WHITE PAPER-ELECTRICAL INSULATION

Choosing the Proper Electrical Insulating Material
for Mission-Critical Applications
by Richard Orstad, P.E.
There are hundreds of decisions required when designing mission critical electro-mechanical components. In every one of these decisions, choosing the right material combinations for a specific application can mean the difference between success and failure. Most of these design decisions are made utilizing the same material choices design after design, sometimes compromising the true intent of the project simply because the designer is unaware of the many other material choices available. With this in mind, a primer in common and not-so-common electrical insulating materials may be helpful.

Polyester films: For simple electrical insulating applications where a thin film is required, polyester films are probably the most common type of electrical insulator material used. Polyester films are commonly characterized as either PET (polyethylene terephthalate) or PEN (polyethylene naphthalate), the differences lying in their chemical composition and their resulting physical and electrical insulating properties. PET films, such as Mylar® or Melinex®, offer good dielectric withstanding resistance within a relative temperature range (Tg of 78°C), where as PEN films, such as Teonex®, typically provide similar electrical performance at a much higher temperature range (Tg of 120°C). In applications involving higher temperatures, PEN films are often a better choice than PET films given its 3-4 times greater stiffness at temperatures above 125 °C , as well as its 20°C greater operating temperature than PET (180°C vs. 160°C). Of course, PEN films are more expensive than PET films; however for mission critical applications this cost difference may be negligible. These thin films are found in thousands of applications including flexible electronics, battery and motor insulations, and electronic component manufacturing.
Polyether materials: Where higher temperature environments prevent the use of PEN films, often times the mechanical design engineer will consider the use of poly ether ether ketone (peek) or polyetherimide (PEI) materials such as Ultem®. PEI materials have a significantly higher glass transition temperature than PEN films, at 216°C. A common PEI material, Ultem 1000® film has a continuous operating temperature rating of 171°C with exceptional flame and heat resistance. Another benefit of Ultem 1000® material is its availability in film, sheet, or extruded rod forms, allowing the design engineer greater flexibility in designing critical mechanical components depending on the specifics of the application. Again, just as PEN films are typically more expensive than PET films, the greater performance attributes of the PEI materials lends itself to a higher price point than the PEN or PET films. The specific requirements of the electro-mechanical component, as well as the requirements of the specific application must be weighed when determining what material to choose. Because of the different material forms available, PEI materials are often used in aircraft components, microwave applications, and electric/electrical components.
Polyimide materials: Where even greater temperature resistance is required while maintaining excellent electrical insulating performance, polyimide materials are often called upon. Polyimide films such as Kapton® have been used for years as an outstanding electrical insulating material, and thicker polyimide materials such as Vespel®, Torlon®, and Cirlex® continue to be utilized as alternatives to PEI materials where mission critical applications require precision engineered materials. Cirlex®, made from 100% Kapton® polyimide film, has a glass transition temperature of 351°C, far exceeding that of PEI materials, providing exceptional stability at demanding temperatures. Its very low Coefficient of Thermal Expansion (20 ppm/°C) along with its high tensile strength (32000 psi @ 200°C at 9 mil) makes Cirlex® an exceptionally strong and stable material across its operating temperature range of -269°C to 351°C. Another unique characteristic of Cirlex® is its availability in increments of 0.001” from 0.004” up to 0.125” or thicker. This allows a tremendous amount of design flexibility for the mechanical engineer, as the engineer can enter the

design phase without thinking of material thickness limitations, but rather design specifically for their application knowing the right thickness material is available to them. The availability of Cirlex® in 0.001" increments also greatly reduces the amount of machining time required to get to final thickness tolerances, which must be considered when designing for manufacturability.   Cirlex's® physical and mechanical stability are also evident during and after the machining process, as there are no residual stresses built up in the material leaving the final design in its dead-flat form.   In applications where extreme temperature or environmental requirements are needed, the benefits of a polyimide material such as Cirlex® outweigh other material choices.

Finally, there are many instances where a mechanical component requires a metal-to-polymer lamination process, such as bonding copper to polyimide. In many cases, an appropriate PSA or B-stage adhesive is chosen to bond the two materials. However, the addition of an adhesive layer provides an opportunity for component failure, introducing potential outgassing or delamination issues at elevated environmental conditions. Eliminate the adhesive layer and the engineer will eliminate the weak link in the application. One solution for these types of applications is the use of adhesiveless laminate bonding technology. Polyimide is closely matched to the CTE of copper, and using an adhesiveless laminate allows the seamless marriage of conductor and insulator in an application, allowing the engineer even greater flexibility in design capability. Whereas the use of Copper-clad laminates used to be subjugated to the limits of flexible circuits, the advent of adhesiveless laminate bonding technology with polyimide allows the mechanical engineer seemingly limitless possibilities in advanced mission critical electro-mechanical component design.

Conclusion: Choosing the right material for an electro-mechanical component is a delicate balance between form, fit, function and price. It is important for the engineer to consider all aspects of the functional design of the part as it relates to the physical, electrical, and thermal properties of the environment in which it will be performing. Making certain that the correct electrical insulating material is selected, whether it is a PET, PEN, PEI or polyimide, depends on the specific application the component will be functioning as well as the surrounding temperature and environment of the application. For mission-critical applications, making the correct choice of an electrical insulator is oftentimes less dependent on price than it is on environmental conditions, and therefore selecting the proper material is favored to those that provide the greater environmental resistance and mechanical stability.

About the author: **Richard Orstad, P.E., M.B.A.**, is a Professional Engineer with over 20 years of experience in Engineering, Project and Product Management, Manufacturing Operations, and Sales and Marketing Management. He holds several patents in electrical connector design, has written several white papers on Industrial Automation, and presented these topics at international conferences focused on the Hard Disk Drive Industry. Richard is the Eastern Regional Sales Manager for Fralock, a provider of precision converted Engineered Materials solutions for the Military/Aerospace, Medical, and Electronics industries.