Recent developments in pressure-sensitive adhesives

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Developments in packaging and material handling have opened up new markets for pressure-sensitive adhesives.

Several papers have addressed the development and use of pressure-sensitive adhesives (PSA) since the TAPPI Polymers, Laminations and Coatings Conference in 1984. Until that year, applications for self-adhesive labels had been reviewed in only one paper (*1*). Four papers addressed this issue in 1987. There are other indications of increased awareness of this long-lived but still healthy and growing market segment. A wide variety of new label face stocks have appeared on the market in the past few years. A number of new laminate suppliers have recently entered the market. And established coaters of other PSA-coated materials are broadening their product lines to include roll and sheet stocks for label use.

The U.S. market for PSAs is large and growing. The size of the market and the distribution of the produced tonnage among the various market segments, including self-adhesive labels, is open to debate. Estimates for 1985 from six varied but credible sources ranged from 263 million lb (dry) to 742 million lb. The average of these six estimates was 480 million lb, and the average projected compound annual growth rate (CAGR) was 6.2%. A more recent study (*2*) forecasts an 8.3% CAGR through 1996.

Tapes, by general consensus, represent the largest market segment. The 1986 distribution, based on shipment values, was 66.4% tapes, 19.7% labels, and 13.9% other (*2*). This translates into roughly 100 million lb (dry) of adhesive for label uses.

Another recent study (*3*) estimates that the U.S. production of self-adhesive labels in 1985 was approximately 1 billion m^2. Assuming a 6.2% CAGR and an average adhesive deposition of 14 lb (dry) per 3000-ft^2 ream, an estimated 56 million lb (dry) of adhesive was used in label applications in 1986. Label applications in the United States are a significant consumer of PSAs.

Label evolution

Self-adhesive labels represent one of the oldest of the major market segments in the PSA industry. Stanley Avery originated the concept with his introduction of peel-off price-marking labels in 1935. Those early years following the introduction of pressure-sensitive labels must appear nostalgically simple to today's label producer. Face stocks were almost exclusively paper; adhesives were solvent-borne rubber/resins; and most of the end use was in price marking and other forms of secondary labeling.

Today, the producers of label stock, along with the printers and converters, face an often bewildering array of options. Rubber-based PSAs are still available in their original solution form, but now they are also available as waterborne latexes and 100%-solids hot melts. PSAs based on acrylic copolymer chemistries are supplied in solution, emulsion, and 100%-solids forms. New, non-acrylic, multipolymer emulsions with synergistic properties are available, and electron-beam- and ultraviolet-curable systems are on the horizon. Face stocks range from conventional and modified papers through an ever-increasing variety of plastic films, foils, and metalized substrates.

Label applications continue to expand. Primary labeling, electronic data processing (EDP), and machine-readable barcode labels are prominent examples.

Face stocks and laminates

A look at trade publications serving the printing, converting, and packaging industries shows an increase last year in the number of advertisements and press releases describing the new face stocks and their pressure-sensitive laminates. Paper's dominant position in the self-adhesive-label market is being challenged. This trend is more pronounced in some major markets outside the United States. A study published in 1985 (*3*) indicates that Japan has been leading the way, as seen in **Table I.**

There are several reasons for the trend. Pulp prices have increased significantly while petroleum prices have declined, resulting in stabilization and even reductions in the price of plastics. Packaging innovations, such as the squeezable plastic bottle, dictate the use of conformable, flexible labels. Physically demanding applications, such as industrial barcoding and labels for sterilized containers, place extra demands on face stocks as well as adhesives. Regulatory agencies require

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increasing amounts of safety and nutritional information on certain labels, thus creating a need for better printing surfaces.

Modified papers

Paper suppliers are responding to these evolving requirements by improving their products. Kimberly-Clark's New Generation DURA-FORM®, for example, is a latex-impregnated paper for use in primary labels. A reported two-fold increase in smoothness over the original version provides better print fidelity. Fasson offers a latex paper construction in its Econoflex® line as a lower-cost alternative to polyvinyl chloride (PVC). Conformable papers for squeeze-bottle applications are becoming available.

Polyvinyl chloride

PVC, or "vinyl," was the first major plastic to be used as a face stock. It was first used in the 1950s and remains a significant factor in the marketplace. Its primary disadvantage results from the need for the addition of plasticizers to achieve flexibility and stabilizers to prevent degradation. Plasticizers and stabilizers can migrate and affect adhesive performance, so careful selection and testing is required. A wide variety of olefinic and other plastic films are now available in addition to PVC.

Polyethylene

FLEXcon is advertising two label lines with polyethylene (PE) face stocks. Compucal II® is a PE film with a matte topcoat for variable information labels. The reFLEX® line combines a primed PE face stock with a high-strength polypropylene release liner that is said to be more durable than paper liners.

Polypropylene

Kimberly-Clark's Kimdura®, an oriented polypropylene, is being promoted as an alternative to PVC. It is available topcoated for critical printing applications such as barcodes. Mobil Chemical's Oppalyte® opaque oriented polypropylene films were originally introduced as flexible packaging materials but are now finding use as face stocks.

Polystyrene

Dow Chemical's Opticite® polystyrene films are available in both clear and opaque formats. Both are described as unplasticized and more shrink- and stretch-resistant than PVC. Labels are claimed to dispense well at lower thicknesses than required for PVC. The manufacturers that have introduced clear and opaque laminates based on Opticite include FLEXcon, with their Optical line, Fasson's Opticite prime label line, and Mactac. United Tape and Label, a printer, is promoting their Polyluster labels, which use Opticite film.

Polyethylene/polystyrene

An alloy of polyethylene and polystyrene is offered in the United States under the Polyart® name by Richard Lewis Paper Co., as a distributor for the United Kingdom's BXL Plastics Ltd. The stock is clay coated for ink receptivity.

Polyester

Decora Corp. recently introduced a line of computer-printable, topcoated polyester laminates as alternatives to paper for EDP applications. FLEXcon's FLEXtwin uses an opaque lamination of two separate polyester films in a laminate supplied on a polyester release liner for two-way window decals.

I. Market share for paper and non-paper face stocks, %

	Paper	Non-paper
Japan	80	20
United Kingdom	89	11
United States	95	5

Source: Labels and Labelling Data and Consultancy Service.

Cellulose acetate

Like PVC, cellulose acetate has been used for labels since the 1950s. The increased demand for tamper-evident seals is generating an expanded market for this friable film.

Unspecified plastic films

Manufacturers are also offering laminates based on unidentified plastic films. The 3M Co.'s Primalyn® series, for example, is described as an unplasticized hydrocarbon film and is positioned as a nonshrink, lower-cost replacement for PVC. Mactac's Opticlear® products are being marketed as clear, nondistorting labels for hospital and laboratory use.

Aluminum foil and metalized papers and films

Aluminum foil is used as a face stock for self-adhesive labels and nameplates. Dennison Manufacturing Co. is now offering a high-gloss, metalized paper alternative. While more expensive than foil, it is claimed to reduce waste through elimination of curl. Topflight Corp.'s PRIMO® line of metalized films is being promoted for primary labeling in the cosmetic and over-the-counter (OTC) pharmaceutical markets.

Applications

Paper and the alternative face materials that we have reviewed are used as label face stocks in an increasingly diverse and demanding range of applications.

Price marking

Price marking was the first major market for pressure-sensitive labels. This remains a significant market despite the increased use of scanner-readable, preprinted universal price codes (UPC), which are now being used in more than 35% of U.S. supermarkets. Some states have responded to consumer pressure by enacting statutes that require the use of price labels.

PSAs for this use require a balance of high tack and specific adhesion to a variety of surfaces, with sufficient cohesive strength to prevent edge ooze, which can jam applicator devices.

Primary labels

Primary labels carry brand-name identification and are among the fastest growing applications for PSAs. The growth has been spurred by increasing availability of accurate, high-speed label application equipment and by greater use of difficult-to-label containers, such as plastic

bottles. PSAs require excellent tack for high-speed label placement plus good cohesive strength to resist flagging (wing-up) on curved surfaces. Clear-film labels require clarity and absence of color. In addition, some plastics used for bottles are not effective barriers to migration of plasticizers or oils. PSAs used to label these materials should be free of ingredients that can migrate through the container wall and adulterate the packaged contents.

Electronic data processing labels

EDP labels are another major growth area. These labels are used in combination with computer-generated printing for applications such as inventory control, order picking, and addressing.

PSA requirements are demanding. Good cohesive strength is needed for the high-speed printing/converting operations that are often involved. Adhesion to the release liner must be adequate to prevent predispensing. Since uncoated papers are often used as face materials, penetration resistance is important. Many of these labels are applied to corrugated boxes, often in warehouses where temperatures can be as low as 40°F, requiring low-temperature bonding capabilities. In addition, corrugated boxes are frequently made from recycled materials, resulting in a variable and often difficult-to-bond surface.

Barcode labels

The market for machine-readable barcode labels is also growing rapidly. The original use was for UPC/OCR scanning in retail outlets. Barcode labels are now moving into industrial applications, where they are used for inventory control and component coding in product assembly by the health care, automotive, and electronics industries. Some of the end uses are demanding, on both the adhesive and face materials. Autoclavable labels in some health care applications must resist temperatures as high as 250°F for extended periods. Labels used for printed circuits must be able to withstand short-term exposure at 500°F or more. Labels on machinery components are exposed to severe stresses during handling. In addition to requirements for high strength and environmental resistance, the critical aspect of print quality demands a face material that can resist ink penetration. The use of plastic films is increasing. Overlamination with PSA-coated plastic films provides protection in harsh environments and the ability to resist abrasion from contact scanners.

Thermally printed labels

Thermally printed, self-adhesive labels have become an important market segment in a relatively short time. They are replacing impact-printed, heat-seal labels in computer-controlled weighing operations for meat and poultry pricing and inventory control. Low-temperature adhesion to polyolefin packaging films is a major requirement. Thermal printing is based on activation of a heat-sensitive topcoat on the face material. Since this coating is rendered ineffective by a variety of chemicals, nonmigratory adhesives are important.

Tamper-evident seals

The need for tamper-evident closures became apparent in 1982, when several people died after ingesting OTC nonprescription drugs that had been laced with poison. Dozens of actual and threatened incidents have occurred since, and a variety of tamper-evident systems have been introduced in response. Pressure-sensitive-applied safety seals are among them. Most of the current applications are for OTC drugs such as pain relievers and decongestants. The U.S. Food and Drug Administration now requires at least two tamper-evident barriers on such medication, e.g., a blister-packaged card for the capsules plus sealed end flaps on the outer carton. While not yet legally required, food companies are also starting to add tamper-evident features.

Destruction of the label or other evidence of tampering, such as ink lift from the printed substrate, is the primary requirement. This is achieved by combining a fragile face material, usually lightweight paper or cellulose-acetate film, with an aggressive, high-peel-strength PSA. Fluorescent dyes are often added to the adhesive for inspection purposes on the labeling line, since missing seals are presumed to be evidence of tampering.

Problems and opportunities

In spite of the availability of new face materials and improved PSAs, problem areas remain. Some of these are long-term and continuing, such as adhesion to cold, damp surfaces and to low-energy materials such as untreated polyethylene. Others are new, resulting from emerging technologies that are placing new demands on adhesives and face stocks.

Release liners

Both printing/converting and label-application speeds are increasing. With this increase, the silicone-coated liner and its interaction with the PSA become more critical. Web breaks and V-tears in the liner cause unacceptable scrap loss and downtime. Just as various plastic films are now competing with or complementing paper for face materials, film release liners are becoming more common.

Siliconized polyester liners have been used for some time in applications such as PSA-coated overlaminating films in the graphic arts market, where appearance is critical. Polyolefin grades are now being introduced as well. Fasson's oriented polypropylene Bronx® liner and the biaxially oriented polypropylene liner used by FLEXcon on their reFLEX grades are examples. FLEXcon claims both greater tear resistance and increased compressibility for cleaner diecutting.

PSAs with reduced variation in release values have entered the market. National's NACOR® 90, a new waterborne grade, provides consistent release independent of the cure cycle and the age of the silicone coating prior to lamination. **Table II** compares the release values of NACOR 90 and acrylic emulsion PSAs with a low-temperature-curing, 100% solids silicone system—Dow Corning's SYL-OFF® 7610/7611.

Low-energy surfaces

Materials with low surface energy, such as polyethylene and polypropylene, have been a persistent problem in pressure-sensitive-labeling applications. Soft, rubber-based PSAs bond fairly well but are difficult to convert. Acrylic adhesives convert well but exhibit low bond strength unless the surface is pretreated to improve wettability. This technique is sometimes used on bottle

II. Adhesive release values for NACOR 90 and acrylic emulsions, g/min at 400 in./min

Cure temperature	Cure time, s	Coating age before lamination: In-line NACOR 90	In-line Acrylic	24 h NACOR 90	24 h Acrylic	7 days NACOR 90	7 days Acrylic
180°F (83°C)							
	50	15	64	10	86	20	40
	80	10	54	13	40	15	40
	100	10	45	15	40	15	30
	150	10	40	15	40	15	30
300°F (149°C)							
	10	10	35	15	30	15	28
	20	10	25	15	20	15	20
	40	10	13	15	15	15	20
	80	10	10	15	15	15	25
390°F (200°C)							
	5	10	30	15	20	15	20
	15	10	15	15	15	15	20
	30	10	15	15	13	15	20
	60	10	13	15	15	15	20

labeling lines, but it cannot be used for flexible packaging and other labeling areas. Recently developed PSAs that combine the adhesive properties of rubber with the desirable convertibility and aging characteristics of acrylics appear to be a solution to the problem.

Amber and opal glass

Colored bottles are used for packaging light-sensitive materials, such as pharmaceutical products. Like the olefin plastics, these surfaces tend to have low surface energy. In this case, the low surface energy results from the greater amount of mold-release agent used in the manufacture of colored glass as opposed to clear glass. Flame treatment is commonly used to burn off the release agents. However, the development of PSAs with greater tolerance would be a better solution.

Polyvinyl chloride

PVC, which is widely used in the manufacture of consumer goods such as luggage, is also used as a label face material. The troublesome migration of plasticizers and stabilizers is a problem that applies to both PVC substrates and labels. When PVC is the substrate to be labelled, however, the label supplier has no direct control over which type of label is used. If the labeler selects a product coated with rubber-based PSAs, staining and softening usually occur. Stain-resistant, nonpaper face materials help with the staining problem, although not with the edge ooze or flagging that is caused by softening. Plasticizer-resistant PSAs should be used.

Sterilization: resistance to heat and radiation

For certain health care applications, pressure-sensitive labels are exposed to sterilization cycles under steam autoclaving conditions, e.g., 20 min at 250°F. Many of these applications involve bonding of the label around a tight radius, as with narrow-diameter glass vials. Heat-resistant PSAs should be used to avoid flagging (wing-up) or, even worse, label loss.

Another sterilization process—exposure to gamma rays from radioactive elements such as Cobalt 60—is becoming more common. Studies show that bond strength is not affected much by exposure to the relatively low dosages of 2.5 Mrad (radiation absorbed dose). Discoloration of some rubber-based PSAs can occur, however (*4*).

The future

New applications for self-adhesive labeling have appeared with regularity over the past few years. These applications have been supported by improvements in adhesives, face materials, and release liners. Respected forecasters are predicting continued health and growth for the pressure-sensitive label industry. However, the startup of nine plants for the production of laminates since 1980 is the best indicator of the current mood of optimism within the industry.

Literature cited

1. LaFollette, W.R., 1985 Polymers, Laminations and Coatings Conference Proceedings, TAPPI PRESS, Atlanta, p. 177.
2. Specialists in Business Information (SBI), Wantaugh, N.Y., July 1986.
3. Labels and Labeling Data and Consultancy Service, Ltd., Potters Bar, England, 1985.
4. Fries, J.A. and Fenton, M.D., 1986 Polymers, Laminations and Coatings Conference Proceedings, TAPPI PRESS, Atlanta, p. 33.

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