

Included in this special edition is our annual **ASI** Top 20 article, which features the top adhesive and sealant manufacturers in the world. To create this article, **ASI** researches the leading adhesive and sealant manufacturers from across the globe to provide a detailed account of what these companies accomplished in 2024. The list, which is compiled using sales figures and additional details for finished adhesives and sealants, is a consistent resource for the industry, and it ranks among the most popular articles from our eMagazine and website.

As online sales have grown over the last two decades, demand for packaging has increased as well. And coinciding with this growth in the packaging market is demand from consumers and industry for more sustainable alternatives. An article by Trinseo, featured in this special print edition, outlines methods and technologies that allow companies to develop more sustainable packaging materials. These include ways to improve your manufacturing process and a discussion of biobased feedstocks and their use in the production of more sustainable latex binders.

Another trend that continues within the adhesive and sealant industry is the increasing use of hot-melt technologies. An article written by experts at Bostik examined the performance of UV-curable acrylic hot-melt pressure-sensitive adhesives (UV HMPSAs), as affected by four different experimental factors: coating method, adhesive thickness, the addition of a tackifier, and the duration of UV curing. They tested for peel, tack, and shear of the finished UV HMPSAs. The researchers concluded that different combinations of these four factors affect the penetration of UV radiation into the product, and that UV penetration should be considered when optimizing an application, in addition to other mechanical effects.

I would like to thank the authors who contributed the articles we are featuring in this edition. And of course, thanks to our readers for your ongoing support and loyalty to **ASI**. If you are not a subscriber but you have enjoyed the content of this print publication, I encourage you to visit our website at www.adhesivesmag.com, click "Sign Up" on the right side of the top navigation bar and register for our website. While there, you can also sign up for our eMagazine and one or all of our four eNewsletters. **ASI**

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FEATURE ARTICLE

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Every year, **ASI** presents the annual Top 20 list of leading global adhesive and sealant manufacturers, emphasizing sales figures and other details for finished adhesives and sealants, as well as related products such as tapes and labels.

When creating this article, we research the leading worldwide manufacturers of adhesives and sealants and compile the **ASI Top 20**. In considering the rankings, we focus on 2023 sales figures and other details for finished adhesives and sealants, as well as related products such as tapes and labels.

In addition to information supplied by company contacts, we gathered details from annual reports, company websites, press releases, and other sources. In cases where organizations did not respond to our requests or declined to provide adhesives/sealants-focused information, and reasonable estimates could not be made based on publicly available information, some companies did unfortunately have to be left out.

If you would like your company to be considered for the 2025 **ASI Top 20**, or if you have any questions or suggestions for future rankings, please contact Karen Parker, editor-in-chief, at (248) 833-7364 or parkerk@bnpmedia.com. >>

No. 1 | Henkel GmbH & Co. KGaA

Düsseldorf, Germany
www.henkel.com
CEO: Carsten Knobel
Executive Vice President, Adhesive Technologies: Mark Dorn
Sources: company contact, annual report

Henkel is a multi-national chemical and consumer goods provider known for a range of consumer and industrial products, including adhesives, sealants, functional coatings, cosmetics, and household cleaning products. Founded in 1876, the company is organized in two business units: Adhesive Technologies and Consumer Brands. Henkel recorded revenue of approximately €21.5 billion (approx. $23.73 billion) in 2023, down 3.9% compared to 2022. The Adhesive Technologies business accounted for 50% of that revenue with approximately €10.79 billion (approximately $11.9 billion) in sales for 2023, down 4% compared to 2022.

The Adhesive Technologies business unit serves various industries, such as automotive, electronics, packaging, aerospace, medical, building and construction, and general manufacturing. The business unit operates within three business areas: Mobility & Electronics, which accounted for 36% of segment sales in 2023; Packaging & Consumer Goods, which represented 32% of segment sales in 2023; and Craftsmen, Construction & Professional, which accounted for 33% of segment sales in 2023. Sales in Mobility & Electronics were €3.848 billion (approximately $4.25 billion); Packaging & Consumer Goods sales were €3.413 billion (approximately $3.77 billion); Craftsmen, Construction & Professional posted 2023 sales of €3.529 billion (approximately $3.895 billion).

Major brands platforms within the Henkel Adhesive Technologies portfolio include the Loctite, Technomelt, Bonderite, Teroson, and Aquence brands for industrial products and Pritt, Loctite, Ceresit, and Pattex for consumers and craftsmen.

NOTES: In November 2023, the Adhesive Technologies business unit purchased US-based Critica Infrastructure, a supplier of maintenance, repair and overhaul (MRO) composite solutions for critical infrastructure, including oil and gas transmission and municipal water supply systems. Active in many countries, Critica has a strong focus on North America with annual sales of around $110 million.

In April of 2024, Henkel completed its acquisition of Seal for Life Industries LLC from Arsenal Capital Partners. U.S.-based Seal for Life supplies protective coating and sealing solutions to a variety of infrastructure markets, including renewable energy, oil and gas, and water.

Henkel opened its Technology Center in Bridgewater, New Jersey, in May 2023. The 70,000-square-foot facility offers a unique and interactive destination for the company's strategic partners and customers. In February 2024, the company announced construction of its first integrated innovation and technology center in Latin America, located in Jundiaí, Sao Paulo. Henkel expects the new center to create a collaborative ecosystem for developing innovations and solutions for the Adhesive Technologies business unit, as well as being a hub for training, capacity building, and interaction with customers and partners in the region.

In June 2023, the Adhesive Technologies business unit broke ground on a new manufacturing facility within the Yantai Chemical Industry Park in Shandong Province, China. The new plant will enhance Henkel's production capacity of high-impact adhesive products in China and better meet the growing demand from domestic and international markets.

No. 2 | 3M

St. Paul, Minnesota
www.3m.com
CEO: William Brown
Sources: company contact, annual report, press releases

Founded in 1902, 3M is a multi-national conglomerate providing products in fields including worker safety, healthcare, and industrial and consumer goods. For 2023, 3M posted $32.7 billion in net sales, a decline of 4.5% year-on year.

The company operates in four business groups: Safety & Industrial, which posted $11.0 billion in sales for 2023 (34% of total sales); Consumer, with $5.0 billion in 2023 sales (15% of total sales); Healthcare, with $8.2 billion in 2023 sales (25% of total sales); and Transportation & Electronics, with $8.5 billion in sales for 2023 (26% of total sales).

In March of 2024, 3M approved the planned spin-off of its Health Care business, now Solventum Corp., that was completed on April 1st. 3M's remaining organization consists of 16 divisions managed under three business groups: Consumer, Safety & Industrial, and Transportation & Electronics. Many of the divisions leverage the company's Adhesives technology platform.

Examples of brand offerings within 3M's portfolio of adhesive products include the following: Scotch-Weld™ structural adhesives; VHB™ Tape; Scotch® Masking, Packaging and Filament tapes; Command™ adhesive products, and Post it ® repositionable note products.

"Throughout 2023, we executed our priorities and delivered on our commitments – including expanding underlying operating margins and cash flow. We initiated actions to restructure our organization and simplify our supply chain, while progressing our Health Care spin and addressing legal matters," said Executive Chairman and former CEO Mike Roman.

William Brown was appointed 3M chief executive officer, and Mike Roman appointed 3M executive chairman, both effective May 1, 2024. "I am excited for the opportunity to lead this iconic global company," said Brown. "The company has made significant positive changes under Mike's leadership, and I am looking forward to building on that progress as CEO as 3M continues to deliver for its customers, shareholders, employees, and communities around the globe."

NOTES: In June 2023, 3M announced it had entered into a broad class resolution to support PFAS remediation for public water suppliers that detect PFAS at any level or may do so in the future. The company agreed to contribute up to a present value of $10.3 billion, payable over 13 years. In August 2023, the company announced that it has reached an agreement to resolve the Combat Arms Earplug litigation against Aearo Technologies (Aearo) and 3M. 3M agreed to contribute a total amount of $6.0 billion between 2023 and 2029. In December, the company sold its 50% equity stake in Combi Packaging Systems LLC to SIAT Group. Combi is a U.S.-based producer and distributor of end-of-line packaging machinery and spare parts. It also acts as the service and warehousing provider for the 3M-Matic™ Case Sealing equipment brand primarily in North America. In conjunction with the sale, 3M continues to sell 3M-Matic products, whose brand, technologies, and portfolio are retained by 3M and will continue to be sold through approved channels worldwide.

In March of 2024, 3M approved the planned spin-off of its Health Care business, now Solventum Corp. The spinoff was completed on April 1, 2024.

No. 3 | Avery Dennison Corp.

Mentor, Ohio
www.averydennison.com
President and Chief Executive Officer: Deon Stander
Sources: annual report, press releases

A global materials science and digital identification solutions provider, Avery Dennison currently employs approximately 35,000 people in close to 200 manufacturing and distribution facilities; it operates in over 50 countries. The company provides branding and information labeling solutions, including pressure-sensitive materials. Industries served include home and personal care, apparel, e-commerce, logistics, food and grocery, pharmaceuticals, and automotive. In 2023, international operations constituted approximately 69% of the company's net sales.

With total 2023 net sales of $8.36 billion, Avery Dennison operates within two business groups: Materials Group, which includes label materials, graphic and reflective materials, and functional bonding materials such as tapes, and Solutions Group, which provides RFID solutions, branding and embellishment solutions, data management and identification solutions, and pricing and productivity solutions. The Materials Group delivered approximately $5.81 billion in 2023, accounting for 69% of total 2023 sales. The Solutions Group had net sales of approximately $2.55 billion, accounting for 31% of total 2023 sales. (The company declined to provide specific adhesives/sealants-related sales and other details.)

Among the company's brand offering are: Fasson®-, JAC®-, and Avery Dennison®-brand pressure-sensitive label materials and performance tapes products, and e Yongle®-brand tapes for wire harnessing and cable wrapping.

NOTES: In June 2023, Avery Dennison announced the election of Deon Stander, the company's president and chief operating officer, as the new president and CEO. Mitch Butier, who had served as the company's chairman and CEO, is now serving as executive chairman of the company's board of directors.

In the third quarter of 2023, the company approved a restructuring plan to optimize the European footprint of its Materials Group by reducing operations in a manufacturing facility in Belgium. The plan included the reduction of approximately 210 positions and resulted in recorded restructuring charges of $30.4 million in 2023.

In November of 2023, Avery Dennison completed its acquisition of Silver Crystal Group, a Canada-based provider of sports apparel customization and application solutions across in-venue, direct-to-business, and e-commerce platforms. In May of 2023, the company acquired LG Group Inc., a Maryland-based designer and manufacturer of apparel brand embellishments. In March of 2023, the company acquired Thermopatch Inc., a New York-based manufacturer specializing in labeling, embellishments, and transfers for the sports, industrial laundry, workwear, and hospitality industries.

No. 4 | H.B. Fuller

St. Paul, Minnesota
www.hbfuller.com
CEO: Celeste Mastin
Sources: annual report, 10K filing, press releases, company contact

Founded in 1887 by Harvey Benjamin Fuller, H.B. Fuller is a provider of functional coatings, adhesives, and sealants with operations around the globe. The company serves customers across more than 30 market segments, including electronics, disposable hygiene, medical, transportation, aerospace, clean energy, packaging, construction, woodworking, general industries, and other consumer businesses. H.B. Fuller employs over 7,200 people. It has 81 manufacturing plants and operates facilities or offices in 34 countries.

The company's net revenue was down slightly in 2023 at $3.51 billion, compared to $3.75 billion in 2022. In its annual report, the company stated the decrease of 6.4% in net revenue compared to 2022 was driven mainly by a lower sales volume of 8.4% and a decrease of 2.4% because of currency fluctuation. These drops were somewhat offset by increases due to acquisitions and product pricing. Another factor was lowered revenue (by 1.8%) due to an extra week in 2022.

The company operates in three global business units—Hygiene, Health and Consumable Adhesives; Engineering Adhesives; and Construction Adhesives. In 2023, the Hygiene, Health and Consumable Adhesives business unit accounted for 45% of revenue for the company. Engineering Adhesives accounted for 41% of 2023 revenue, and Construction Adhesives accounted for 14% of revenue.

Net revenue in the company's Hygiene, Health and Consumable Adhesives business unit was $1.6 billion, down 5.6% compared to revenue in 2022. With 36 facilities, the segment serves markets such as packaging, hygiene, tape and label, medical, and beauty.

The Engineering Adhesives business unit posted net revenue in 2023 of $1.4 billion, down 6.8% compared to 2022. This business unit operates 28 facilities and sells into the energy, electronics, automotive, transportation, and wood and composites industries, among others.

With 14% of 2023 revenue, the Construction Adhesives business unit operates 17 facilities. The segment saw 2023 sales decrease by 7.7% to $481 million. It is active in markets such as flooring, commercial roofing, and building envelope and infrastructure.

"As the largest pureplay adhesives company in the world, we are focused on enhancing our portfolio mix while capitalizing on the tremendous growth and margin expansion opportunities before us, and continuing to generate strong cash flow and improved profitability, while investing in programs and partnerships that attract and retain top talent and benefit the communities in which we live and work. Above all, we will continue to deliver the value our customers expect from us," said CEO Celeste Mastin.

NOTES: H.B. Fuller had six acquisitions in 2023 across several geographies and global business units.

In January 2023, the company acquired the assets of Aspen Research. Aspen, located in Minnesota, is a contract research organization that develops and manufactures innovative solutions for some of the adhesives used in H.B. Fuller's insulating glass market. The acquisition is expected to expand the Engineering Adhesives footprint in North America and strengthen its capabilities in insulating glass.

In May, the company announced the acquisition of Beardow Adams, a multinational industrial adhesive manufacturer based in the UK. In business since 1976, Beardow Adams had customers in approximately 70 countries and manufacturing capabilities across Europe and the United States. H.B. Fuller completed two acquisitions in June: Adhezion Biomedical, a privately held U.S. medical adhesives business, and XCHEM International, an adhesives manufacturer in the United Arab Emirates. In September, the company announced the acquisition of Sanglier Limited, a UK-based manufacturer of and filler of sprayable (aerosol and canister) industrial adhesives. The acquisition expands H.B. Fuller's product portfolio of construction and engineering adhesives across the UK and Europe.

In December, H.B. Fuller acquired Lemtapes Oy in Finland, a solutions provider of ecological, innovative tapes and adhesives for the packaging and plywood industries. The acquisition of Lemtapes is expected to reinforce the company's strategic position in Europe, especially for its adhesives coated solutions products. This acquisition will also accelerate the company's growth strategy of fast-growing, high-margin businesses while adding technology capabilities and strong customer relationships.

H.B. Fuller continues to focus on innovation. In its annual report, the company reported that 23% of its 2023 revenue came from new products introduced in the past five years. Among those products was the company's EV Protect 4006, which won the 2023 Adhesive and Sealant Council (ASC) Innovation Award. The lightweight encapsulant for lithium-ion batteries helps to make EVs and battery storage banks safer by reducing or delaying thermal propagation. The company was again honored in 2024 when Jayesh Bokria, Thomas Kauffman, Andrew Prybylowski, David McDougall, and team received the 2024 Adhesive and Sealant Council (ASC) Innovation Award for their development entitled, "Thermoplastic Encapsulant Platform for Photovoltaic Modules." The TPx platform enables lower levelized cost of energy (LCOE) and supply chain versatility while ensuring the critical performance requirements for thin-film modules by leveraging underutilized raw material feedstreams.

No. 5 | Arkema

Colombes, France
www.arkema.com
Chairman and CEO: Thierry Le Hénaff
Bostik CEO: Vincent Legros
Sources: company contact, annual report

Arkema is a diversified global chemical company that serves the general industry, consumer goods and electronics, building and construction, transportation and energy, and water, health and nutrition industries. The company operates within the following segments: Adhesives Solutions, which represented 29% of total group sales in 2023; Advanced Materials, which represented 38% of total group sales in 2023; Coating

Solutions, which accounted for 25% of total group sales in 2023; and Intermediates, which had 8% of total group sales in 2023. Total group sales for the company in 2023 were €9.514 billion (approx. $10.5 billion), a change of -17% compared to €11.550 billion (approx. $12.75 billion) in 2022. The company employs approximately 21,100 individuals operating in 55 countries. In terms of its geographic footprint, North America accounted for 37% of total sales in 2023, Europe accounted for 34% of sales, while Asia accounted for 24% and the rest of the world recorded 5% of 2023 sales.

With 17 research and development centers employing approximately 1,800 researchers, the company allocates approximately 2.9% of sales to research and development.

The company's Adhesive Solutions segment provides bonding and assembling solutions, including pressure-sensitive adhesives, engineering and thermal adhesives, specialty hot-melt adhesives, and high-performance sealants. The segment achieved sales of €2.714 billion (approximately $2.995 billion) in 2023, a decline of 6.3% compared to sales in 2022. However, sales in the second half of 2023 grew by 16%.

The Adhesive Solutions segment was created after the company integrated Bostik in 2015. In 2022, the company acquired Ashland's Performance Adhesives business, a leader in high-performance adhesives. The segment has two business lines: Construction & Consumer and Industrial Assembly. Sales in the segment's Construction & Consumer business line were approximately 46% of segment sales, while the Industrial Assembly business line accounted for approximately 54% of sales.

NOTES: In February 2023, Arkema launched the most complete and integrated offering on the market for pressure sensitive adhesives. Aligned with the group's unique strategy to leverage its three synergistic Specialty Materials segments, this broad product range combines Arkema's technological expertise in the adhesives market, strengthened by the recent acquisition of Ashland Performance Adhesives, and leading acrylic value chain solutions.

In May 2023, Arkema announced the acquisition of Polytec PT, a specialist in adhesives for batteries and electronics located in Germany. In making the announcement, Arkema stated that the acquisition will strengthen Bostik's product offering serving the fast-growing batteries and electronics market segments.

The company purchased Arc Building Products in December 2023. Based in Ireland, Arc Building products specializes in tile adhesives, floor preparation systems, building chemicals, and sealant and bonding solutions. Annual sales are approximately €15 million (convert to dollars).

In May of 2024, the company announced that it had acquired Dow's flexible packaging laminating adhesives business. The business is a leading producer of adhesives used in the flexible packaging market and generates annual sales of approximately $250 million.

Additionally, Bostik announced in March 2024 that it has invested in UV acrylic hot-melt pressure sensitive adhesive (UV acrylic HMPSA) capabilities, expanding the manufacture of UV acrylic HMPSAs within its North American facilities.

No. 6 | Sika

Baar, Switzerland
www.sika.com
CEO: Thomas Hasler
Sources: annual report, press releases, company website

Founded in 1910, Sika started out when Kaspar Winkler invented Sika-1, a quick-setting waterproofing admixture for mortar. The innovation was used to waterproof the Gotthard Tunnel, a key connection between northern and southern Europe. From that beginning the company has grown to

be a multinational specialty chemicals company developing and producing systems and products for bonding, sealing, damping, reinforcing, and protecting in the building and construction and motor vehicle industries. The company organizes its product offerings into Construction Solutions and Industry Solutions, with specified target markets including: concrete, waterproofing, roofing, building finishing, flooring engineered refurbishment, and industry. For the seven construction-focused segments, Sika produces products ranging from sealants, adhesives, and tapes to spray foams and coatings, among many others. The Industry market focuses on a range of solutions (including structural adhesives and sealants) for automotive and commercial vehicle assembly.

Sika again recorded strong growth in 2023, recording increased net sales. The company also reported an increase in number of employees of 21.1%. Sika reported approximately CHF 11.24 billion (approximately $13.4 billion) in net sales, representing an increase of 7.1% year-over-year. (Specific adhesives/sealants-related sales and other details are not available.)

The company reports its financial results primarily according to key regions: EMEA (Europe, Middle East, Africa), Americas, and Asia-Pacific, as well as a Global Business segment that targets the automotive industry. All segments saw sales increase in 2023: EMEA, 14.8% to CHF 4.499 billion (~ $5.3 billion); Americas, 14.9% to CHF 3.424 billion (~ $4.1 billion); Asia-Pacific, 15.1% to CHF 2.474 billion (~$ 2.9 billion); and Global Business, 10% to CHF 842 million (~ $1.0 billion).

Worldwide, Sika has approximately 33,547 employees, approximately 400 manufacturing facilities, and subsidiaries in 101 countries. The company had R&D centers worldwide, with more than 1,780 employees working in research and development.

NOTES: In May 2023, Sika closed the acquisition of MBCC Group Mannheim, Germany, after receiving all necessary regulatory approvals. The company

reports that the transaction strengthens Sika's range of products and services across the entire construction life cycle and across all regions. To close the transaction and to comply with regulatory requirements, Sika sold MBCC Group's chemical admixtures assets in the UK, the United States, Canada, Europe, Australia, and New Zealand to private equity firm Cinven. The business now acquired by Sika generated sales of CHF 2.1 billion in 2022, employs 6,200 people and operates in over 60 countries and 95 production facilities.

The company also acquired Thiessen Team USA, a U.S. manufacturer of shotcrete and grouting products for the mining industry within the United States, and announced it has agreed to acquire Chema, a leading manufacturer of tile setting materials in Peru. At the end of 2023, the company announced the purchase of a 30% stake in Concria Oy, a Finnish startup company specializing in highly innovative concrete floors. In April of 2024, the company announced its acquisition of Kwik Bond Polymers LLC, a manufacturer of polymer systems for the refurbishment of concrete infrastructure.

No. 7 | RPM International Inc.

Medina, Ohio
www.rpminc.com
Chairman and CEO: Frank C. Sullivan
Sources: press releases, annual report

RPM International is a multinational company founded in 1947 and consists of subsidiaries that manufacture, market, and sell specialty chemical products including specialty coatings, sealants, building materials, and related services. Included among the company's brands are Kwik Seal, Tremco, Universal Sealants, Miracle Sealants, SEAL-KRETE, Touch 'n Foam, and Zinsser. The company employs approximately 17,300 people worldwide with 121 manufacturing facilities. In 2023, the company completed six acquisitions.

RPM's total sales grew approximately 10% in its fiscal year 2023 (ended May 31, 2023), reaching $7.26 billion. The company's four business units include: Construction Products Group, Consumer Group, Performance Coatings Group, and Specialty Products Group. Adhesives and sealants are produced primarily in the Construction Products and Consumer groups. (The company declined to provide specific adhesives/sealants-related sales and other details.)

Representing 36% of total net 2023 sales, the Construction Products Group experienced record sales and profitability, achieving sales of $2.6 billion for the year, a 5% increase over the previous year. This segment, which includes the Tremco business, produces construction sealants and adhesives, as well as waterproofing solutions and many other products.

Fiscal 2023 sales for the Consumer Group reached $2.5 billion, representing 35% of RPM's total sales. Caulks, sealants, and adhesives are among the many products produced by companies in this segment, including DAP.

NOTES: In January of 2024, RPM announced the opening of a new Innovation Center of Excellence in Greensboro, North Carolina. The 60,000-square-foot facility is designed to harness the collective expertise among RPM companies and is home to chemists and technical experts. In October 2023, the company announced the acquisition of the wall system fabrication segment of NOW Specialties LLC by RPM's Tremco CPG Inc. Now part of Tremco Construction Products Group, the Texas-based fabrication business is a leading wall system fabricator specializing in metal composite material and aluminum composite material panels and has annual net sales of approximately $20 million.

No. 8 | LINTEC Corp.

Tokyo, Japan
www.lintec-global.com
President and CEO: Makoto Hattori
Sources: investor presentation, summary of consolidated financial results

Established in 1934, LINTEC is a manufacturer of adhesive-related products, including adhesive papers and films for seals and labels, automotive-use products, window films, semiconductor-related tapes and equipment, LCD-related products, color papers for envelopes, and release papers and films. With a presence in approximately 19 countries and regions, the company employs approximately approximately 5,400 people.

Total net sales for LINTEC fell by 2.9% in its fiscal year that ended March 31, 2024. The company has three Japan-based consolidated subsidiaries, as well as approximately 39 additional consolidated subsidiaries around the world.

In the Printing and Industrial Materials Products business segment, 2023 fiscal year sales increased by 30.0%. This group produces products such as adhesives for automotive applications, adhesive tapes for industrial applications, adhesive papers and films for labels, and films for numerous additional applications, as well as many other products. The U.S.-based Mactac subsidiary is part of this segment.*

Sales in the Electronic and Optical Products segment decreased by 14.6% overall. Products produced by this segment include tapes for semiconductor applications, multilayer ceramic capacitor-related tapes, and adhesives for touchscreen applications, among others.

(*Editor's note: Since Mactac, LINTEC's U.S. subsidiary, provided adhesives/sealants-related details and requested that they be withheld, specific sales levels for LINTEC will likewise not be published to avoid any potential conclusions being drawn. Mactac's sales were subtracted when determining LINTEC's ranking.)

NOTES: In October 2023, LINTEC announced it had developed two new labelstock products that peel off cleanly during the washing process after plastic container collection and can be efficiently recovered.

At the end of April of 2024, the company announced the development of a new bump support film (BSF) that improves the durability and reliability of semiconductor chips, using resin to protect the ball bump interconnection between the die and substrate. The new product, a tape integrated with back grinding tape, became available on May 1, 2024.

No. 9 | Huntsman Corp.

The Woodlands, Texas
www.huntsman.com
President and CEO: Peter R. Huntsman
Sources: company website, 10K form, press releases

Founded by Jon M. Huntsman in 1970, Huntsman is a specialty chemicals provider that posted revenues of approximately $6.1 billion in 2023. The company operates in three product segments: Polyurethanes, Performance Products, and Advanced Materials. In 2023, the Polyurethanes segment accounted for 63% of revenue, the Performance Products accounted for 19%, and the Advanced Materials segment accounted for 18%.

Huntsman's Advanced Materials division produces polymer resin systems and adhesives. The division total sales for 2023 was approximately $1.09 billion. Among the end-markets served by this division are infrastructure, general industry, automotive, commodity, and aerospace.

Among the brands within the Advanced Materials division is ARALDITE® high-performance adhesive technologies.

NOTES: In April 2023, Huntsman announced that its production site in Monthey, Switzerland, had implemented a mass-balance concept and achieved REDcert certification, covering the production of epoxy resins products used in a variety of consumer and industrial markets.

No. 10 | Illinois Tool Works Inc.

Glenview, Illinois
www.itw.com
President and CEO: Christopher A. O'Herlihy
Sources: company website, annual report, press releases

Founded in 1912, Illinois Tool Works is a multi-industrial manufacturing company operating in seven industry segments and employing approximately 46,000 people.

ITW produces adhesives and sealants and related products in two of its seven business segments. (The company declined to provide specific adhesives/sealants-related sales and other details.) Total revenue increased by approximately 1% in 2023, to nearly $16.1 billion.

Among many other products, ITW's Polymers & Fluids business produces industrial, construction, and consumer adhesives, as well as sealants. The division's revenue of $1.8 billion accounted for 11% of ITW's total revenue in 2023. The division's sales decreased by approximately 5.3% compared to the prior year.

The Test & Measurement and Electronics division produces pressure-sensitive adhesives for applications in electronics, medical, transportation, and telecommunications (among many other products). Sales for that division increased by 0.5% compared to 2022, reaching $2.83 billion for the year. The division accounted for 18% of ITW's overall 2023 sales.

NOTES: In early 2024, E. Scott Santi retired as chief executive officer; Christopher A. O'Herlihy was appointed president and CEO in January 2024.

No. 11 | Wacker Chemie AG

Munich, Germany
www.wacker.com
President and CEO: Christian Hartel, Ph.D.
Sources: annual report, press releases

Wacker's Silicones business segment manufactures silicone sealants, along with elastomers, emulsions, resins, and many other products. With 6,040 employees as of December 31, 2023, the segment's total sales reached nearly €2.74 billion (approximately $3.02 billion). This represents a 20.9% decrease over 2022, which the company attributed to "weaker volumes and prices and by exchange-rate effects." Regionally, sales declined in all three regions; the Americas, Asia, and Europe. (The company does not provide specific adhesives/sealants-related sales and other information.)

According to the company, WACKER is one of the world's leading actors in the areas of potting compounds and silicone-based thermal interface materials.

NOTES: In May of 2024, the company announced the acquisition of the manufacturing assets and know-how of U.S.-based Bio Med Sciences Inc., expanding its expertise and business in silicone-coated healthcare products. In September 2023, the company announced an investment of approximately €150 million to expand its specialty silicone manufacturing capacities at the Zhangjiagang site in Jiangsu Province, China. The company will construct several new production lines, where it will manufacture functional silicone fluids, silicone emulsions, and silicone elastomer gels. In March 2023, WACKER announced a planned expansion of production and cartridge filling capacities for silicone sealants at its Nünchritz site. Some €20 million has been budgeted for the new manufacturing lines, which are scheduled to begin production in the fall of 2024. In July 2023, Dr. Thomas Koini took over as president of the WACKER SILICONES division upon the retirement of Dr. Robert Gnann.

Image courtesy of Igor Nikushin / iStock / Getty Images Plus

No. 12 | Pidilite Industries Ltd.

Mumbai, India
www.pidilite.com
Chairman: Madhukar Parekh
Sources: company website, press releases, analyst presentation

Established in 1959, Pidilite Industries is a leading manufacturer of adhesives and sealants, and construction chemicals, craftsman products, DIY products, and polymer emulsions in India. Company brands include Fevicol, M-Seal, Fevikwik, Fevistik, and Dr. Fixit.

Pidilite operates with three main business segments: Consumer & Bazaar (82.5% of total net sales), Business to Business (17.0%), and Others (0.5%). The company's consolidated net sales in its 2024 fiscal year (ended March 31, 2024) were Rs 12,337 cr (approximately $1.480 billion), representing an increase of 5% over the prior fiscal year. The company attributed increased sales to robust underlying volume growth across categories and geographies and an improvement in product mix. The Business to Business segment and the Consumer & Bazaar segment both saw growth in the fiscal year 2024.

Adhesives and sealants products produced in the Consumer & Bazaar segment represented 55.5% of total net sales for the year, or approximately Rs 6,847 cr (~ $822 million). Pidilite also produces industrial sealants in the Business to Business segment. Sales here reached about Rs 641.5 cr (~ $77 million), or 5.2% of total sales.

With over 8,900 global employees, Pidilite operates manufacturing facilities in India, the U.S., Thailand, Dubai, Brazil, Egypt, Bangladesh, Sri Lanka, and Kenya. The company has five R&D centers (three in India and one each in Singapore and the United States).

No. 13 | Berry Global Inc.

Evansville, Indiana
www.berryglobal.com
CEO: Kevin Kwilinski
Sources: annual report, press releases

Berry Global Group Inc. supplies a range of rigid, flexible, and non-woven products to customers in industries such as healthcare, personal care, and food and beverage. The company is organized in four reporting segments: Consumer Packaging International; Consumer Packaging North America; Engineered Materials; and Health, Hygiene & Specialties. The company reported total net sales for fiscal year 2023 (ended September 30, 2023) of $12.66 billion.

Net sales in Berry Global's Health, Hygiene & Specialties segment decreased 17% to $2.6 billion in the 2023 fiscal year (ended September 30, 2023). The segment produces adhesives, sealants, and tapes (among many additional products) for applications in aerospace, automotive, construction, medical, and others. (The company does not provide specific adhesives/sealants-related sales and other information.)

"I am pleased to report we exceeded our adjusted earnings per share outlook and significantly beat our free cash flow guidance by over $100 million. Our 3% volume decline in the quarter improved sequentially and was better than expected, as soft market demand was mitigated by market share gains supported by recent capital investments," said Kevin Kwilinski, Berry's CEO.

NOTES: In August 2023, Berry Global announced that its Board of Directors elected Kevin Kwilinski as chief executive officer. The appointment became effective October 2, 2023. In connection with that appointment, the board elected Stephen Sterrett, lead independent director, as chairman of the board, also effective on October 2, 2023.

In 2023, Berry Global ranked among America's Most Responsible Companies, presented by *Newsweek* and global research firm Statista Inc. Ranking 35 out of 600 of the most responsible companies in the United States across 14 industry subcategories, Berry was recognized for its commitment to environmental, social, and corporate governance (ESG).

No. 14 | DuPont

Wilmington, Delaware
www.dupont.com
CEO: Lori Koch
Parent Company: DuPont de Nemours, Inc.
Sources: 10K report, company website

DuPont provides technology-based materials and solutions to key markets that include electronics, transportation, construction, water, healthcare, and worker safety. The company reported full-year 2023 net sales of approximately $12.01 billion, representing a decrease of 7% compared to 2022.

"In the face of inventory destocking that impacted many of our end-markets in 2023 and continued economic softness in China, our teams remained focused on sound operational execution and driving productivity and cost discipline," said Ed Breen, DuPont's executive chairman of the Board of Directors. "We delivered significant year-over-year cash flow improvement in

2023, including a strong fourth quarter finish, which underscores our ongoing prioritization of working capital management."

DuPont produces adhesives and related solutions for applications in electric and hybrid vehicles and the automotive aftermarket, along with composite, glass, and rubber-to-substrate bonding. **ASI** was unable to get adhesive sales from the company.

NOTES: In May of 2024, DuPont selected Lori D. Koch, the company's chief financial officer, to succeed Edward D. Breen as the company's chief executive officer. The new appointment became effective on June 1, and Breen transitioned from CEO to full-time executive chairman of the Board of Directors. In June of 2024, the company announced a plan separate into three distinct, publicly traded companies. The company would separate its Electronics and Water businesses into two separate entities, while the New DuPont would continue as a diversified industrial company.

No. 15 | Mactac

Stow, Ohio
www.mactac.com
CEO: Ed LaForge
Parent Company: LINTEC Corp.*
Sources: company contact, company website, press release

Mactac pressure-sensitive adhesives and related products (e.g., films, tapes, labels) are used in a range of applications, including transportation, building and construction, graphics, medical, and more. The company has supported customers for more than 60 years, helping to grow and diversity businesses.

Image courtesy of undefined undefined / iStock / Getty Images Plus

Mactac finalized the acquisition of Label Supply, headquartered in Ontario, Canada in June of 2024. Label Supply has been servicing the Canadian roll label market for more than three decades. The acquisition will expand both companies' geographic reach within the Canadian market, providing specialty products, service, and large quantities to more customers throughout Eastern Canada.

"Label Supply runs a highly successful business that is fast, agile and customer service centric. They excel at meeting small to medium converters' needs within Ontario, Canada, particularly the greater Toronto region," said Ed LaForge, Mactac president and CEO. "This acquisition, like others we've made within the past two years, will build upon the proven success of Label Supply. We will enhance what they do by broadening service throughout Eastern Canada and providing additional equipment and technology solutions that will also meet the needs of the region's larger customers."

NOTES: In November 2023, Mactac Engineered Tapes & Laminates announced the launch of a materials selection guide for customers in the electric vehicle (EV) battery and e-mobility markets. The guide is designed to help users choose the right PSA for their unique bonding application.

In early 2022, the company acquired Spinnaker Coating, a producer of pressure-sensitive roll-label and sheet-base materials. Also in the first half of 2022, the company acquired CSI – SoCal, a custom slitting and distribution center for roll label printers located in Ontario, Calif., under an asset purchase agreement worth $2.5 million.

(*Editor's note: A listing for LINTEC is included separately.)

No. 16 | Nan Pao Resins Chemical Co., Ltd.

Tainan City, Taiwan
www.nanpao.com
CEO: Ming-Hsien Hsu
Sources: company website, press releases

Founded in 1963, Nan Pao is a leading manufacturer of specialty adhesives, footwear adhesives, liquid and powder coatings, hot-melt adhesives, and construction materials in Taiwan. The company employs over 2,800 employees throughout the world, with factories in China, Vietnam, Indonesia, Malaysia, Thailand, India, the Philippines, Singapore, and Australia.

Consolidated revenue for Nan Pao decreased 6.47% in 2023, reaching nearly NT$20.5 billion (approximately $716 million). **ASI** estimates that adhesives accounted for approximately 74% of that revenue, or about NT$16 billion (~ $520 million). Nan Pao invests 2-3% of its revenue to researching new technologies.

NOTES: In 2022, the company celebrated the opening of its new headquarters and R&D Center. According to the company, "The dedication of the HQ and R&D Center represents our remarkable

achievement on our 60th anniversary. We introduced modernized and efficient equipment for better innovation performances at the Adhesives R&D Center such as water-based PU, hot-melt adhesives, adhesives for flexible packaging, footwear adhesives, nonwoven adhesives and optical adhesives."

NanPao announced recently that the company is prioritizing ESG and the development of green products and sees sustainability to be a core competitive edge. The company also declared that it will move towards net zero by 2050. NanPao aims to focus on long-term sustainable growth, integrating ESG into its corporate culture, not only to respond to trends and customer requirements but also to pursue more solid competitive advantages and help society.

No. 17 | Jowat Corp.

Detmold, Germany
www.jowat.com
Board of Directors: Klaus Kullman; Ralf Nitschke; Christian Terfloth, Ph.D.
Sources: company website, company contact, press releases

Jowat SE produces industrial adhesives for a range of applications, including woodworking and furniture manufacturing, paper and packaging, graphic arts, textiles, automotive, and electrical/electronics. Founded in 1919, the company remains a family-owned business. Its manufacturing facilities are located in: Detmold and Elsteraue, Germany; High Point, N.C., Buchrain, Switzerland; and Bandar Baru Enstek, Malaysia. About two-thirds of Jowat's employees are located in Europe, with most of those in Germany. The remainder of the company's workforce is in North and South America, as well as the Asia-Pacific region.

For the fourth consecutive year, Jowat was named a Best Managed Company. The Best Managed Companies (BMC) program is a competition organized in Germany by Deloitte Private, Credit Suisse, the Frankfurter Allgemeine Zeitung, and the Federation of German Industries (BDI) for successful enterprises from Germany's Mittelstand. "We are delighted to have been honored with the Best Managed Company title in 2023 again," said Ralf Nitschke, member of the Board of Directors at Jowat SE, at the award ceremony in Düsseldorf on May 25, 2023.

The company continues to invest in research and development.

NOTES: In June of 2023, the company announced it had received ISCC PLUS certification for its German manufacturing locations in Detmold and Elsteraue. The accreditation allows the company to manufacture sustainable adhesive using the mass balance approach. "The first ISCC PLUS certification is an important step for the entire Jowat Group and strengthens our strategy to increase the sustainability of adhesive bonding," said Dr. Christian Terfloth, member of the Board of Directors at Jowat SE. "The mass balance approach provides a great opportunity for the chemical industry. It enables us to actively and successfully take part in the European Green Deal."

In September 2023, the company hosted its first Jowat Forum: Bonding & Packaging. With a focus on sustainability, over 70 experts from science and industry participated in the event that included presentations, specialized workshops, and an exchange platform.

In March of 2024, Jowat inaugurated a new manufacturing location in China. Located in Zhejiang province, around 70 kilometers from Shanghai, the new facility is set to produce approximately 9,000 tonnes of adhesives annually for the Asian market. Focused on water-based dispersion adhesives and solutions for the consumer electronics market, the facility spans over 11,000 square meters and has production and storage facilities, as well as a research and development center.

No. 18 | DELO Industrial Adhesives

Windach, Germany
www.delo-adhesives.com
Managing Partners: Wolf Herold, Sabine Herold, Karl Bitzer, Christian Walther
Sources: press releases, company website, company contact

DELO produces industrial adhesives for automotive, consumer electronics, and semicon applications, as well as dispensing and curing equipment. The company's total sales for its 2023 fiscal year (ended March 31, 2024) reached €229 million (approximately $249 million), a 12% increase over the 2022 fiscal year.

For the 2023 fiscal year, DELO reports that approximately half of its sales were generated in Asia, with the other half divided between Europe and North America. The most important pillars in terms of sales were the semiconductor, automotive, and consumer electronics markets. Since high R&D expenditures are part of the company's strategy, the company again invested approximately 15% of revenues in research and development for fiscal 2023.

In 2023, the company celebrated the 25th anniversary of its management buyout, in which managing partners Sabine and Dr. Wolf Herold took over the company, making it again an independent family business. The company had 1,080 employees at the end of its 2023 fiscal year and expects that figure to reach 1,150 by the 2024/25 fiscal year.

Some of the company's brand include: DELO DUALBOND (dual-curing adhesives and sealants), DELOLUX (UV-curing lamps), and DELO-DOT (jet-dispensing valves).

"After a few challenging years due to COVID-19, strapped supply chains and the war in Ukraine, all of which prompted constant rescheduling of logistics processes, this past fiscal year could be characterized as more routine," said Dr. Wolf Herold, managing partner of DELO. "Nevertheless, there was great uncertainty among our customers as a result of a more cautious global market, making our twelve percent increase all the more remarkable."

NOTES: DELO's entrance into the medical electronics industry occurred within fiscal year 2023.

The company recently successfully acquired land on which to build an additional production facility in Malaysia. The new site is located near Kuala Lumpur. Major investments are also being made at headquarters in Windach, Germany. Construction work is underway for a fully automated 6,000 m^2 warehouse.

In April of 2024, the company started producing its own green electricity after completing and commissioning a photovoltaic system with almost 4,000 panels across all roofs on its campus in Windach, Germany. In addition, DELO also made expansions to its American offices in Boston and San Jose.

No. 19 | Toagosei Group

Tokyo, Japan
www.toagosei.co.jp
President and CEO: Mikishi Takamura
Sources: annual report, investor presentation, company website, press releases

Toagosei Group's Adhesive Material segment comprises five main companies: Aron Packaging Co., Ltd.; Toagosei America Inc.; Elmer's & Toagosei Co.; Toagosei (Zhuhai) Ltd.; and Toagosei Hong Kong Ltd. The segment produces instant adhesives (including the Aron Alpha and Krazy Glue brands), as well as functional adhesives (including reactive, hot-melt, and light-cure products) for applications in automotive, electronics, and other industries.

The Adhesive Material segment saw net sales decrease by 11.46% in 2023 compared to 2022

sales, reaching almost ¥12.41 billion (approximately $87.96 million). The company reports that its adhesives for automotive batteries for both hybrid and fuel-cell vehicles are being adopted in an increasing number of new vehicles, including Toyota. The company reported that in fiscal year 2023, sales of instant glue for industrial use increased due to automotive-related sales increasing. Demand for the company's functional adhesives grew due to an increase in sales for automotive batteries.

No. 20 | General Sealants, Inc.

City of Industry, California
www.generalsealants.com
CEO: Brad Boyle
Sources: company contact, company website

Since its establishment in 1964, General Sealants, Inc. has devoted over 60 years to specializing in the manufacturing of extruded sealants tailored to a wide array of industries. These include aerospace, telecommunications, automotive OEM, composites, HVAC, pipelines, highways, industrial manufacturing, construction, and the RV/caravan sectors. The company's diverse product lineup encompasses butyl, ethylene propylene, polyacrylic, polyolefin, polysulfide, and silicone sealants, which are distributed across more than 75 countries globally.

In 2023, General Sealants made substantial R&D investments to enhance capabilities in the automotive, pipeline protection, and composites industries. Its continued significant investment in R&D throughout 2024 underscores its commitment to actively listen to its customers and develop solutions that are precisely tailored to address their unique application challenges.

"I am excited to announce that in 2024, General Sealants is celebrating our 60th anniversary. We take immense pride in reaching this significant milestone, which underscores our dedication to excellence and innovation in the industry. Additionally, I am excited

Image courtesy of monsitj / iStock / Getty Images Plus

to share that we are nearly doubling our production footprint with the construction of a new, state-of-the-art factory. This facility will feature the latest machinery and production technology, enhancing our capacity to meet the evolving demands of our global clientele. This expansion reaffirms our dedication to delivering exceptional products and services across all the markets we serve," said Patrick Boyle, COO of General Sealants

NOTES: New products introduced by the company in 2023 include: GS# CF3 — a sealant that complies with FDA regulation CFR 21, making it ideal for applications in or around food and food packaging.; and GS# 517-1 — a product specially developed for the automotive industry, this sealant helps reduce noise, vibration, and harshness (NVH). It can be backed with a variety of materials, including aluminum, vinyl, EPDM, and foam, to enhance its effectiveness. **ASI**

FEATURE ARTICLE

DEVELOPING MORE SUSTAINABLE PACKAGING MATERIALS

Image courtesy of Nikita Burdenkov / iStock / Getty Images Plus

To compete in the evolving sustainability landscape, manufacturers need to invest in current technologies and new chemistries to develop products with validated sustainability claims.

Daniele Vinci, Business Development Manager, CASE EMEA, Trinseo

Shipping and home deliveries continue to boom as more and more consumers turn to online shopping as their go-to method for purchases. In fact, the Pitney Bowes' Parcel Shipping Index found 161 billion parcels were shipped in 2022, averaging 441 million parcels a day.[1]

Our increased reliance on shipping materials highlights a clear need for durable packaging materials that can withstand the journey from the warehouse to consumers. However, packaging materials must balance durability with sustainability, particularly as consumer demand continues to rise for more sustainable commerce and regulatory bodies like the European Union (EU) introduce guidelines to reduce waste caused by packaging.

Manufacturers must face the challenge of creating more environmentally friendly materials without compromising the necessary performance and durability. Examining the manufacturing process and chemistries of key materials used for packaging materials, such as latex binders, can help the industry keep up with the increased demand for parcel shipping while also meeting sustainability requirements.

Improving Manufacturing Processes

When looking at the materials used in shipping, many materials — such as paper and cardboard — have long been established as recyclable. In fact, many countries across the globe know how to collect and process these materials to make them more sustainable.

On the other hand, current latex binders found in tapes and labels are not inherently recyclable but instead can be formulated to impart sustainability characteristics onto the end product without compromising their reliability. Latex binders play a critical role in packaging applications as they impart packaging with durability and other performance properties, in turn enabling packages to make it to the consumer's doorstep in one piece.

To further sustainability within latex binders and, in turn, improve the environmental impact of the end product, industry players should look to incorporate mass-balance procedures into their manufacturing processes. This chain-of-custody model is designed to accelerate the uptake of sustainable feedstocks in existing value chains by enabling a step-by-step transition towards renewable materials.

Manufacturers can easily trace the flow of sustainable and non-sustainable materials throughout the production of latex binders, validating the end product's sustainability claims and allowing them to create a product that still meets performance needs. The ability to provide accurate data throughout the manufacturing process will undoubtedly help industry players understand their progress in meeting regulatory requirements.

Latex binders can also be formulated to reduce carbon emissions, with their environmental impact easily traced by product carbon footprint reports. Manufacturers can introduce more sustainable feedstocks developed under the mass-balance approach, reducing the product carbon footprint of the packaging application. Each latex binder can be designed to perform at the same level as its fossil-based counterpart.

Taking it a step further, manufacturers can look to decarbonize their operations to help improve sustainability. Decarbonization strategies allow manufacturers to transform how they use energy while also reducing their greenhouse gas emissions. Sites can be outfitted to replace thermally driven processes with renewable energy sources such as electrochemical, solar, or hydroelectric methods. Furthermore, sites can implement simple steps to reduce energy consumption, such as switching to LED lightbulbs. Reexamining a site's energy usage and the development of latex binders is a simple way to begin making a more sustainable end product.

Introducing New Materials

Looking beyond the typical formulation of latex binders for packaging applications, there is potential to incorporate new chemistries that improve the sustainability of the end product. Bio-based feedstocks can be introduced into latex binder production and can be formulated to meet the manufacturer's end goals. Utilizing a natural material, industry players can formulate latex binders that perform on the same level as their fossil-based counterparts. Manufacturers can adjust the level of bio-based materials to meet a company's specific needs while also ensuring that the latex binder continues to deliver critical performance properties for packaging materials like high shear strength. The introduction of bio-based latex binders will be an especially important tool for manufacturers as we continue to learn more about the EU's sustainability goals.

There is also the potential to incorporate recycled feedstocks into the formulation of latex binders, supporting a more circular economy and helping manufacturers align with regulatory requirements. Recent investments in chemical recycling technology can take post-consumer products, or products at the end of their lifespan, and break down the polymers within the product to extract the feedstock needed for new latex binders.

Known as depolymerization, this type of chemical recycling returns the monomers from recycled sources to their original state without the physical degradation typically caused by mechanical recycling. This allows the recycled monomer to be repolymerized to make a new latex binder while exhibiting similar performance properties of a virgin feedstock. This process works especially well when recycling styrene from post-consumer wastes such as yogurt pots and single-use packaging, and creates a recycled styrene for use in latex binder formulations.

The packaging industry should also look to the introduction of polyhydroxyalkanoates (PHA) dispersion technology. PHA is created when microbes consume organic materials and produce extra energy. This compound can then be harnessed for latex binder production and performs like a binder produced using fossil sources. Additionally, because PHA is biodegradable under the right conditions, it can further enhance the sustainable potential of the binder and end-applications. PHA dispersion has the potential to transform the packaging industry by developing materials that meet performance and sustainability needs.

Looking Ahead at Sustainability

The methods for improving the sustainability of packaging materials will remain ever-changing as industry players and consumers begin to adapt and understand new guidelines and regulations. Companies will need to keep a close eye on the changing targets set forth by governments round the world and take calculated risks as they work towards meeting these goals.

We must utilize current technologies that improve sustainability while investing in new technology and chemistries to create an even more sustainable product. Industry players must be willing to look to more bio-based and mass-balanced solutions to provide clear data on an end product's environmental impact in a scalable manner.

Image courtesy of Artfully79 / iStock / Getty Images Plus

Furthermore, we must look to introducing new systems that will allow for chemical recycling – technology that uses chemicals to break polymers down into smaller monomers that can be recycled into a new feedstock. While we remain uncertain of specific sustainability regulations, investing in technology now will be pivotal for future innovation within the packaging industry.

To compete in this evolving sustainability landscape, manufacturers will need to invest in current technologies and new chemistries to develop more products with validated sustainability claims. Industry players must also be willing to take calculated risks to build the infrastructure and value chain needed to support the development of sustainable products. **ASI**

To learn more about Trinseo, visit www.trinseo.com.

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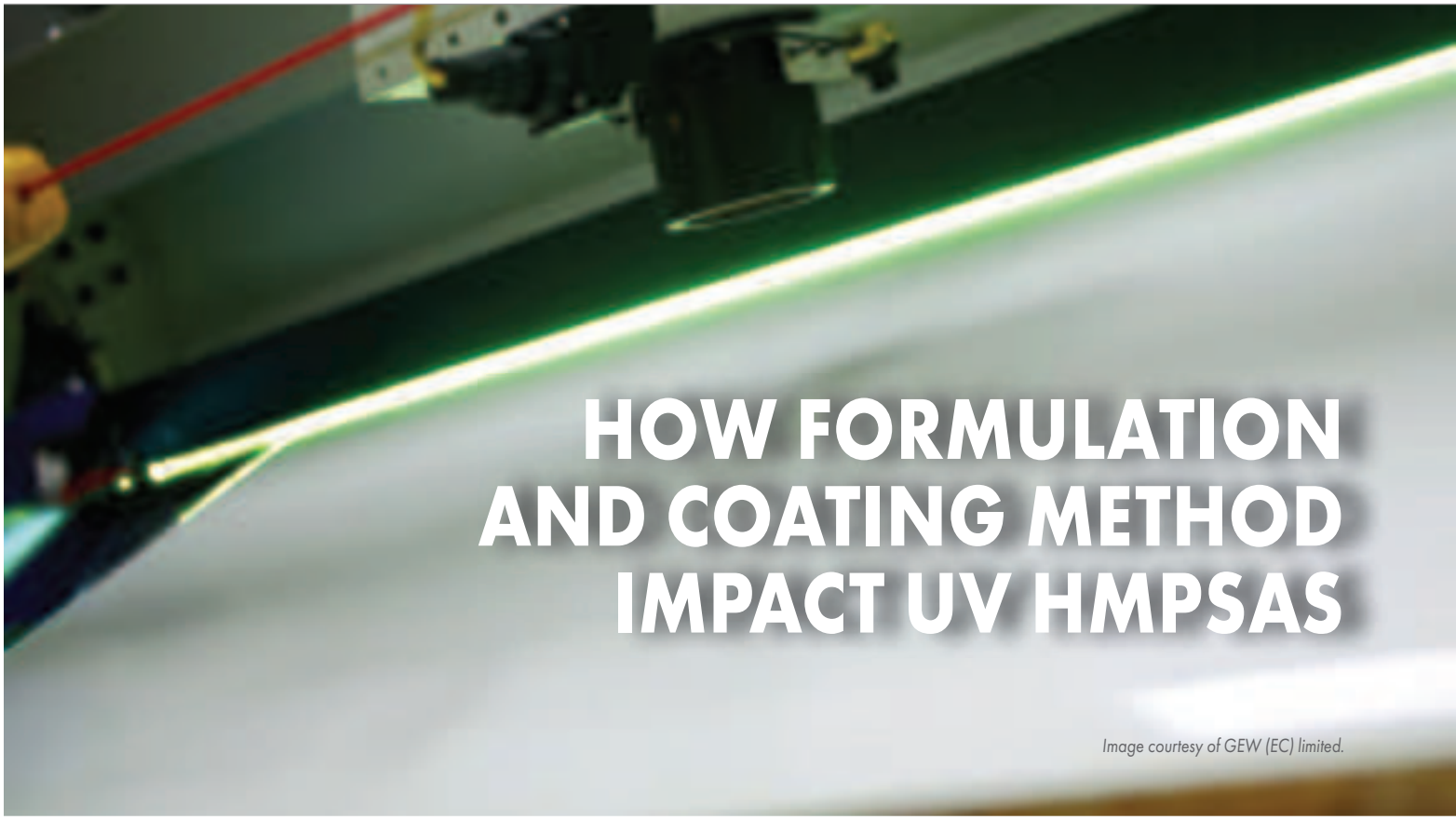

HOW FORMULATION AND COATING METHOD IMPACT UV HMPSAS

Image courtesy of GEW (EC) limited.

Understanding how tackification and coating method impact the effectiveness of UV curing helps to ensure that UV HMPSA properties are properly balanced for their intended end-use application.

By a team of technical experts at Bostik, Inc.

Commonly used in label, non-PVC graphic and specialty tape applications, UV-curable acrylic, hot-melt pressure-sensitive adhesives (UV HMPSAs) are gaining popularity due to their quick curing properties, excellent adhesion, and versatility. In particular, many converters are switching from solvent-based rubber, solvent-based acrylic, and rubber-based HMPSAs to UV HMPSAs because they offer high durability on par with most solvent-based rubber, solvent-based acrylic adhesives and overcome limitations found in rubber-based hot-melt adhesives while also keeping environmental impact to a minimum. However, curing process challenges exist with UV HMPSAs, in particular with how the formulation and coating method (direct or transfer) can impact peel, loop tack, shear, and Williams Plasticity (WP). In this paper, we will explore how tackification and coating method impact the effectiveness of UV curing with H-Bulb. Understanding how these key variables influence performance helps to ensure that UV HMPSA properties are properly balanced for their intended end-use application.

(To note: In this article, “base” refers to an unformulated UV HMPSA, and “tackified” means base with the addition of tackifier.)

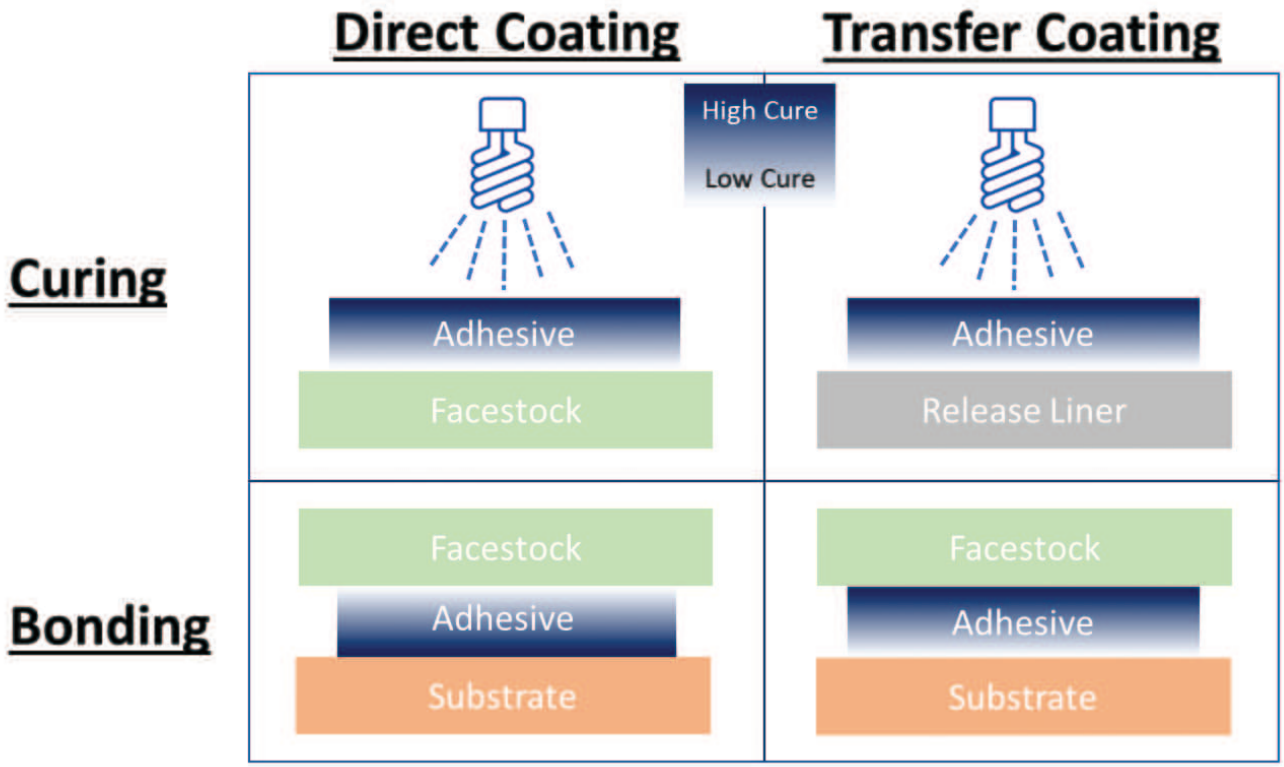

Figure 1: Pictogram highlighting differences between direct and transfer-coated adhesive constructions. Note that the hardest portion of the PSA bonds to the substrate when direct coating, and the softest portion of the PSA bonds to the substrate when transfer coating.

UV HMPSA Formulation

When considering how UV HMPSAs will perform, it's important first to understand how adhesive formulation impacts cure via a UV light. For example, many HMPSA components either absorb, or block, some of the UV light. This includes pigments and photoinitiators as well as any additives that have C = C bond unsaturation or aromaticity, such as tackifiers, plasticizers, or pigments.

Because these materials compete for UV light, addition of additives that absorb UV light limits the effective penetration of the UV light through the sample. This lower effective UV light dosage, especially at increasing concentrations of these additives, will limit the cure-through for the depth of the adhesive. Careful formulation is required to balance properties and also ensure the efficacy of the ingredients.

UV HMPSA Coating Method

UV HMPSAs can be either direct or transfer coated during the manufacturing process. However, just like with the formulation, the coating method impacts end-use performance.

When UV HMPSAs are direct coated, the adhesive is applied directly onto the facestock. The final adhesive performance is primarily based on the directly-irradiated surface, which has a higher level of cure compared to the rest of the adhesive layer. However, when UV HMPSAs are transfer coated, the directly-irradiated adhesive surface (high cure) is then laminated to the facestock. Therefore, adhesive performance is mostly based on the low cure surface, which is the softest portion of the entire adhesive layer (see Figure 1). Since high cure adhesives favor the cohesive properties (shear), and low cure adhesives favor the adhesive properties (tack, peel), the structural

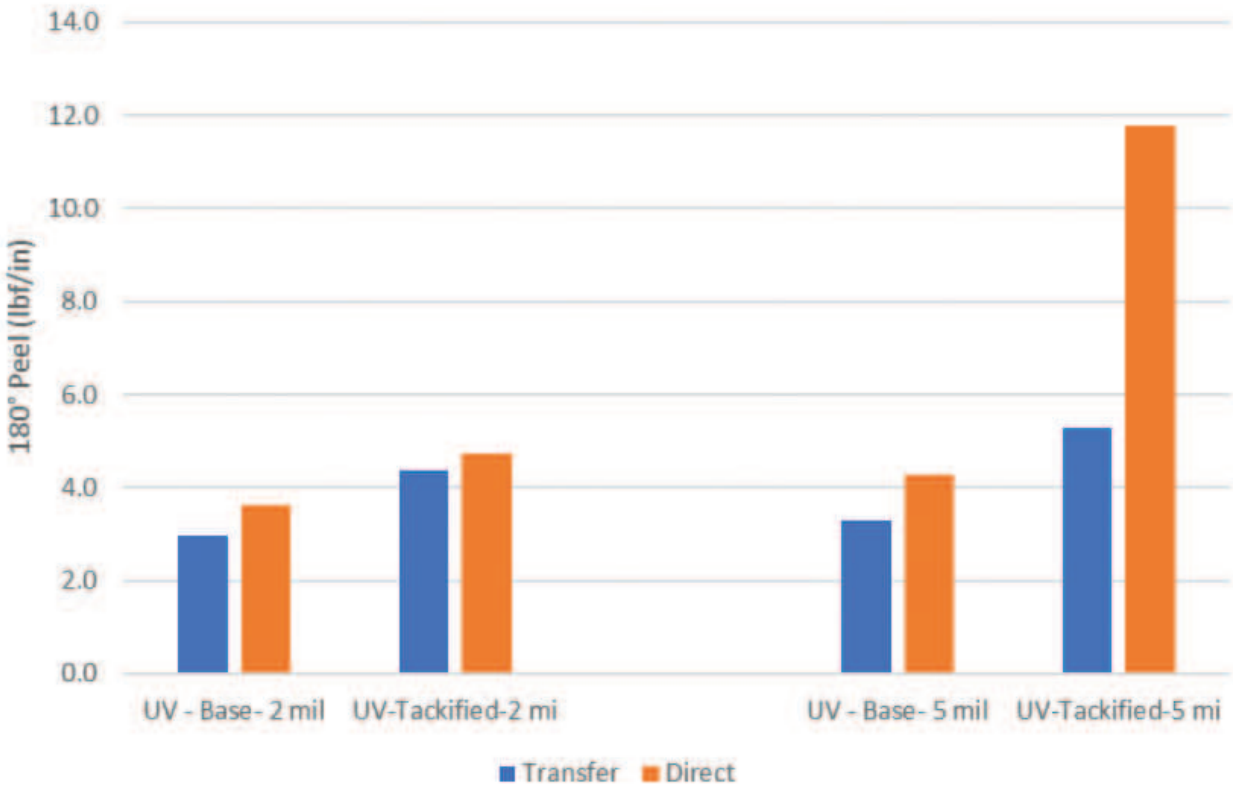

Figure 2: Peel performance of UV-cured base adhesive at 2 mil cured with 60 mJ/cm2 and 5 mil cured with 100 J/cm2 UVC light irradiated with a H-Bulb with and without tackifier.

differences resulting from direct- vs. transfer-coated adhesive films drive dramatic differences in all aspects of adhesive performance.

As coat weight thicknesses increase, the variation observed in peel, tack, and static shear across direct- and transfer-coated materials can be seen in the following section. This variation increases further as adhesives are tackified and there are additional materials vying for the UV light.

Further, viscoelastic properties for UV HMPSAs are substantially different when compared to traditional solvent rubber-based adhesives. Because traditional solvent rubber-based adhesive cure takes place via thermal activation or the removal of inhibiting solvent, they are much more uniformly cured across the adhesive depth. As a result, the adhesive properties between most direct-coated and transfer-coated constructions will be almost identical. Additionally, UV HMPSA cure is extremely sensitive to the dose of light at the molecular level. Higher amounts of UV light increase the level of cure, which has the effect of making the adhesive "harder" and increasing shear.

In the following sections, we will examine how peel, tack, and shear are impacted by the coating method and adhesive thickness and the addition of a tackifier. For all of the studies, the 2 mil adhesive was cured with 60 mJ/cm2 UVC light, and the 5 mil samples were cured with 100 mJ/cm2 UVC light with a H-bulb.

Peel Performance

For the 2 mil adhesive samples, the peel difference is 0.4 to 0.6 lbf/in between direct coated and transfer coated. For the 5 mil sample both direct coated and transfer coated, the peel difference is a significantly greater 1.0 to 6.5 lbf/in. The direct-coated adhesives

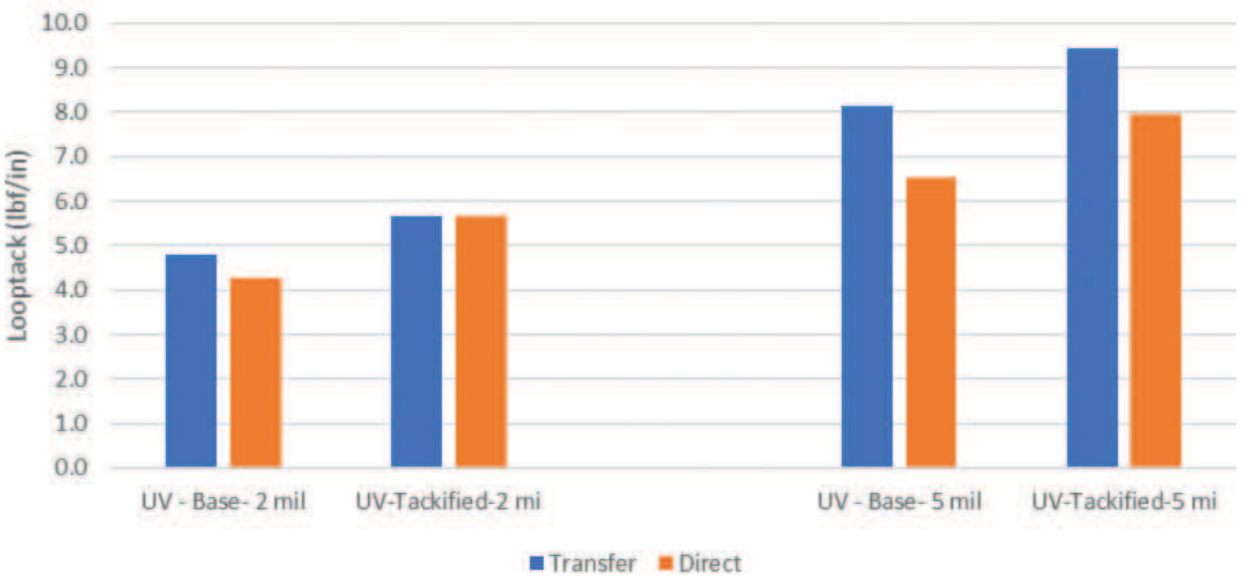

Figure 3: Loop tack of UV-cured base adhesive at 2 mil cured with 60 mJ/cm2 and 5 mil cured with 100 J/cm2 UVC light irradiated with a H-Bulb with and without tackifier.

have a lower peel value, which was attributed to the higher degree of cure at the adhesive surface. This indicates that the direct-coated material test surface (directly irradiated) may have a higher cure/modulus than the transfer-coated material test surface (indirectly irradiated). Addition of tackifier increases the UV absorption of the adhesive. Increased UV light absorption may have an impact on the penetration of light and the wavelength of light that can penetrate through the bulk of the adhesive. Peel values between direct-coated adhesives and transfer-coated adhesives that have been tackified at 5 mil have the largest differential of all the samples at 6.5 lbf/in. In both direct and transfer-coated UV HMPSAs, the addition of tackifiers causes peel strength variation between coating processes to increase when the coat weight is 5 mil or greater. The reason for this increase has to do with the variation in light exposure and the resulting crosslink density through the depth of the adhesive.

The thicker the adhesive, the bigger differential will result in comparing peel strength between direct- and transfer-coated surfaces. This is only exacerbated by the addition of light-absorbing materials such as tackifiers.

Loop Tack Performance

Like with peel, UV HMPSA loop tack performance is similarly impacted by direct or transfer coat at 5 mil coat weight, especially when UV absorbing tackifiers are present. Results for loop tack tests are shown in Figure 3 for base and tackified adhesives coated at 2 and 5 mil coat weights. The loop tack differential between direct- and transfer-coated samples increases when comparing the 5 mil to the 2 mil coat weight samples. The loop tack difference between the 2 mil sample both direct and transfer coated is 0.1 to 0.5 lbf/in. For the 5 mil sample both direct and transfer coated, the loop tack difference is significantly greater at 1.5 lbf/in. The direct-coated surface has a higher crosslink density. The high amount of UVC light that irradiates the surface efficiently crosslinks the surface of the direct-coated adhesive. As the light penetrates the adhesive, UV light is absorbed by the photoinitiator and tackifier. Therefore, lower UV doses penetrate across the adhesive. The absorption of UV light leads to less crosslinking across the adhesive from top (irradiated directly) to bottom (not irradiated).

The thicker the adhesive, the bigger differential you will see in loop tack between direct- and transfer-

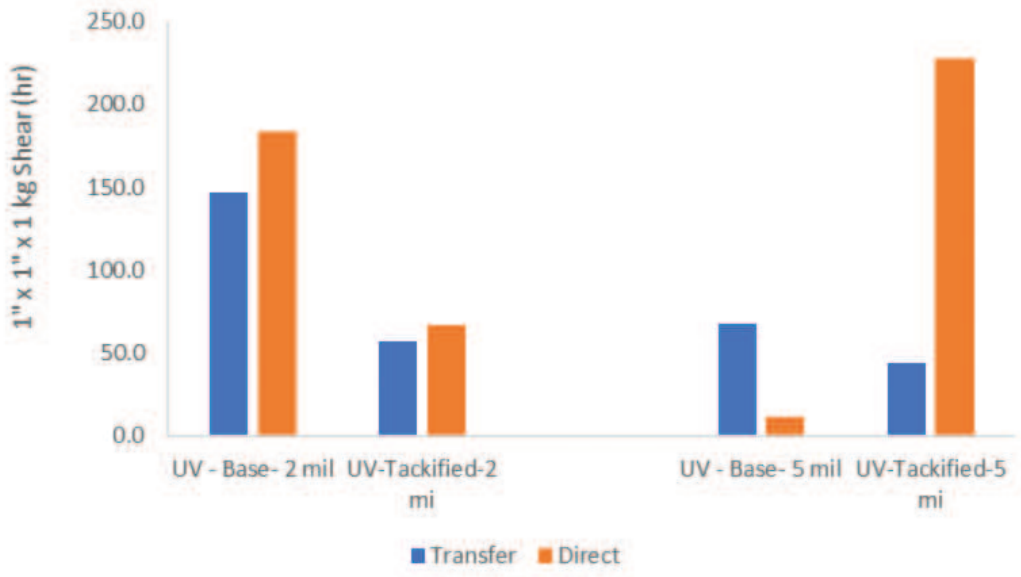

Figure 4: Static shear of UV-cured base adhesive at 2 mil cured with 60 mJ/cm2 and 5 mil cured with 100 J/cm2 UVC light irradiated with a H-Bulb with and without tackifier.

coated surfaces because of less crosslinking across the entire adhesive.

Static Shear Performance

Results for static shear tests are shown in Figure 4 for base and tackified adhesives at 2 and 5 mil coat weights. For the base adhesive, increasing the coat weight leads to a dramatic shift in shear values when comparing direct- and transfer-coated adhesives. The dramatic difference for direct-coated adhesives is attributed to the high UVC dose at the surface. The high UVC dose at the surface leads to a high modulus at the surface and poor wet out of the stainless-steel surface. Therefore, the mixed failure-mode of static shear test can be misleading when relying on shear only as a measure of the cohesive strength of the adhesive.

Tackifier added to the base adhesive impacts the surface cure and cure through the bulk of the adhesive. The direct-coated material shear outlasts the transfer-coated adhesives. Failure mode is cohesive for all samples.

If the static shear results of the 5 mil tackified are compared to the 5 mil base results, there are some noticeable differences. First, the direct-coated shears for the tackified samples are failing cohesively, versus a mix of cohesive and adhesive failure for base at 5 mil coat weights. The mixed failure mechanisms of the base indicate poor wet-out of the stainless-steel plates by the base and lower shear values result. A longer dwell time before hanging shear weights on the samples may make the data more reproducible and provide more accurate shear value for the base. Tackified samples generally show higher shear values when direct coated than the base.

Williams Plasticity

Williams Plasticity (WP) is an indirect measure of the storage modulus of an adhesive and is not impacted by surface effects (i.e., wet-out/flow). The results of all UV HMPSAs are shown in Figure 5.

The difference in these performance characteristics while having similar WP values indicates that the samples cured with light likely have a differential modulus across the thickness of the sample. The samples have a high differential in peel, loop tack, and shear for the base samples. A differential

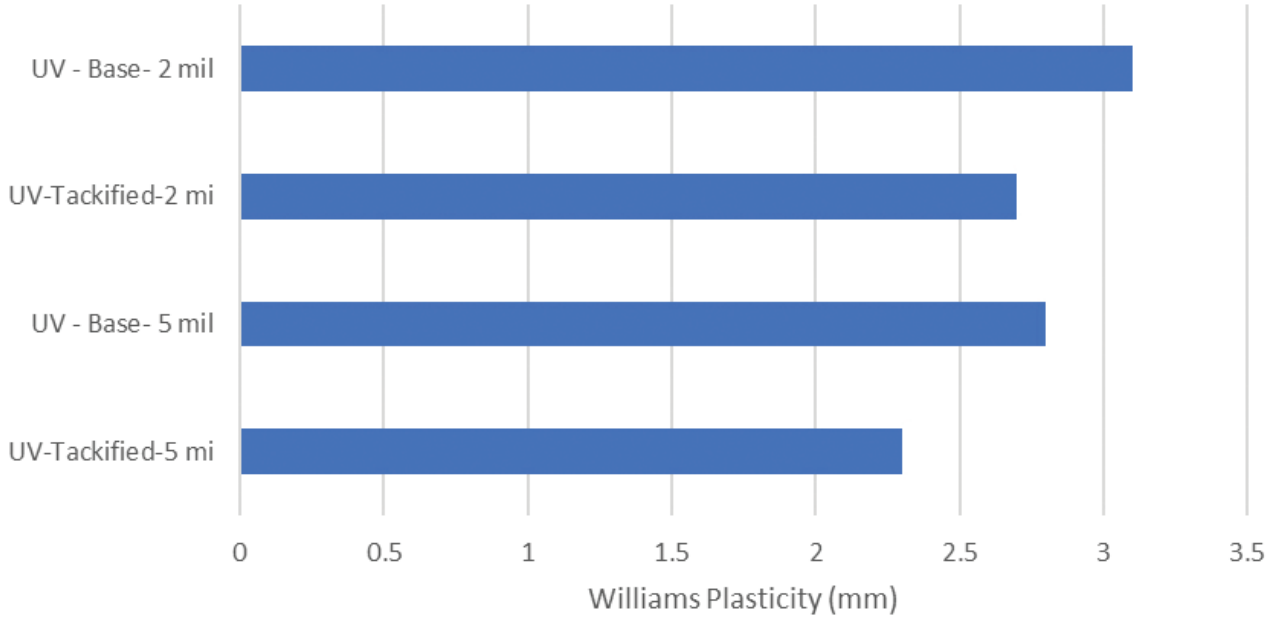

Figure 5: Williams Plasticity of base and tackified UV HMPSA adhesive at 2 and 5 mil.

modulus across the adhesive is highlighted by the sensitivity of shear tests of UV-cured samples to fail with mixed cohesive/adhesive failure and the large differential in loop tack. The mixed mode failure of UV-cured samples demonstrates a higher modulus at the surface that was direct coated compared to the surface that was transfer coated. For the tackified adhesive, samples coated at 2 mil coat weight demonstrate the highest WP. Increasing the coat weight leads to a lower WP result. Because 2 mil samples have a higher WP than the 5 mil thick samples, the cure across the samples is not homogenous at the dose ranges chosen for this study. The absorbance of UV light across the thickness of the adhesive makes this condition difficult to overcome with the types of UV lights chosen for this study without over-curing the surface.

Conclusion

During this work, it was shown that the adhesive formulation, adhesive thickness, and coating method all impact the adhesive properties of UV HMPSAs. In general, UV HMPSAs cured with the H-Bulb demonstrate a different adhesive performance for peel, loop tack, and shear when comparing the directly irradiated (direct-coated) and indirectly irradiated (transfer-coated) surfaces. An increase in thickness and addition of additives that absorb UV light increased the variance in performance for each coating method. A difference in crosslink density at each surface due to varied light exposure leads to different viscoelastic response during testing. Cohesive strength was increased with higher UVC dose, but shear failure mode transitioned to mixed adhesive/cohesive failure, resulting in less consistent results. The results of this study highlight the considerations for coating and formulating UV HMPSAs. An understanding of the UV HMPSA formulation and interaction with light will allow for a thoughtful process to be designed for curing the adhesive to obtain the desired performance. Additionally, UV HMPSAs performance can be adjusted to manipulate the UV HMPSAs crosslink density and therefore the viscoelastic performance. **ASI**

This paper was written by the technical experts at Bostik, Inc. If you have any questions about UV HMPSAs and the information noted here, visit www.bostik.com/us/en_US/customer-support.

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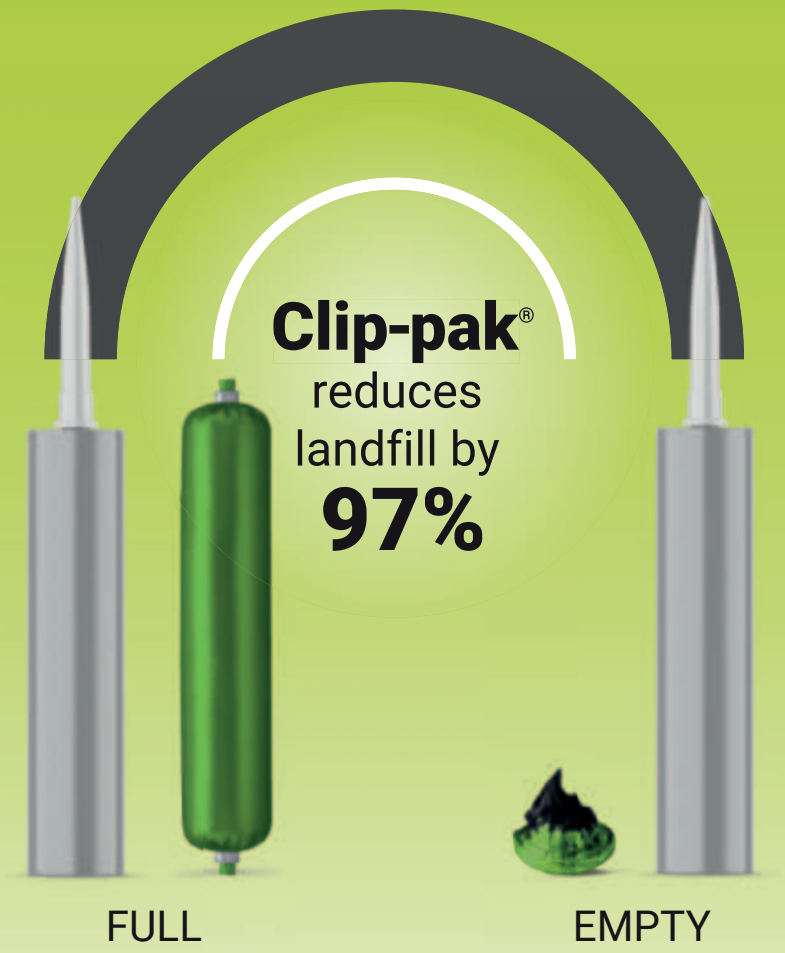

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