INSULATING MATERIALS

This report lists a number of commonly used insulating materials found in electronic and electric equipment. Although this listing is somewhat long, it is not comprehensive- the choices available can be overwhelming. Fortunately many superb and inexpensive materials are available and the final choice may be somewhat arbitrary and the designer is advised to obtain samples of several candidates before making a final decision. Trade names do not represent a particular brand preference but are included for clarity.

INSULATING MATERIALS

A.B.S.: Acrylonitrile, butadiene, and styrene combine to form this common plastic often used to make housings or other mechanical parts.

ACETATE: Acetates have good electrical insulating properties and is the material used to make movie and microfilm.

ACRYLIC: Lucite and Plexiglass are trade names for acrylic which has widespread use where toughness and transparency are required. Solvent cement is quite effective for welding pieces together.

BERYLLIUM OXIDE: A hard white ceramic-like material used as an electrical insulator where high thermal conductivity is required. Beryllium oxide is highly toxic in powder form and should never be filed or sanded and consequently has fallen out of common use. Power semiconductor heat sinks can still be found with beryllium oxide spacers for electrical insulation.

CERAMIC: Ceramics are used to fabricate insulators, components, and circuit boards. The good electrical insulating properties are complemented by the high thermal conductivity.

DELRIN: This Dupont acetal resin is made from polymerized formaldehyde and finds uses similar to nylon. The material is rigid and has excellent mechanical and electrical properties making its use common in appliances and electronics.

EPOXY/FIBERGLASS: This laminate is quite common due to its superior strength and excellent electrical properties even in humid environment. Most modern circuit boards are made from a grade of epoxy/fiberglass. (Grades include G10/FR4 and G11/FR5 extended temperature grade.)

GLASS: Glass insulation comes in a wide variety of forms including solid glass, fiber tapes, fiberglass sheets and mats, woven tubing and cloth, and various composites. High temperature operation is a key feature.

KAPTON: Polyimide film has exceptionally good heat resistance and superb mechanical and electrical properties. Kapton tapes are fairly expensive but often indispensable.

KYNAR: As is Teflon, Kynar is a floropolymer with excellent chemical and abrasion resistance. It is readily machined and welded.

LEXAN and MERLON: These polycarbonates have excellent electrical insulating properties. Optical grades are available and the material is so tough that it meets U.L. requirements for burglary-resistance. Non-transparent grades are machined to make strong insulators, rollers, and other mechanical parts.

MELAMINE: Melamine laminated with woven glass makes a very hard laminate with good dimensional stability and arc resistance. (Grades G5 is the mechanical grade and G9 is the electrical grade.)

MICA: Mica sheets or "stove mica" is used for electrical insulation where high temperatures are encountered. Thermal conductivity is high so mica insulators are useful for heatsinking transistors or other components with electrically conductive cases. Puncture resistance is good but the edges of the mica should be flush against a flat surface to prevent flaking. Mica finds uses in composite tapes and sheets which are useful to 600 degrees centigrade with excellent corona resistance. Sheets and rods of mica bonded with glass can tolerate extreme temperatures, radiation, high voltage, and moisture. This rather expensive laminate may be machined and it will not burn or outgas.

NEOPRENE: Neoprene rubber is the material used for most wet suits. This black rubber is commonly used for gaskets, shock absorbers, grommets, and foams.

NOMEX: Nomex is a Dupont aromatic polyamide with an operating temperature range over 220 degrees centigrade and with superb high voltage breakdown. It is an excellent choice for standardization since it outperforms many other materials.

NYLON: Nylon has good resistance to abrasion, chemicals, and high voltages and is often used to fashion electro-mechanical components. Nylon is extruded and cast and is filled with a variety of other materials to improve weathering, impact resistance, coefficient of friction, and stiffness.

P.E.T.: Polyethylene terephthalate is a highly dimensionally stable thermoplastic with good immunity to moisture. This excellent insulator has a low coefficient of friction and is excellent for guides and other moving parts.

P.E.T.G.: A clear, tough copolyester commonly used for durable "bubble-packs" or food containers.

PHENOLICS: Phenolic laminated sheets are usually brown or black and have excellent mechanical properties. Phenolics are commonly used in the manufacture of switches and similar components because it is easily machined and provides excellent insulation. Phenolic laminates are widely used for terminal boards, connectors, boxes, and components. (Grades x, xx, xxx are paper/phenolic and grades c, ce, l, le are cotton/phenolic which is not the best choice for insulation. Grade N-1 is nylon/phenolic and has good electrical properties even in high humidity but exhibits some cold flow.)

POLYESTER (MYLAR): A strong material often used in film sheets and tapes for graphic arts and electronics. Those shiny balloons and "space blankets" are usually made from metalized Mylar. Mylar is also used as a dielectric in capacitors.

POLYOLEFINS: Polyethylene is the white Teflon-like material used for food cutting board. Different densities are available with the ultra-high molecular weight grade at the top offering toughness outlasting steel in some applications. Polypropylene is another widely used polyolefin.

POLYSTYRENE: A clear insulator with superb dielectric properties. Polystyrene capacitors exhibit little dielectric adsorption and virtually no leakage. Liquid polystyrene or Q-dope is a low-loss coil dope used to secure windings and other components in RF circuits.

POLYURETHANE: Polyurethane is another common polymer which features abrasion and tear resistance along with a host of desirable characteristics. Degrading little over time or temperature, polyurethane is popular in both commercial and consumer applications.

PVC: Polyvinylcloride or PVC is perhaps the most common insulating material. Most wiring is insulated with PVC including house wiring. Irradiated PVC has superior strength and resistance to heat. PVC tapes and tubing are also quite common.
Electrical and electronic housings are commonly molded from PVC.

SILICONE/FIBERGLASS: Glass cloth impregnated with a silicone resin binder makes an excellent laminate with good dielectric loss when dry. (Grades include G7.)

SILICONE RUBBER: A variety of silicone foam rubbers are available for insulating and cushioning electronic assemblies. Silicone rubbers exhibit a wish list of characteristics including superb chemical resistance, high temperature performance, good thermal and electrical resistance, long-term resiliency, and easy fabrication. Liquid silicone rubbers are available in electrical grades for conformal coating, potting, and gluing. Silicone rubbers found in the hardware store should be avoided in electronic assemblies because they produce acetic acid. Silicone rubbers filled with aluminum oxide are available for applications requiring thermal conductivity.

TFE (TEFLON): Teflon is an excellent high temperature insulation with superb electrical properties. Teflon tubing and wire insulation comes in a variety of colors and typically feels slippery. The insulation is impervious to the heat and chemicals normally encountered in electronics manufacturing but the material will "cold flow" so Teflon insulation is avoided where sharp corners or points are encountered. Laminated TFE circuit boards take advantage of Teflon's excellent microwave characteristics.
Teflon emits a dangerous gas when exposed to extreme heat. White Teflon terminals are commonly used where extremely good insulation is required. The slick surface repels water so the insulation properties are fantastic even in high humidity. High quality I.C. sockets are made from Teflon to reduce leakage currents. Teflon and Teflon composite tapes with adhesive are available. FEP is a lower temperature Teflon.

THERMOPLASTICS: Other thermoplastics include Polysulfone, Polyetherimide, Polyamide-imide, and polyphenylene with trade names like Noryl, Ultem, Udel, Vespel, and Torlon. These materials are grouped here for completeness and are not particularly similar. For example Vespel is SP polyimide with amazing properties but commanding an equally amazing price- a 10 inch sheet could cost thousands of dollars, whereas Polysulfone (Udel) is a rather good engineering material with a cost for the same 10 inch sheet near thirty dollars.

ELECTRICAL INSULATING PAPERS

A variety of insulating papers are available specifically designed for insulating electrical circuits.

Rag and craft paper often called Transformer Paper is often used to separate windings in transformers or in applications where no sharp edges might poke through the relatively weak paper. Grey and tan are common colors.

Fishpaper is a curious name referring to a grey cotton rag paper usually vulcanized and often laminated with Mylar. The Mylar may have paper on one or both sides and many thickness grades are available. Tear and puncture resistance are excellent and the thinner grades are easily cut with scissors. Other "sandwich materials" are available including 100% polyester laminates and are usually a distinct color. The paper/Mylar laminates resist soldering heat better since the paper doesn't melt and the Dacron/Mylar laminates resist moisture best. Laminates with thicker polyester centers are fashioned into insulating plates in many electro-mechanical devices. A typical application may be observed inside most older electrical timers where a printed and folded piece of laminated paper keeps the user's fingers away from the high voltage when adjusting the position of the on and off trippers. Papers made with temperature resistant nylon and/or glass weaves have excellent electrical properties and good temperature resistance.

Thin sheets of epoxy-fiberglass usually green in color are commonly used for insulating PCB's and electronic assemblies with potentially sharp projections. Puncture resistance is superb even for sheets thin enough to be quite flexible.

A simple clear polyester sheet is sometimes used for insulation but is offers far less puncture and temperature resistance than the laminates. The ordinary appearance may prove to be a liability also: one computer maker uses such a sheet to insulate the motherboard from the chassis and many novices have left this critical insulator out when reassembling their computer with disastrous results. Die-cut laminates look important and are easily printed.

TAPES

Tapes are made from many of the above materials. Vinyl tapes are commonly used for wire insulation and are available in all the colors necessary for color coding. Mylar tapes are common in electronics: film capacitors often have a final wrap of yellow Mylar tape. Acetate tapes are used where good conformability is desired as when covering coils as is white cotton cloth tape. Glass cloth electrical tape with thermosetting adhesive (adhesive that permanently sets with temperature) is used to secure and protect heater windings or insulate components exposed to heat. Kapton, Teflon, and other insulators from the above list are used to make high performance specialty tapes for harsh temperature or chemical environment.

FOAMS

Foams are available for both thermal insulation and mechanical / acoustical insulation. Choosing a foam for vibration damping can prove difficult. Many foams become stiff at cold temperatures and will "take a set" at elevated temperatures. Some foams may have excellent temperature characteristics but exhibit too much "spring" giving the assembly an unacceptable resonance. Evaluate several materials

before choosing- foams are made from many of the insulating materials mentioned above. Some of the more common foams are listed below.

NEOPRENE: Neoprene foam (black) is often used for shock absorbing and vibration damping.

POLYSTYRENE: Styrofoam is the white foam used in inexpensive ice chests and packing peanuts. It is an excellent insulator but cannot tolerate elevated temperatures.

POLYURETHANE: Urethane foams are available in both rigid and flexible forms. The insulating properties are excellent and elevated temperature tolerance is good. Machined pieces of rigid polyurethane are often used as thermal insulators in electronic equipment. The soft foams are good for vibration and sound attenuation and are available with a wide variety of properties.

SILICONE: Silicone foams provide excellent vibration damping characteristics and excellent high temperature performance and chemical resistance.

VINYL: Vinyl foam has very little "spring" and is useful for vibration damping.

LAMINATES: Various foams are often laminated with a heavy center layer to create a sound and vibration barrier. Lead has been used as the massive layer but the obvious concerns have led to different materials such as metal oxide filled plastics.

The complete list of foam rubbers, plastics, and other foam materials could fill a bookshelf so this partial list should not confine the imagination. The yellow pages of any large city will yield the names of plastic companies which usually carry the solid insulating materials mentioned. Gasket suppliers will have a surprising assortment of sheets and foams including specialty electronic materials. The manufacturers can often supply the name of distributors but if they don't it doesn't mean that local suppliers aren't there. Check thoroughly before buying some huge minimum quantity from the factory- almost all of the materials mentioned are available from distributors in small quantities. Industry directories will supply the name of material suppliers if the local distributors cannot. Used bookstores often have old copies of "E.E.M.", "Goldbook" or "Thomas Register" which can give you a list of manufacturers. Ask for the name of the local factory representative since he will probably know the names of local suppliers in his territory since he probably visits them on sales calls.