Continuous R2R Coating Methodology to Manufacture Precision Microstructures for Displays, High-Brightness LEDs, Traffic Signs, Solar Concentrators and other Light Management Products

Introduction

Annual sales for microstructured products will exceed $5 billion this year and is projected to reach $11 billion by 2009. Two examples of microreplicated products we see on a daily basis are the plastic films used in lap-top computer screens and reflective sheeting used in the latest version of high-brightness traffic signs. These two markets currently represent $3 billion and $1.5 billion respectively in annual sales.

Reflective traffic signs have been around for decades but the latest products are the result of a manufacturing process that produces 150 micron film having 22,000 microreplicated prisms per square inch. Microprisms capture and reflect light with much greater efficiency than the previous technology using encapsulated glass spheres which had been used since the early 50's. The new technology improved product performance by a factor of four allowing the better performing products to be sold at a higher price while reducing manufacturing cost compared to the previous generation of products.

Two primary plastic layers that improve the optical efficiency of LCD displays are called Brightness Enhancing Film (BEF) and consist of microscopic lenticular grooves that enhance and direct light uniformly towards the viewer while consuming less battery power than previous designs.

Essentially, microreplication is the creation of tiny, precisely shaped structures arrayed to dramatically alter the physical and optical properties of a plastic surface.

High-speed low-cost methods to microreplicate microstructured polymers provide enabling manufacturing technology for a broad range of emerging products.

The term microreplication was coined by combining micro (smaller than what the unaided eye can see without a microscope) and replicate, to copy continuously on the surface of a substrate. Microreplication describes a process that copies microscopic features on to the surface of plastic film with a high degree of precision continuously.

Two companies that have successfully commercialized low cost, continuous (roll to roll) manufacturing processes using microreplication are 3M, and what was formerly Stimsonite Corporation, since acquired by Avery Dennison. Stimsonite commercialized the first micro-prismatic reflective sheeting for high-brightness traffic signs in 1986. Three year later 3M began manufacturing a similar product by using a different manufacturing platform and independent intellectual property. These two platforms have become benchmarks in the field of microreplication and each has advantages and disadvantages. More recently a third manufacturing platform has been developed that provides improvements to the microreplication process and has competitive advantages compared to the earlier technology.

Markets for the Microreplication Process

There is a broad range of applications for microreplicated products. Some of which include, but are not limited to:

Micro Technology	Application
▪ BEF (Brightness Enhancing Film) and other light-guide or light-management films.	Lap-Top computer screens and displays
▪ Micro-Prismatic Reflective Sheeting	Traffic Signs
▪ High-Brightness LED Arrays	Flat-panel displays, cell phones, and most commercial lighting applications
▪ Fresnel lenses	Rear-projection TV

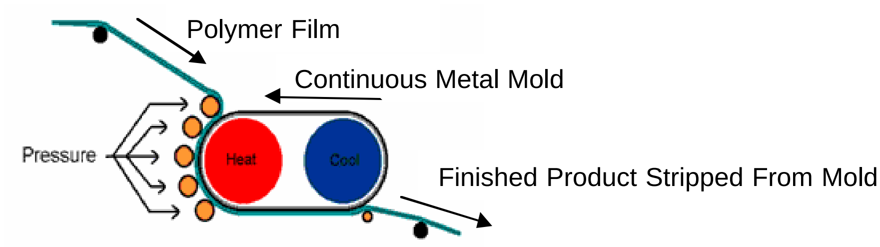
- Large area optical concentrators — Solar collectors
- Micro-lenses arrays — Cell phone screens
- Flat panel display technology — Monitors, Flat TV displays
- Microfluidics — High speed diagnostic testing
- Hollow micro-needle arrays — Drug delivery components
- Tissue culture media — Accelerated skin and heart tissue growth
- Fuel cell components — PEM plates (proton exchange membrane)
- CMP (Chemical Mechanical Plannerization) — Polishing silicon wafers
- Personal care products — Dermal abrasion

History

The Two Previous Microreplication Platforms Include:

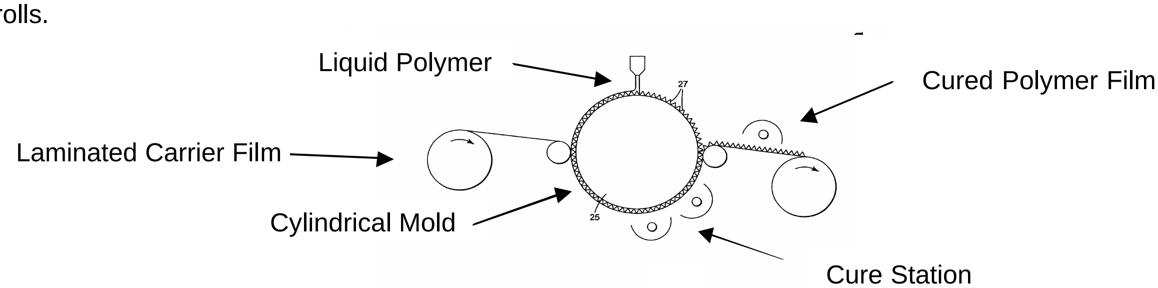
The Process Generally known as "Embossing"
A useful analogy to understand the embossing process is injection molding. For decades injection molding has been developed and refined to manufacture a wide range of plastic products. Plastic pellet is melted → pressed into a mold → and then cooled → setting the plastic in the shape of the mold so it can be removed from the machine.

Microreplication is essentially a continuous molding process that forms, or replicates microscopic shapes on the surface of plastic films allowing these products to be used for very specific optical, medical and mechanical applications. Rolls of commercially available plastic such as polycarbonate or acrylic enter the process → microscopic features are formed on the surface of the plastic then cooled→ Finished (microreplicated) product is stripped from the mold and wound into rolls.



The Process Generally known as "Cast & Cure"

The cast & cure process uses formulated liquid polymers to fill the mold (liquid casting) → the liquid polymer is then either UV or radiation cured to form a film → The cured film is then stripped from the mold and wound into rolls.



Both technology platforms require the use of a precision cylindrical mold which can require considerable up-front cost and fabrication time.

The embossing process has the advantage of using low cost commercially available thermoplastics such as PMMA and polycarbonate but requires a slow processing speed.

The cast & cure process is faster but requires custom formulated polymers that are more expense many of which used proprietary technology.

The Advantages of the New Manufacturing Platform

The new manufacturing platform is an extension of powder-coating technology. Unlike conventional powder coating the cured polymer layer is removed from the metal mold as a stand-alone film having the precision microstructures replicated on the surface. The technology is a continuous roll-to-roll process whereby powder coated polymers are coated on to rotating molds, cured, removed and wound into rolls.

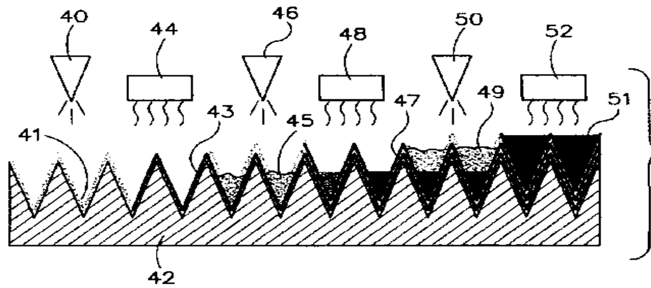
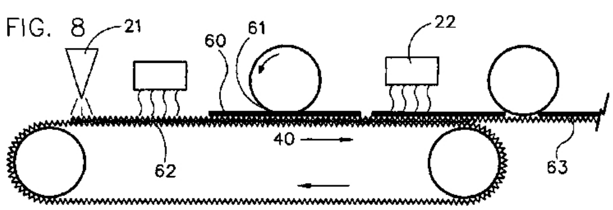


FIG. 10

Powder-coating polymers directly to the mold dramatically increases manufacturing speed

FIG. 8



The Competitive Advantage of the New Process Technology

- Higher manufacturing speed
- A wider range of polymer substrates can be processed
- Improved optical performance by use of polymers having less absorption and reduced birefringence
- The final product can be thin film or thicker, ridged substrates millimeters thick
- Polymers can be combined in layers providing optical and mechanical advantages
- New and proprietary intellectual property

One of the primary competitive advantages of the new technology is speed. Machine speeds can be as much as ten times the earlier embossing process. The process also has the advantage of manufacture both flexible and rigid substrates up to several millimeters thick such as components being developed for the high-brightness LED lighting market. The new process further allows the use of polymers that are either thermoplastic or thermosetting which is outside the scope of the earlier technology. This allows the new process to serve a broader range of emerging markets more effectively than either the cast & cure or the embossing process would on their own.

Component	Embossing Method	Cast & Cure	Injection Molding	10x Method
Polymer Cost (Typical)	$2.0 Sq/M (Extruded)	$4.0/M (Formulated)	$1.0 Sq./M (Pellet)	$1.3 Sq/M (Powder)
Line Speed	1-3 M/Min	10 M/Min	< 1 M/Min	>10M/Min
Original Mold Cost	>100k	>100k	>100k	<100k
Copies of Mold	<10k	<10k	Not Available	<10k
Optical Efficiency Losses	Polymer Impurities	Polymer Impurities	Residual Stress Polymer Impurities	Minimal Loss
Capital Equipment Cost	X	X	X	30% Less

The cost of the mold is highly dependant on the features to be replicated and the finished product size but in most cases the new methodology will have a favorable cost-benefit ratio and faster time to market.

Please feel free to contact us with specific questions regarding applications for this technology.

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