The development of LEDs and SMD electronics on transparent conductive polyester film

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The vacuum sputtering of transparent conductive materials on glass and polymers has opened a window of applications using electronic small mounted devices (SMD) laminated in glass. LEDs and other electronic SMDs may be mounted on transparent conductive films to produce flexible, and ready-to-laminate films. The big advantage of highly flexible film substrates is the ability to be transported by airmail in simple packaging. Ready-to-laminate LED and SMD embedded films enable to produce new products without the need to invest in electronic pick & place machinery.

HISTORY

In 1910, French researcher Eduard Benedictus patented[1] the gluing of two glasses by using a polymer based on cellulose acetate. The resulting product called “Triplex” was most interesting in many aspects. Unlike ordinary or tempered glass, which falls apart when fractured, laminated glass stayed in place.

However, before a satisfactory safety glass could be marketed in commercial quantities, raw materials, including glass, plastic, and bonding agents, as well as the manufacturing technique, had to be improved. Different solution were developed, such as tough, clear, flexible plastic sheets made of polyvinyl butyral (PVB), ethylene vinyl acetate (EVA) or thermoplastic polyurethane (TPU), which could be sandwiched between glass to create a safe and

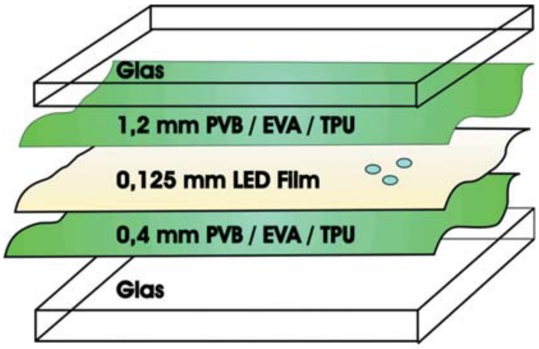


Fig. 1 - Typical specification of laminated glass using LED embedded films

breakproof material. Today, laminated glass helps keep the building envelope intact, reduces the danger of glass shards, and helps prevent people from falling through sudden openings. Users of laminated glass soon discovered that it also helped reduce noise, block harmful UV rays and protect against break-ins. In cars and in buildings, the use of laminated glass continues to grow, increasing safety worldwide.

In 1877, Prof. A. W. Wright[2] of Yale University published a paper in the American Journal of Science and Arts on the use of an "electrical deposition apparatus" to form mirrors and study their properties. There still is some confusion as whether Wright was using sputtering or gaseous arcing. But there is no doubt that this early research anticipated later developments, including cathode shielding, multi-layer coatings, substrate motion, and hybrid processing. The applications of vacuum coatings progressed from the simple single layer coatings on plates in the 1930s and 1940s to coatings on flexible materials in the 1950s. This research anticipated the energy crises in the 1970s proving the need for energy conservation coatings on large areas of glass and polymer webs. As published in Patents of Ford Motors (1989)[3] and *Saint-Gobain* (1990)[4], the use of transparent high conductive layers on glass was a quite important solution for pure heating applications. But since the 1980s companies such as Sharp KK5 (1983) started to mount small electronic devices (SMDs) such as LEDs on transparent conductive glass or films. The patterning of transparent conductive layers was carried out by laser[6,7] or by wet etching technology[8,9]. While *Matsushita Electric Ind.*[10] would claim in 1983 the encapsulation by vacuum pressure bonding using PVB, *Fuji Electric Co*[11] and *Nippon Sheet Glass*[12] would widen the technique to the use of Silicon and EVA. Beside this modern sheet type of lamination companies such as *Stanley Electric Co*[13] continued the development of

Fig. 3 - Table. PVB laminated by Glas Trösch, Switzerland. Powered @ 48 VDC, 20 mA

Fig. 2 - Transparent powered LED stair containing LED film from SUN-TEC. EVA type lamination by Sofraver, Switzerland. Powered @ 24 VDC, 20 mA per glass

Figure 4

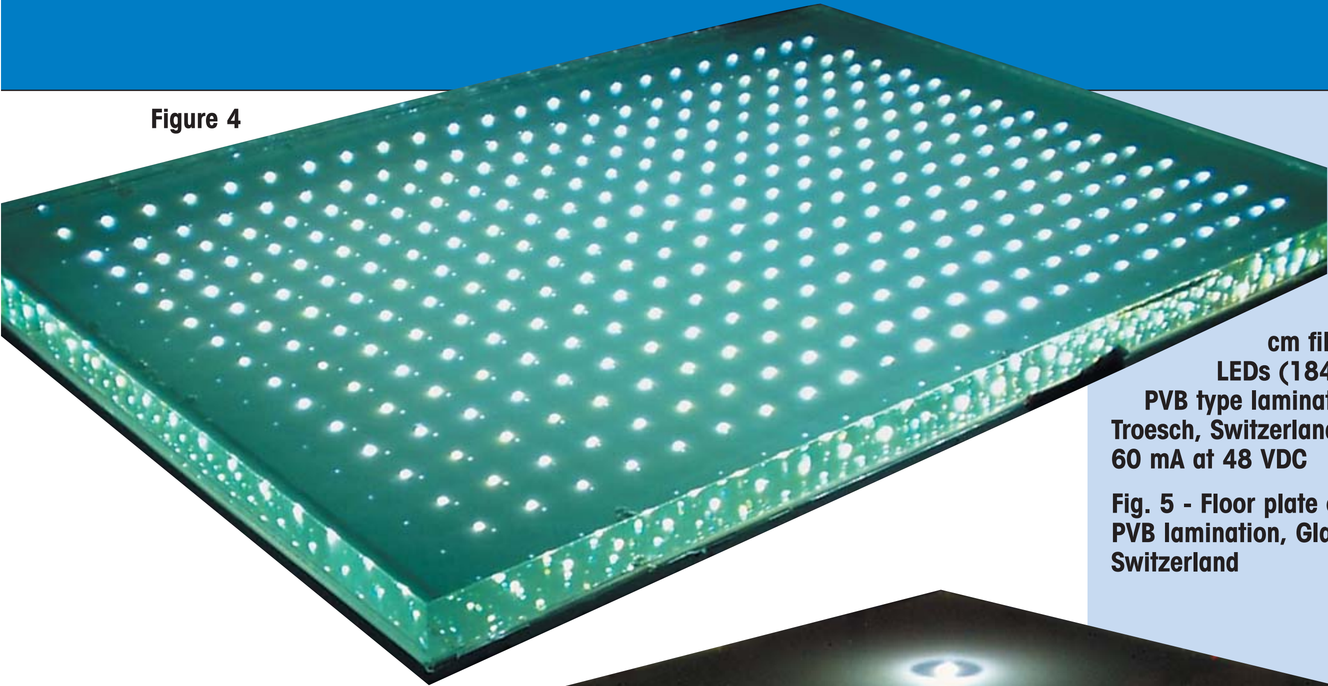
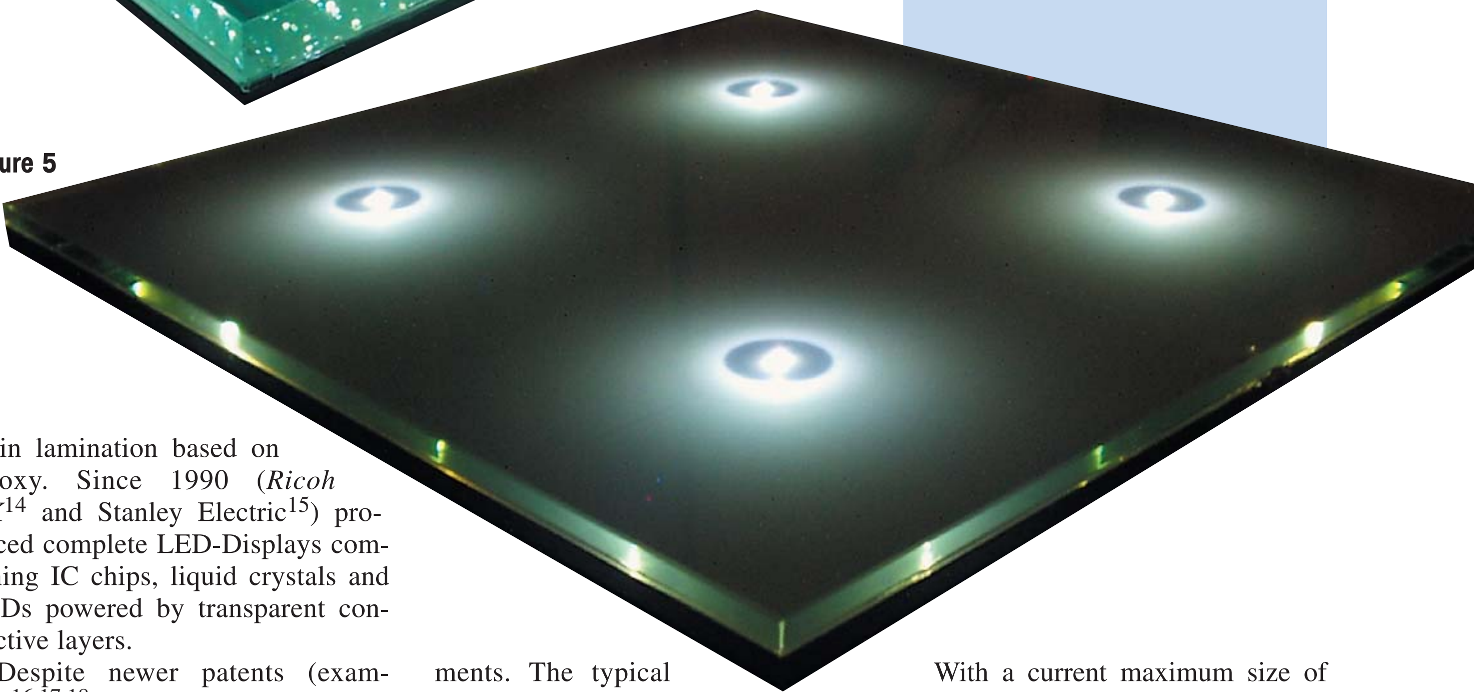


**Fig. 4
52 cm x 36 cm film with 345 LEDs (1843 LEDs/m^2)
PVB type lamination by Glas Troesch, Switzerland. Current: 60 mA at 48 VDC**

Fig. 5 - Floor plate of 50 x 50 cm, PVB lamination, Glas Troesch, Switzerland

Figure 5



resin lamination based on Epoxy. Since 1990 (*Ricoh KK*[14] and Stanley Electric[15]) produced complete LED-Displays combining IC chips, liquid crystals and LEDs powered by transparent conductive layers.

Despite newer patents (examples[16,17,18]), the main technological questions regarding the mounting of SMD elements on patterned transparent conductive glass and its lamination was obviously well developed before 1990.

The disadvantage to transport heavy glasses from pure glass metallizing companies to electronic mounting sites and to forward these heavy weight flat half-fabricated SMD mounted glasses to glass lamination units has driven companies to develop low weight SMD embedded films, which may be transported by air-mail as rolled material.

CURRENT MATERIALS

For the past three years, SUN-TEC's SMD- and LED-embedded films have been processed by well-known glass laminating companies to produce transparent powered elements. The typical specification of the laminated glass, as shown in Figure 1, is completely air free and it may be used for indoor as well as humid outdoor environment.

The use of transparent polymers such as TPU, EVA or PVB in combination with vacuum or autoclaving technology enable the glass industry to produce standard elements as well as customer designs with respect to size or functionality. Stairs, windows and tables might need less than 20 LEDs per sheet, resulting in currents below 100 mA.

As shown in Figure 4, it is possible that transparent conductive oxides on polyester film may power quite a high quantity of SMD LEDs without significant heat production within the glass laminates. This is due to the fact, that SMD-LEDs are powered with less than 20 mA @ 3.5 V per LED.

With a current maximum size of 3,500 x 1,250 millimetres, the transparent conductive layer, as well as the connection between the films and the SMD/LED elements, have to withstand rolled packaging (current diameter 16 centimetres) and transport, rough daily handling as well as high sheer strength at maximum lamination temperatures of 125°C. As shown in Figure 6, LED and SMD embedded films may be laminated together with additional layers between the glass.

As shown in Figure 7, SUN-TEC delivers customer designs with respect to size, geometry and placement of the LEDs. These designs are usually sent by e-mail as AutoCAD file (DWG, DXF).

SUMMARY AND FUTURE DEVELOPMENTS

The vacuum sputtered transparent conductive materials on glass and polymers have opened a wide window of applications using electronic small mounted devices (SMD) laminated between glass, PMME or polycarbonate. LEDs and other electronic SMD may be mounted on transparent conductive films to produce flexible, and ready to laminate films. The big advantage of highly flexible film substrates is the ability to be transported by fast and low weight airmail in a simple cylindrical packaging paperboard with 16 centimetres diameter. Furthermore, ready to laminate LED and SMD embedded films enable glass laminating companies to produce own new products without the need to invest in electronic pick & place machinery.

Further ongoing developments are:
- separately controlled full colour RGB LEDs for media walls;
- high power LEDs;
- Infra Red sensorial SMD elements in glass (Figure 8);
- film for transparent heating applications; and
- transparent conductive films for electromagnetic induction sensors.

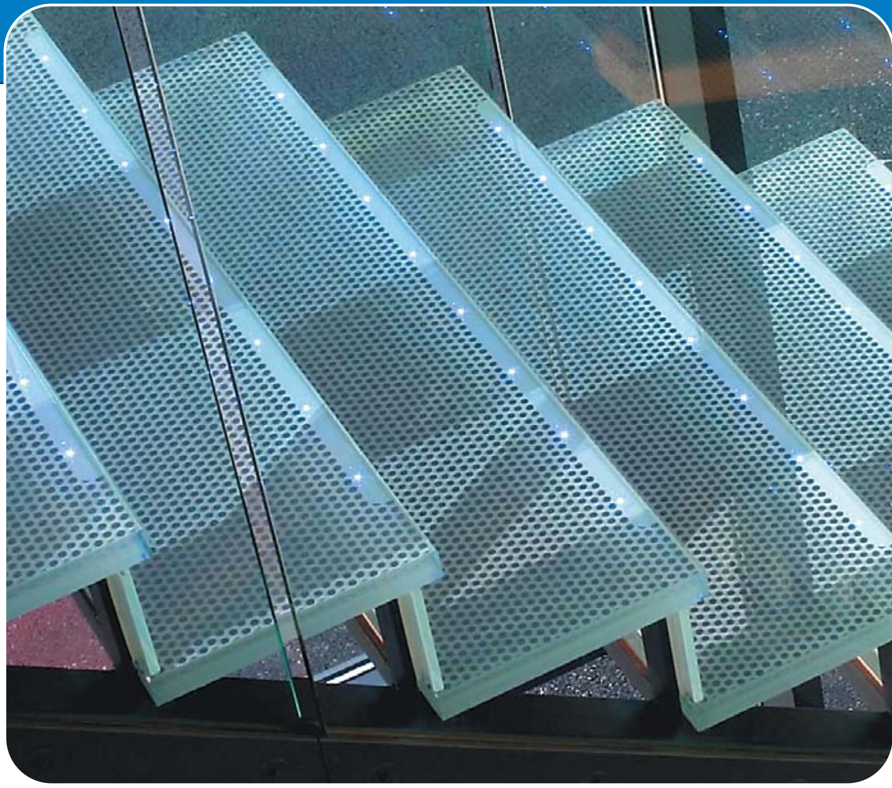


Fig. 6 - EVA stair laminated by Romag, UK

Fig. 7 - 325 LEDs for LOGO "Reflections" before lamination

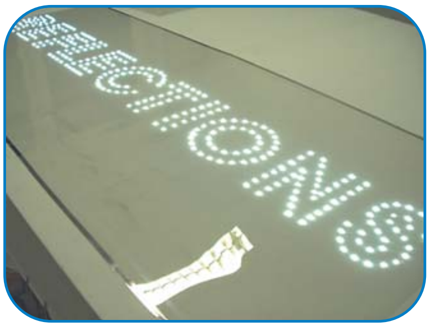


Fig. 8 - Use of IR sensitive SMD elements for sensorial applications

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