Engineers use polymer films in a broad range of industries. In imaging, films show up in photographic, reprographic, and electronic devices. Magnetic-media manufacturers also rely on high-quality flexible films to manufacture information-handling products. Packaging firms use films to protect products, extend the shelf life, and give a visual punch to products sitting on shelves. And in the electronics industry, films are used to make flexible circuits and membrane switches.

Polymer films have so many uses because they can have a variety of characteristics, including high tensile and impact strength, the ability to keep out moisture and gasses, heat resistance and weatherability, and a range of electrical ratings.

Generally, the properties of resin-based films stem from the basic polymer, but those properties can be tailored for applications. In fact, there are several treatments that improve film’s heat stability, mechanical properties, electrical characteristics, barrier properties, and bond strength. For example, some surface treatments remove low-molecular-weight residues, cleaning the film’s surface and improving its adhesion and appearance.

Engineers can also add modifiers and pigments to improve film performance. UV and heat stabilizers are among the most commonly used additives. And fabrication techniques such as coextrusion and lamination can create hybrid films with the best properties of two or more individual films – strength combined with barrier properties and optical clarity, for example.

Polymer Films

Engineers also have a long list of polymer films to choose from, which lets them mix and match properties to best meet their application’s needs.

Oriented and unoriented nylon films are strong, even at high temperatures. They...
**Comparing Polycarbonate and Polyester Films**

Polyester and polycarbonate films are often used to make membrane touch switches (MTS). This is because they possess the properties - toughness, durability, processability and aesthetics - required for this demanding application. The choice of films depends on several factors: switch part or component, electronic requirements, end use environment, and the application’s appearance and performance requirements.

The three major parts of a membrane switch are the circuit layer(s), spacer, and graphic overlay.

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**Circuit Layer**

This layer holds electronic circuitry and a failure can render the switches inoperable. Circuitry is applied as conductive inks and these inks are cured at 300°F. So the film must:

- Withstand curing temperatures without shrinking too much or breaking down.
- Resist cracking during flexing, which would break the conductive-ink paths.
- Not deform during use, which can collapse a switch so it will not work.
- Withstand chemicals without cracking or delaminating the conductive ink.

The overwhelming choice for the circuit layer is polyester (PET). It withstands processing temperatures and can be heat stabilized to reduce shrinking. PET has good flex-fatigue resistance and high tensile strength, which lets its resist cracking and deformation. It also resists chemicals. And several conductive inks are compatible with print-treated and non-treated PET films.

**Polycarbonate (PC)** is not a good choice because:

- It softens and deforms when curing the conductive ink.
- It lacks the flex fatigue resistance of PET.
- PC film may crack when exposed to stresses and chemicals in working environments.

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**Spacer Layer**

This layer keeps the top and bottom circuits in register and prevents switch contacts from touching each other until the switch is pushed. It has a pressure sensitive adhesive on both sides. No special properties are required except that:

- It can be die cut.
- It bonds well to the adhesive.
- It bends and moves with the circuit layer film in to changes in temperature and humidity.

Almost any material can be used as a spacer as long as its thermal and hygroscopic expansion rates match.

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Membrane switches consist of several layers made of polyester and/or polycarbonate, including the graphic overlay, circuitry layer, and spacer. They are often held together with adhesives.

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**Polyimides**, both thermoplastics and thermosets, retain their principal properties over a wide temperature range. These films have useful mechanical properties, even at cryogenic temperatures. At -453 °F, the film can be bent around a small mandrel without breaking and, at 932 °F, its tensile strength is 4,500 psi.

**Fluoropolymer** films minimize transmission of moisture vapors.

**Polyetheretherketone** (PEEK) offers outstanding thermal properties and resist many solvents and proprietary fluids. PEEK can be laminated to PEEK or other substrates. PEEK film is available in a transparent, thermoformable grade and in a higher-temperature, heat-stabilized version, which is more crystalline and less transparent (also thermoformable).

**Acrylic** films are noted for exceptional clarity and weatherability, and also offer favorable stiffness, density, chemical resistance, and toughness.
amount of stress depends on the film's stiffness, thickness, and the bend radius. The film can also be stressed when it is compressed, such as when the film is clamped between two other parts. When stressed, polycarbonate film becomes more vulnerable to aggressive chemicals and they can damage the film, causing a range of problems ranging from slight surface hazing to cracks running through the film (stress cracks).

For polycarbonate film, high stresses are about 1,500 psi. This is the equivalent of hanging a 15-lb. weight from a 1-in. wide strip of 0.01-in. film.

**GRAPHIC OVERLAY**

This is the layer that is seen, touched, and cleaned. It is typically printed on the back side and graphically shows the buttons while protecting the electronics. So the overlay films should:

- Withstand the flexing during switch actuation for the design life of the device.
- Resist scratching and abrasion, as well as chemicals.
- Provide the dielectric strength to resist electrostatic discharge.
- Resist chemicals in the working environment.
- Provide an aesthetic appearance.

The choice of film for the overlay depends on which of the above properties are most important. The requirements of a heart monitor, for example, will differ from those of a dishwasher. Each film has advantages that will make it an obvious top choice for certain applications. Conversely, each film has disadvantages that will exclude it from some applications.

Here's a summary of how the two films compare:

- Switch life is affected by film thickness, switch travel, spacer hole diameter, spacer thickness, shape of actuator, temperature, flat vs. embossed, embossed shape and height, type of inks and coatings used, and the working environment. In almost all cases, PET out-performs PC. A non-embossed PET overlay can handle over 100,000,000 actuations. A PC overlay can also reach these high actuation levels, but only under perfect conditions. In the real world, actuation pressures and chemical exposure shorten that life to 10,000,000 or less. Embossing the overlay reduces the life of both films. Depending on the embossing and switch travel, PET could drop to 10,000,000 and PC to less than 100,000 actuations.
- PET is slightly harder to scratch than PC but it still cannot survive normal use without protection, usually a hard coat. The availability of PC in textures such as suede and velvet lets it resist abrasions without a hard coat. PET is better at resisting chemicals.
- The dielectric strength of PET is slightly greater than PC - 21 Kv vs. 18 Kv at a film thickness of 10 mils. However, the availability of PC in heavier gauges lets it protect better against electrostatic discharge - 26 Kv at 20 mils.
- Appearance and processing. This is where PC outshines PET. PC is available in a wider range of gauges and textures, making it more attractive to designers. PC is also considered easier to process. It is clearer in heavier gauges, which makes color matching easier. And it does not need to be stabilized to resist shrinking under ink curing conditions (below 250° F). PC is easier to die cut without splitting the edges. It embosses easier without needing high temperatures to set the shape. Inks adhere more readily to PC than PET, which can lower the cost of overlays.

In conclusion, polyester is best for long-term reliability, while polycarbonate is best when appearance is important and the switch won’t be used too much.

**WORKING WITH POLYCARBONATE FILM**

Polycarbonate films are tough, clear, and can deflect heat. They are commonly used for labels, switch overlays, and signs. The film is often decorated on one or both sides, die cut, then fixed in the final application by mechanical means or a pressure sensitive adhesive. In most of these applications the film remains flat and performs well.

In some cases, however, the film must conform to curved surfaces. Bending polycarbonate film creates stress on the bend's outside curve. The
Polyester film can be clear or opaque, as well as white or translucent.

Or bending the same film to a 1-in. radius (2-in. dia. circle). In general, uncoated polycarbonate film should not be cold formed to a radius tighter than 100 times its thickness.

If stress is below 1,500 psi, polycarbonate film will survive indefinitely in normal environments. In aggressive or industrial environments, polycarbonate film should not be stressed to 1,500 psi unless it carries a chemical resistant coating.

If stress on the film can’t be removed or sufficiently reduced in the design phase, and the part can’t be protected from the environment, then a more chemically resistant film such as polyester should be used.

Polyester films are tough, durable, and dimensionally stable. They can be metallized, embossed, slit, die cut, and laminated. They are available in crystal clear, white, opaque, and translucent forms, and the surface can be glassy smooth, matte, or antistatic. They also resist chemicals.

Unfortunately, polyester films tend to shrink when temperatures get high enough, which can happen in processing. A technique called preshrinking improves the film’s dimensional stability and lets the film meet tight dimensional tolerances, a common criteria for use in membrane switches.

Films used in membrane switches normally shrink by up to 3% in the machine direction and 2% in the cross machine or transverse direction when exposed to 190°C for at least five minutes. The film will shrink less at ink drying temperatures (90°C to 150°C), but it still may shrink more than 0.1%, which means it will be out of tolerance.

For preshrinking, the film should be flat and unrestrained. So if it is to move through preshrinking on a continuous web, minimum tension should be used. The film must be heated to 90°C to 200°C. The actual temperature should be 15°C to 30°C higher than the final processing temperatures. Manufacturers should empirically determine exactly how long it takes to thoroughly heat the film to this temperature and be sure not to let film overheat because once it reaches the proper temperature, it can start shrinking within five minutes.

**Polymer Coatings**

Metals such as steel and aluminum are often coated with polymers so that they resist corrosion, a common problem. But coating for metals and other materials also protect against chemicals and the aging effects of oxidation. Coating can also be aesthetic or ergonomic, giving parts an attractive, easy-to-clean surface, or making parts easier to grip. These coatings must adhere well to substrates and not chip easily or degrade from heat, moisture, salt, or chemicals. Some of these coatings are replacing chrome and cadmium coatings due in part to concerns about heavy metals.

Here’s a rundown of some of the common polymers used as coatings.

**Acrylics and alkyds:** These materials are widely used on farm equipment and industrial products requiring corrosion protection at a moderate cost. Alkyd resins are often chosen based on how well they withstand weather and how easy they are to apply with low-cost, low-toxicity solvents. Alkyd paints are also relatively high in solids, so the paint film becomes thick with a minimum number of coats.

Adding silicone to acrylics and alkyds improves weatherability and durability. For the best durability,
Epoxy finishes: These coating adhere more strongly to metals than most other organic coatings. This is why they are often used as primers under materials which have good barrier properties but marginal adhesive characteristics. Epoxies are also cost effective because they protect against corrosion despite being applied in thinner coats, which lets manufacturers use less material.

Coating thickness vary from 1 mil for light-duty protection to as much as 20 mil for devices used to handle corrosive chemicals or abrasive materials. But thicker layers of epoxy are more brittle than other organic coatings.

Polycarbonate film can be made smooth or with a variety of textures.
Nylon 11: These coatings provide an attractive appearance while protecting against chemicals, abrasion, and impacts. For thicknesses from 2.5 to 8 mil, nylon is applied by electrostatic spray. Heavier coatings (to 50 mil) are applied by the fluidized-bed method.

Fluorocarbons: No organic coating is more impervious to chemicals and solvents than fluorocarbons. That is because they are almost inert. Common fluorocarbon coatings used for corrosion resistance include polytetrafluoroethylene (PTFE or Teflon), perfluoroalkoxy (PFA, which Dupont calls Teflon PFA), ethylene chlorotrifluoroethylene (ECTFE), fluorinated ethylene propylene (FEP), and polyvinylidene difluoride (PVDF).

PVDF and ECTFE coatings work best in limiting damage due to impacts, while PVDF also stands up under abrasive conditions and has the highest compressive strength of the fluorocarbons. PTFE, FEP, and PFA also resist impacts, but they tend to creep more under load. PFA and PVDF coatings can handle high temperatures but PTFE is the fluorocarbon that resists the highest temperatures (600°F). PTFE is also used as a dry lubricant.

Combination coatings: These mixtures take anodizing or hard-coat plating and add low-friction polymers and dry lubricants. The coatings become part of the metal substrate’s top layer and increases hardness and other surface properties.

Proprietary combination coatings have been developed for steel, stainless steel, copper, magnesium, aluminum, and titanium to improve surface characteristics. Coatings also improve specific properties such as lubricity, corrosion resistance, or wear resistance.

Powder coatings: This group of coatings blends properties of plastics and paints. The coatings are made using typical plastics-industry equipment. The mixture is sent through a melt-mix extruder and then ground. Liquid can be added and it is applied like paint.

Most powder coatings have relied on either an epoxy or polyester resin base. Acrylics, however, are becoming more important, and other possible bases include nylon, vinyl, and various fluoropolymers.

Powder coatings were developed to reduce volatile organic compound (VOC) emissions. VOCs are a problem with solvent-based paints. Overspray from those paints contains solvents that get released into the atmosphere despite the best recovery equipment. But powder coatings are recyclable. Overspray is totally contained, easily collected easily, then reused. If some becomes too dirty or contaminated for recycling, there are safe disposal techniques.

Powder coatings show promise as a substitute for clear coats in the automotive industry. Present solvent-based paints could be replaced by a clear powder coating that cures at roughly the same temperature as conventional paints. Powder coatings may also replace the baked-on porcelain enamel used for appliances.

The most commonly used process for applying powder coatings is electrostatic spraying. In this method, powder is given a charge and sprayed onto electrically grounded parts. Baking them completes the cure. Nonconductive parts must be primed or heated to give them an electrostatic attraction.

Another application method for powders is the fluid-bed process. It sends air through a porous membrane at the bottom of a tank full of powder. The powder gets aerated and swirls around in the tank. A part to be coated is heated and dipped into the tank, so that the powder melts on the surface. This process imparts thick coatings, and is suitable only for metal parts that retain heat long enough to be coated.