The Development of a Photopolymer Based Additive Manufacturing Process for Producing a Unique No-label Look Decoration Without a Laminated Face-stock

Anthony Carignano

Keywords: pressure sensitive, no-look labels, narrow web, rigid packaging

Abstract

Plastics are used in virtually every shape and form in our daily lives. They provide a lighter weight alternative to aluminum and glass. Plastics play a vital role in maintaining the shelf-life and safety of consumer products during transport and product storage. Over the past decade, consumer backlash has grown significantly over single-use plastic packaging encompassing both flexible and rigid structures. Increasingly aware of the scope of consumer product packaging pollution, governments in developed and emerging economies have introduced levies and bans to combat single-use plastic waste and limit its global transport as a commodity. The negative impact of improperly disposed of single-use plastics and their accumulation in marine and land environments has driven global brand owners towards a more critical assessment regarding the sustainability and recyclability of consumer product packaging in general.

Plastics, aluminum, and glass in the form of materials used for rigid containers all use some prime labeling system to call attention to the product and inform the consumer of its ingredients. If improperly designed, prime labels can present high cost of ownership challenges concerning waste and recyclability.

This paper will provide an overview of Crystal decorating technology for narrow web prime label applications. Crystal decorating chemistry, hardware, and carrier film selections will be discussed. The paper will describe how Crystal's unique product and manufacturing process could conceptually provide near-zero waste to landfill for printers/converters and the ability to decorate at lower caliper than extruded films. The paper will then discuss Crystal decorating application

ACTEGA North America Technologies Inc.

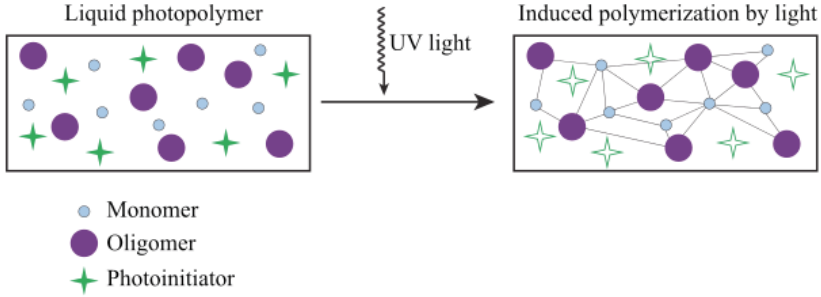
performance attributes. References will be made comparing the performance and appearance of Crystal decorating to "No-Look" pressure sensitive labeling used for rigid container decoration.

Introduction

Crystal is a joint chemistry and hardware approach for creating narrow web label decorations. The technology uses conventional inline narrow web press assets in combination with modified pressure sensitive label (PSL) application hardware. Crystal set-up times and maintenance requirements for printing are equal to that conventional narrow web printing where photopolymer based chemistries and ultraviolet curing are used. The chemistry is print applied to a siliconized polymeric carrier release film. The use of modified applicator hardware allows for Crystal decorations to be easily transferred to rigid packaging containers with a unique "No-Look" label appearance. Compared to conventional "No-Look" PSL media offerings, Crystal decorations are created without the need for face-stock, generate significantly less matrix waste and with specifically approved release liner structures afford options for reuse or continuous loop recycling.

Crystal Decorating Chemistry

Crystal coatings, inks and adhesives are formulated with photopolymer chemistry. Photopolymers change their properties when exposed to ultraviolet light or non-ionizing radiation. All Crystal starting point formulations may contain blends of monomers, oligomers along with photoinitiators. Monomers are primarily used to adjust for viscosity and adhesion properties. Higher viscosity oligomers provide a variety of performance characteristics such as scratch, abrasion, and solvent resistance. Photoinitiators are compounds that when exposed to ultraviolet light decompose into reactive species that instantaneously activate monomers and oligomers through a process called crosslinking. A wide variety of technologically useful applications within the printing and converting industry rely on photopolymer chemistry such as UV curable coatings, inks, and pressure sensitive adhesives (PSAs).

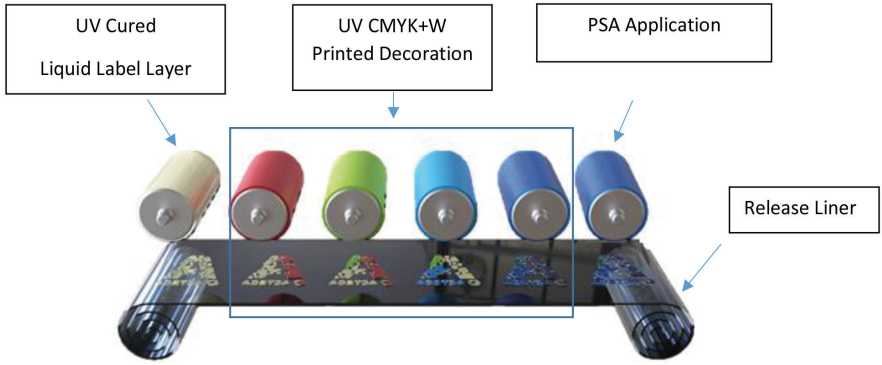


Crystal Decorating Process

Crystal is a joint chemistry and hardware approach for creating prime narrow web decorations. The technology can be applied using conventional inline narrow web printing technologies including flexography, screen, piezo drop-on-demand inkjet, or combinations thereof. Total decoration gauge thicknesses of less than twenty microns can be achieved using a 100% flexographic printing approach. Decoration gauge thicknesses greater than fifty microns are reserved for screen.

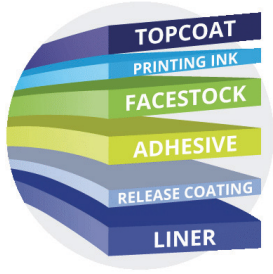
As shown in the 100% flexographic approach below, the first stage in the Crystal decorating process is the application of a clear releasable spot UV coating to a Crystal compliant carrier film. The coating is applied at a minimal thickness of 10 microns on the flexographic first station of an inline press. The clear coating serves as a protective releasable layer. It also provides structural stability and print receptivity for cyan, magenta, yellow, black and white process colors to be applied in layers in registration over the clear layer so that multi-colored images can be produced. The Crystal decoration additive printing process is finalized with the addition of an ultraviolet curable pressure sensitive adhesive (PSA) layer. Surface adhesion of the Crystal decoration is optimized through the PSA layer that anchors the Crystal decoration to rigid packaging surfaces. Significant material cost savings are achieved in applying the PSA in registration with the spot applied multi-colored image layer of the Crystal decoration. Once printed to the release liner, the Crystal decorated release liner is managed as decorated roll stock. The roll stock is placed on an inline applicator modified for transferring Crystal decorations.

Individually printed Crystal decorations are then peel transferred and pressure applied to rigid containers. The rewound spent carrier film is then recycled.



Pressure Sensitive "No-Look" Label Components and Construction

Pressure sensitive labels are composed of a topcoat, face-stock, adhesive, release coating, and liner. The components that make up a PSL are commonly referred to as the 'sandwich' because the label consists of several materials stacked or sandwiched in layers. Most pressure sensitive sandwiches are typically more than seventy-five microns in total gauge thickness depending on application, performance, and appearance requirements. PSL liners generally are 25 to 50 microns in total gauge thickness and are used to support the transport of the label facestock as it passes through a label applicator. "A typical PSL company's label specific waste is made up of two components, matrix, and liner. Matrix waste consists of paper or film stock with adhesive coating and possibly ink. Liner waste is paper or film material composed of silicone and also possibly ink. These waste materials are specific byproducts of label production." Few scalable recycling options have yet to be created for either waste component and pressure sensitive liner films can represent as much as forty percent of overall label raw material cost.



Pressure sensitive label liners in North America are typically made from either polyethylene terephthalate (PET) or super-calendered kraft paper (SCK). PET-based liners provide the best cost performance on a square area basis. The high strength, high-temperature resistance, and uniform caliper of PET permit usage in higher speed conversion application. SCK based liners are commonly used based on their competitive cost per weight in lower line speed roll to roll applications where marginal perforating is required. The ability to use either liner type depends on process temperature profiles, surface energy, and handling requirements.

Crystal Decorating Components and Constructions

Crystal decorations are composed of adhesive, printing ink, topcoat and release coated liner layers. The usage of a face-stock is not required. Crystal decoration components are print applied to a liner carrier film in reverse order to the conventional 'sandwich' structure of a PSL. Printed flexographically, Crystal decoration components, including liner film, are typically much less than 75 microns in total gauge thickness.

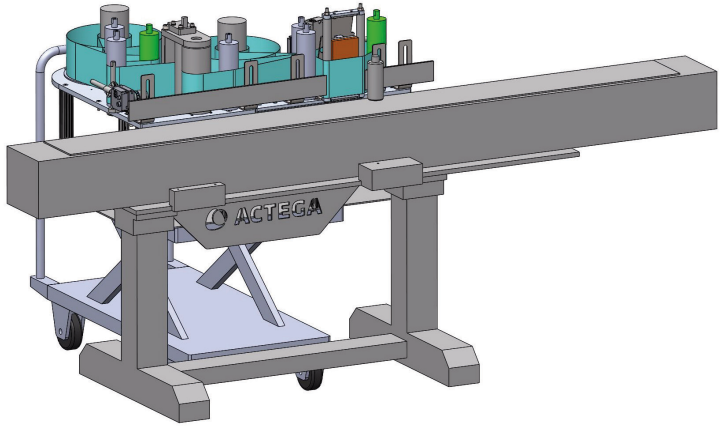
A Crystal topcoat (also referred to as liquid label layer) is functionally designed for the same primary purpose as the top coat used for PSLs. It protects the print printed graphics. It also ensures acceptable physical performance on filling lines, during distribution and consumer use. Both Crystal and PSL top coats can have either a gloss or matte finish to enhance shelf presence. The Crystal release liner used with the Crystal topcoat serves a dual purpose. It provides a homogeneous untreated, uncoated surface for applying the Crystal topcoat without creating inconsistencies in the cured surface of the spot applied transparent coating layer of the Crystal build. It also provides for consistency of surface tension at the liner Crystal clear spot coat interface, thus allowing for repeatability of decoration release. Through extensive testing with numerous release carrier film co-suppliers, it has been established that biaxially oriented polypropylene films with low surface dyne perform best in release performance, flexibility, and memory during Crystal decoration transfers.

Raw Material Reduction to Printer: >50%			
	Conventional Clear Film PSA	**Crystal Label**	**Crystal Savings**
Label or Decoration Area	20 cm^2	4 cm^2	80%
Laminate Area	30 cm^2	0 cm^2	100%
Liner or Carrier Area	30 cm^2	24 cm^2	20%
Matrix/Waste Area	10 cm^2	0 cm^2	100%
Adhesive Area	30 cm^2	4 cm^2	86%

Crystal Decorating Application Hardware

The Crystal applicator is engineered to roll-apply Crystal decorations on to round, straight walled container with a maximum diameter of four and one-half inches. The applicator requires a 110/220 VAC 50/60Hz single phase electrical source with a dedicated 5-amp service. There are no additional air, gas or water hook-ups required for operating a Crystal applicator. Commonly used consumer product container materials such as PET, HDPE, glass, and aluminum are suitable for the Crystal decoration applicator. The Crystal inline decorator is designed to comfortably handle fifty containers per minute with application bursts up to one hundred containers per minute. Future modifications to the Crystal decoration applicator will allow it to handle a more comprehensive array of container sizes,

shapes, and speeds. The Crystal inline decorator is currently in prototype testing and will be available for field trials in H1-2020.



Crystal Decoration & In-Line Decorator	Addressable Containers: Round-Walled, Flat Surface to 4.5" in diameter.		
Application Conditions vs. Substrate	**PET, PP, HDPE**	**Aluminum**	**Glass**
Cold Water Scratch Resistance	**Yes**	**Yes**	**Yes**
Fit for Hot Fill <200F	**Yes**	**Yes**	**Yes**
Fit for Wet Fill	TBD	TBD	TBD
Fit for Room Temp Fill	**Yes**	**Yes**	**Yes**
Fit for Substrate Interface Condensation	TBD	TBD	TBD
Fit for Curved Surface	TBD	TBD	TBD

Crystal Decorating Physical Performance Attributes

Brand owners carefully evaluate surface adhesion and print durability for prime labels used in rigid packaging. Standard performance tests used for determining adhesion performance of Crystal decorations include ASTM F2252 tape pull test which is standard practice for evaluating ink or coating adhesion on flexible packaging materials and ASTM D7932, used to determine the performance of PSLs in extreme distribution environments. Peel and static shear testing are also performed based on target rigid container substrate type.

When considering rigid plastic and glass applications, surface adhesion performance is critical. Most rigid container plastics and glass have inert, nonporous surfaces with low surface energy. Atmospheric plasma and flame surface treaters are used to increase the surface energy with plastics. For many container decorating operations, Pyrosil is a common and effective pretreatment method for glass decorating where high surface adhesion and bonding is required with applied photopolymeric based coatings and adhesives. Aside from proper surface preparation, entanglement at

a molecular level between the container substrate and adhesive is required. UV-curable PSAs have a long established track record with polyolefin based plastics such as polyethylene terephthalate (PET) and high-density polyethylene (HDPE) and container glass. UV cured pressured sensitive adhesives provide high-temperature stability, solvent resistance, and excellent surface bonding when properly formulated. The UV PSAs specified for use with Crystal decorating provide best adhesion performance on PET and HDPE based surfaces when applied at room temperature and under dry conditions.

Although organic solvent resistance testing is typically not required for prime labels used in bottled water or dairy product packaging applications, it is an essential performance requirement for cosmetics and home care products. Methylethylketone (MEK) and isopropyl alcohol (IPA) double rub testing are commonly performed. Passing 50 or more double rubs is an industry standard and demonstrates the fullness of cure for coating and ink used in pressure sensitive labeling. When properly cured, the photopolymer based coatings and inks used with Crystal decorations will naturally have high double rub solvent resistance.

For abrasion resistance, the Sutherland Rub Test ASTM-D5264 is commonly used to determine the abrasion resistance of coatings and inks. Crystal decorations are tested following ASTM-D5264 with abrasive media under a 4-lb. weight load and will survive greater than 150 strokes before decorations begin to abrade. Loading multiple labeled containers on to pallets either under hot or wet and conditions and then shaking the pallets for three to four hours under variable frequencies is yet another way of tested prime label rub resistance at commercial scale.

Regarding recyclability, there are a variety of label systems and materials that are commonly used for consumer product rigid packaging. The label type selected by the brand owner may impact the compatibility of the packaging with today's recycling processes. The label type used will also significantly impact the amount of waste generated when packaging is recycled. Crystal decorations are engineered following the Association for Plastic Recyclers' (APR) Design Resource Document for PET container recycling. According to the APR Design Resource Document, when selecting a label for compatibility with PET recycling, the following considerations are included:

- Impact of the label on automated NIR sortation that identifies PET bottles at a materials recycling facility.
- Can the label be "liberated" from the bottle and "separated" cleanly from the PET?
- Does the label impact the wash water used for recycling?
- How much waste and bale yield loss does the label create?
- Does the label contaminate the closure side stream?
- Can a metalized label be lost at a metal detector?

Compared to shrink-sleeves and conventional printed PSLs, Crystal decorations are spot printed and designed to give a minimalist, "No-Look" appearance. The open graphic design and average 20-micron gauge thickness of a Crystal decoration allow for ease of plastic recyclate identification and sortation. Crystal decorations feature a UV curable PSA technology designed to dissolve and cleanly separate in caustic sink/float baths. When the recyclate label interface cohesive bond is broken, the printed Crystal decoration and adhesive cleanly exfoliate from the recyclate (i.e. PET flake) resulting in the creation of a high-quality post-consumer recyclate resource with significantly reduced landfill burden. UV based clear and pigmented inks have been chosen for all Crystal applications based on their "best chance" of meeting Association of Plastic Recyclers Guidelines.

Summary

This paper discusses Crystal as a joint chemistry and hardware approach for creating narrow web label decorations. The technology uses conventional inline narrow web press assets in combination with modified PSL application hardware to create a "No-Look" prime label design. Compared with standard pressure-sensitive, glue applied, sleeve, in-mold, and heat transfer label technologies, Crystal generates significantly less matrix waste, does not require the use of a face-stock and allows for ease of rigid container recycling without creating municipal recovery facilities and reprocessor bottlenecks which include: recyclate missortation, recyclate yield loss and contamination. In addition, this paper reviews the benefits and the short-time addressable limitations yet to be resolved for Crystal while still beta development.

References

APR Design Guide Resource Document Selection of Labels for PET Containers. https://www.plasticsrecycling.org/apr-design-guide/apr-design-guide-home (accessed May 8, 2019).

Brase, *I. Paper, Film & Foil CONVERTER (PFFC)*. RDG Media, Inc. June 15, 2017.

Dyne Level Does Not Guarantee Surface Adhesion. https://www.enerconind.com/plasma-treating/library/tech-papers-articles/dyne-level-does-not-guarantee-surface-adhesion.aspx (accessed Apr 8, 2019).

Warmkessel, J. R. *European Coatings Journal.* Vincentz March 1, 2008.