Inkjet for 3D Forming Applications

Thermoforming and “The Imaging of Things”

Mike Plier
March 23, 2015

A STRETCH BEYOND THE IMAGINATION

 EFI: Moving beyond the document

• Founded 26 years ago
  – Originator of the Fiery digital front end to control digital copiers.
• June 2005 – entered inkjet market with VUTEk acquisition
• October 2006 – expanded ink capabilities with acquisition of Jetrion from Flint Ink

Scaled growth in ink innovation

• 2006-2014: Building innovation in ink
  – Transition from solvent to UV platforms
  – 2011: adapted Jetrion LED inkjet technology to wide-format platforms for greater versatility and low-energy consumption.
  – Consistent customer growth leads EFI to becoming the industry’s leading manufacturer of UV inkjet ink

Market development

• 2013 – research into new market applications leads to partnership with Polymeric Imaging for thermoformable inks
• EFI introduces 2m and 3m VUTEk GS Pro-TF printers and VUTEk GS-TF inks
  SGIA 2013 Digital Ink Product of the Year
• EFI VUTEk GS Pro-TF products reflect momentum in the “Imaging of Things”

The Imaging of Things
1999 World First UV Screen Formable Ink

Polymeric Imaging
expanding inkjet’s boundaries

- 1970s Chemist Don Sloan develops the industries 1st commercially available UV screen printing inks.
- 1993 Sloan establishes Polymeric Imaging, creating UV formulations to replace solvent-based chemistry.
- 2010 PI develops patented formulation for “deep-draw” thermoformable UV inkjet inks and coatings.
- October, 2014 – EFI builds on existing licensing partnership with PI, acquiring PI’s intellectual property related to thermoformable inkjet technology.

New opportunities in “The Imaging of Things”

- Digital thermoforming technology dovetails with “IoT”: High elongation 3D graphics with vivid color and visually compelling design capabilities.
- Oct 2014 EFI acquisitions all patents and IP related to digital thermoforming technology from PI.
  New Expanded opportunities and product offerings for printing companies with enhanced print capabilities to bring imaging/decoration in house.

Thermoforming: The Digital Advantage

- Thermoforming is a type of vacuum forming process requiring heat and pressure.
- Standard heat is in 280-460+ degree Fahrenheit range.
- Mold/Tool configuration depends on specific product or signage needs or application.
Forming processes

Illustration from Creative Form Plastics Inc., Scarborough, Ontario. www.creativeformplastics.com

Imaging of things! A closer look!

An introduction to disruptive technology! A real life story!

* It took Company X 7.5 hours of labor to produce two 13.5’ X 4’ vacuum formed signs using their current printing and painting methods.
* Using digital printed thermoforming technology they now produce 34 of the same signs in the same amount of time!
* Put another way… What would usually would take them 3.5 weeks to produce…NOW… takes them one day!
* A 93% REDUCTION OF LABOR COSTS.. A 95% INCREASE OF PRODUCTION!

The Bottom Line! By the Numbers!

THE UNFAIR ADVANTAGE

Less is more: monofunctional, low-crosslinking acrylates

A Stretch Beyond the Imagination!

Monofunctional Acrylates

Original custom formulations developed in PI labs

* Enables deep draw thermoforming without cracking or mosaic fractures.
* Original formulations worked in lab tests, but required years of refinement before working in real-world production environments.

Monofunctional structure for phenoxyethyl acrylate, commonly used in energy-cured inks and coatings.

Faster & harder surface but exhibits limited flexibility and adhesion ranges.
Seeing is believing! Who is Who?

Difunctional acrylates

- Most of all development of UV inkjet formulations is centered around difunctional high-crosslinking acrylates.
  - Pros: Fast Cure speeds, excellent chemical resistance & surface harness.
  - Cons: limited adhesion ranges, brittle, prone to shrinkage and edge-curl.

\[
\text{CH}_2=\text{C}=-\text{O}-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}=\text{C}+\text{CH}_2
\]

Defunctional structure for Hexaneidol Diacrylate (HDDA), a reactive diluent used in flexible, energy-cured inks and coatings

What Happens during forming?

- Thermoforming starts here!
  - During the heating cycle both the inks and the plastics become malleable. (Buzz words: Thermo-sag, glass transition phase or “Bubble”)
  - The pigments or dispersions are not thermo-chromatic. They do not shift in color or hue during the heating or forming process!
  - Unlimited elongation! These systems have the ability to meet or exceed the elongation characteristics of the plastic it is printed on.
  - Extremely broad adhesion ranges with a vast application range that goes beyond vacuum forming.

Softer cure and high-heat tolerances

Functional/industrial applications

- Color Management? The Key is Profiling!
  - Distortion software is often needed for proper alignment of graphic image to mold.
  - In most cases with proper color profiling color hue adjustments are not needed!
    - Average draw 4 inches or less. Max Draw???
    - Print images in higher density, but at the same hue/chromatic value
Is it possible to put a circle on this slide around the part(s) of the equation that make it difunctional?
“Free film” = superior color

- Successful color placement requires ink that exhibits “free film” characteristics.
- Cured film could almost stand alone as its own layer, like a sheet of cellophane
- Free film properties, combined with high density, provide consistent color during the forming process

Key attributes

- Formed parts/signage decoration with fewer steps
- Elimination of screen printing set up costs or hand painting and vinyl lettering process “Tail of the Tape”
- Superior elongation characteristics support deep draw thermoforming while maintaining opacity on various plastics, including PETG, acrylic, polycarbonate, polystyrene and PVC.
- Inks withstand heat forming and cutting without cracking, chipping or loss of adhesion.
- Water and moisture resistance enable durable, lasting images.

Taking thermoforming to its limits

- Successful applications with >24-inches of draw
- >1,000% elongation
- Aspect ratios >30:1

Imaging of things! Thermoform Applications

- Aeronautical: Interior trim, Covers & cowlings (NASA)
- Agricultural: Trays, Tubs, Clear Growing Domes, Lawn Mower enclosures
- Automotive: Wheel & Hub covers, Ski and storage, auto interiors, deflectors, dash clusters, Sports and outdoor vehicles cowlings
- Marine: Boat hulls, canoes & Kayaks, hatches and dashboards
- Electronics: Hand held, appliances, computer, instrumentation
- Entertainment: backdrops, costumes, Animation models, Simulations
- Medical: scanners, masks, Prosthesis parts
- Architectural: tub & shower enclosures, Jacuzzis, custom counters
- POP: Packaging, Blister pack, Signage, Vending, fast food

Know your plastics

Plastics are comprised of two fundamental groups!

Thermoset (Crystalline or Rigid) & Thermoplastic (Amorphous or Pliable)
- Some plastics have Hydro-scopic tendencies (Ability to absorb moisture) causing pinholes or star-lighting.
- Forming temperatures vary from plastic to plastic.
- Select the appropriate plastic for it intended end use!
- The right plastic for the job... Impact resistance? Weathering? Dimensional stability after forming? Resistance to solvents, chemicals or abrasion.

Coating/protection

- Some applications require enhancement coatings or laminates.
  - Important factor in outdoor equipment, automotive, marine, and ATV applications that may require high levels of abrasion, chemical, solvent and protection from UV exposure!
  - These enhancements can be applied both pre-formed and post-formed
  - Methods of application includes screen printing, roll-coating, spray coating and lamination.
LED: a new frontier

- March 1, 2015 EFI opens new state of the art ink and coatings R&D facility in K.C., Mo.
- Future projects include leveraging EFI’s LED inkjet expertise with thermo-formable high elongation technology and enhancement coatings.
- New formulations with LED-based photo-initiators using wavelengths of 365-400 nanometers. (Conventional UV inks being 320-365)

LED & Beyond thermoforming

- Key LED advantage:
  - Curing at 81-degrees Fahrenheit works better with dimensionally unstable substrates.
  - Material stability, low distortion reduced material degradation.
  - Extended lamp life and lower cost energy costs

New packaging opportunities?

- With LED, deep-draw characteristics on a thin film could create new opportunities in vacuum-forming
- Leverage superior flexibility and color consistency, in thin film packaging applications like direct decorating for blister pack applications.

Process simplification/cost reduction

- Can Elongation Translate into stretching profits and shrink production costs?
- Potential to eliminate cardboard inserts on packages, reducing cost and time in packaging assembly process.
- Single layered 3D food packaging. No more labels?
- Variable data for 3D plastic packaging. (bar codes, Serialization, personalization)

Q&A

Thank you!

Mike Plier
Director, Ink Business Development
EFI Inkjet Solutions
michael.plier@efi.com