

Mass Replication of Holograms and Diffraction Gratings by Embossing

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Abstract

Embossing and its variants have proven to be the most cost-effective and popular means for mass replication of holograms and diffraction gratings. Alternatives such as photopolymers or silver halide films can cost eight to ten times as much as embossed materials. The cost of embossed materials has fallen to the point where they are being used for mainstream product packaging such as software packages, food and beverage containers, candy packages and wrapping paper. Companies can now produce holographic images and gratings at widths of 60 inches and wider, and at speeds of hundreds of feet per minute.

This paper will review the techniques of embossed hologram production from the recording of the master hologram to the production and application of metalized embossed film.

1. Background

The general public may not know of the various industrial and scientific applications of holography and diffraction gratings, but they are surely familiar with holograms on their credit cards, diffraction gratings used in print on paperback books, and holographic stickers on magazines and software boxes. The genesis of the industry reaches back as far as 1822, with the first use of diffraction gratings for decoration.[1] Since then, as engineers strived to make more precise gratings for scientific and astronomical uses, many of the same people endeavored to bring these beautiful effects to the general public in the form of jewelry and decorative features on glass, metal, celluloid and paper.[2,3]

Sir Thomas Merton developed a complete system to mass-produce diffraction gratings, which was patented in 1941.[4] Merton's process included a means to replicate and combine gratings into patterns and then emboss them into celluloid or alginate-impregnated paper. Though today's manufacturing processes differ from Merton's, the essence is the same. The remainder of the paper will give an overview of the embossing process from start to finish.

The primary steps in the process are:

- **Origination**—reation of the master plate in photo-resist or other relief pattern material.
- **Electro-forming—**Replication of the original master by electroplating to form embossing plates.
- **Embossing**— Mounting a nickel master on a press and making impressions into plastic film or paper.
- **Metalizing—**Application of a thin layer of aluminum before or after embossing to enhance brightness.
- **Application**—Conversion of the raw film into a final product by laminating, slitting, and or die cutting.

2. Hologram and Grating Origination Techniques

Embossed holograms and grating patterns are typically recorded in photo-resist. Positive photo-resist is used to record the fringe pattern in relief. Areas in the fringe pattern that receive greater energy during exposure will be removed during development to reveal a "hill and dale" pattern that can be mechanically reproduced.

There are a number of ways to create 3D images and gratings.

2.1 White light transmission holograms

Variations on S.A. Benton's rainbow hologram technique are used to create transmission holograms that can be embossed and viewed in white light.[5] Holographic stereograms use sequences of two-dimensional images to create 3D images in color and with animation. [6]

2.2 Holographic diffraction gratings

Holographic diffraction gratings are made by recording the interference pattern of two or more beams of laser light. Portions of a small gratings can be replicated and combined to form larger grating patterns.[2,8] These patterns are made optically, mechanically or with electron-beam techniques. The mechanical techniques start with a simple grating and replicate it selectively. Each segment of the pattern has a slightly different grating orientation so that the final pattern flashes from all angles. A popular way to make optical patterns is to build up an image by recording thousands of minute, adjacent grating spots to create an image.[9] Each spot can have a different grating orientation or fringe spacing so that different effects can be achieved. Some security images are made by computing fringe patterns and writing the hologram into resist with electron beam devices.

3. Electro-forming Procedures

However the master is recorded, the result is a relief pattern in photo-resist or plastic. The original photo-resist cannot be used as an embossing tool, therefore it is necessary to produce a durable metal replica. The most common procedure for replicating the master uses nickel electroplating. The master must first be made conductive. In one popular method, silver is applied using a dual spray gun containing a two-part solution. Alternatively, vacuum metalizing can be used for smaller parts. Electroless nickel has also been used by some in the field. [10]

Once made conductive, the master is usually immersed in an electro-plating bath where it is nickel-plated to a desired thickness. This typically takes six to eight hours. The nickel layer is then peeled from the photo-resist master, which is destroyed in the process. The first nickel replica is used to make intermediate masters, which in turn yield the final embossing shims. A given job may require from ten to a thousand shims.

4. Embossing Techniques

Most embossing is done from nickel master plates called shims. The master shim is mounted on a heated roller in an embossing machine. Under controlled pressure, a second smooth roller presses the material to be embossed, into the heated shim. The relief pattern from the shim is pressed into the film or coated paper, which retains the pattern. Some materials are coated with proprietary coatings before embossing. A number of materials can be embossed directly without coatings. Figure two below depicts a wide web embossing machine.

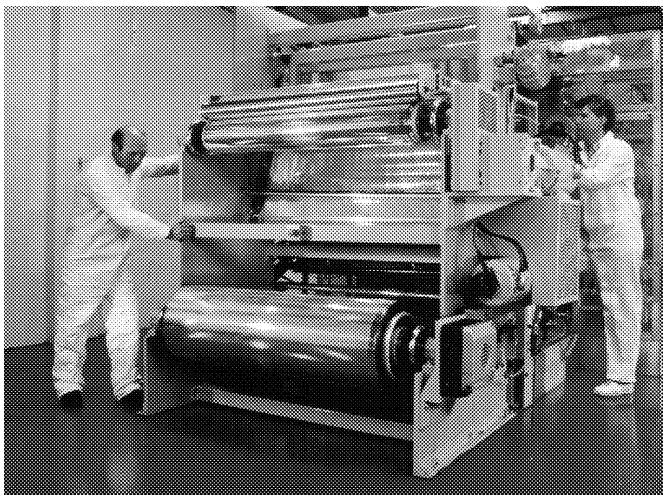

Figure 2. 48" wide web embossing machine.

5. Metalizing

Most hologram and grating products are vacuum-metalized with aluminum to enhance the brightness of the material. Without metalizing, the diffraction efficiency is typically limited to 30% or less. If the relief pattern is exposed to the air, it will be easily damaged by abrasion or contact with oils from the skin: the oils fill in the fringe pattern, thus rendering the image invisible. If the final product must be transparent, the relief pattern must be coated with a very thin layer of metal or a material of significantly higher index of refraction. This coating maintains brightness of the image while keeping it transparent. Security holograms for drivers licenses and the like are made in this manner.

Six- to twelve-inch narrow web embossing is often done with pre-metalized material such as polyester film. Wider film and paper is usually metalized using a large vacuum metalizer shown in Figure Two. These metalizers typically cost 1.5 to 2 million dollars.

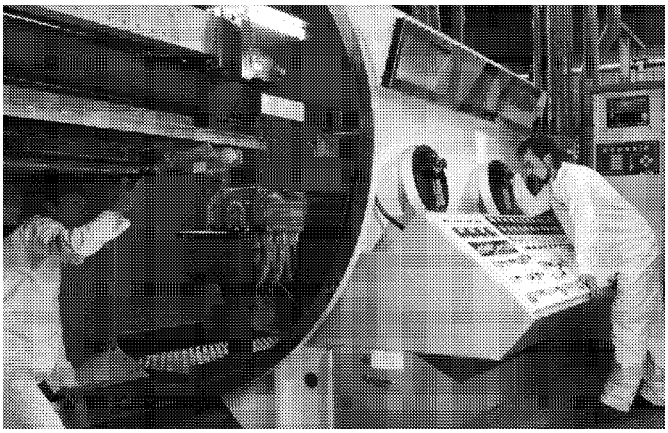

Figure 1. Vacuum metalizer for plastic film. This photo shows the chamber open for loading rolls of film.

6. Application

Embossed gratings and holograms can be applied in a myriad of ways to nearly any substrate.

6.1 Self-adhesive labels

For this type of label, there is a paper or plastic "release liner" that has been coated with a rubber or acrylic based adhesive. The coated liner is applied to the roll of embossed film between a pair of pressure rollers. The holograms are die-cut and the waste film around each label is stripped and discarded. The labels are delivered to the customer in roll form, still attached to the release liner to be machine or hand applied to the final product. Typical uses of holographic labels are:

- Product authentication and anti-counterfeiting: particularly in the software and music industry, and for aircraft and automotive parts.

- Anti-tampering protection to stop clandestine refilling of expensive drugs, cosmetics or motor oil.
- Marketing applications—Attention-getting labels on magazines or product boxes.
- Toys and decorative stickers for household use.

6.2 Lamination

Continuous roll lamination can be used to apply plastic films onto paper or plastic. The laminated material can be cut into sheets or left in roll form for printing and subsequent conversion into cartons and boxes.

6.3 Hot-stamping transfer processes

Hot-stamping transfer foils are made routinely for paper or plastic. The transfer film is specially prepared with multiple layers to release a thin hologram layer when heat and pressure are applied. These foils are used extensively in the printing industry to add sparkle to paperback books. Security holograms are applied to credit cards and to documents using hot-stamping. Some packaging applications using these techniques have been successful but prove to be too expensive for anything but premium or seasonal use.

6.4 Embossed paper products

Prismatic diffraction wrapping paper can be made by direct embossing into coated paper or by transfering an embossed layer of lacquer onto a paper substrate. The direct embossing technique appears to be the most cost-effective for this purpose.

6.5 Direct packaging of snack foods

Candy bars, chips and trading cards have been packaged using overprinted embossed film that has been coated with a heat-seal layer. "Pouch" packaging machines use film from a roll and form it into a pouch which is filled with product and sealed at high speed.

7. Conclusion

This paper has presented a very basic overview of a complex and growing industry. After the initial popular interest in holography and diffraction grating application in the mid 1980's, the industry has grown gradually to the point where it is cost-effective for holograms and diffraction gratings to be used for standard rather than seasonal or premium packaging. Packaging appear to be the application where there is greatest potential for growth.

8. References

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