TIME to CONSIDER THERMOPLASTIC MATERIALS for ELECTRONIC PACKAGING

Ken Gilleo PhD
ET-Trends LLC
Ken@ET-Trends.com

Abstract
Thermoset epoxies, discovered nearly 80 years ago, remain the workhorse material for most electronic packages. However, this may change with the ever-increasing technical and economic challenges along with the dramatic shift to "green materials" driven by RoHS and other environmental regulations. Modern halogen-free thermoplastics can now boast excellent thermomechanical properties and fabrication with highly automated high-efficiency high-volume processes. Plastic injection molding can readily produce precise and intricate 3D structures suitable for electronic, photonic and micro-mechanical packaging. Although there is a well-established packaging infrastructure tied to traditional thermoset epoxies, there is a much larger worldwide manufacturing base that excels in shaping thermoplastics. This is the ideal time to evaluate thermoplastic materials for packages and interconnects for 21st century technology. This paper will describe plastic materials, novel designs, and modified injection molding processes suitable for packaging. Thermoplastics impressive attributes include the lowest moisture uptake, the fastest processing and the highest stability in the world of polymers.

Introduction

Electronics can be conveniently divided into devices (chip; die) and interconnect structures (package routing, printed circuit, etc.). Electronic chip devices, with over 400-million transistors, are now fabricated in nanoscale (1-billionth of a meter) dimensions. MEMS (Micro-Electro-Mechanical Systems) and Optical MEMS (called MOEMS; add "opto" to acronym) technologies have added mechanical and optical features to chips while retaining electronic functionality. MEMS chips are now used in cars, planes, rockets, military vehicles, cell phones, robots, medical devices, and many consumer products. MOEMS, used in digital projectors, the cinema, and HDTV, can claim the title of the world's most complex machine. A single chip contains millions of mechanical parts that are instantly moved under electronic digital control. A modern digital projector or state-of-the-art digital home entertainment center can utilize a chip with 1,300,000 micro-mirrors that point either forward (pixel on) or off-axis (pixel off) to generate the images seen on the screen. The integration of logic, light, RF, and mechanical action on a monolithic device, all mass-produced, opens up a new epoch for technology that requires novel packaging.

Device-level advancements are certainly inspiring and even mind boggling, but these incredible chips MUST have a suitable interface to the outside world. The component package is the primary interface that must handle electrons for traditional chips, but also light and matter for newer classes. Although the package can be viewed as conductor mated to an insulator platform, the huge challenge for industry is selecting the right materials for an optimized design that uses the best processes to cost-effectively manufacture billions of parts. The package plays a key role in the continuing high technology revolution.

PACKAGING REQUIREMENTS

Component packaging is essential technology that is evolving and unfolding at a quickening pace as the industry follows a performance-density roadmap leading to 3D stacked designs and wafer level packaging (WLP) processes. The package remains the vital ***bridge*** between devices and printed circuit boards. But as this gap between chips and Printed Circuit Boards (PCB) widens, the packaging challenge expands. Epoxy thermosets, discovered in 1927, have been used for nearly 50 years as encapsulants for electronics and are still the "workhorse" polymer for most packages[1]. Epoxy molding compounds (EMC) have been the obvious choice ever since the successful development of plastic non-hermetic packaging also called Plastic Encapsulated Microchips (PEM). But epoxies are no longer the only choice for packaging in the 21st century.

Package Definition and Attributes

The deceptively simple component package performs a multitude of functions that rely on material properties. Some features are essential, others are helpful, and a few are product-dependent. Essential requirements include providing the electrical interconnect system between the device and PCB. Rerouting is valuable for some applications but not all; this is a geometric translation that is often used to make high-density chips compatible with a lower density PCB by employing a fan-out design pattern. Environmental protection is nearly always a requirement, but can be very product-specific ranging from low-level protection for highly passivated chips, to extreme for most MEMS and MOEMS devices. The package also provides compatibility between chip interconnect pads that are typically not easily solderable (thin aluminum) and PCB land areas that are designed for solder assembly. The package should be reworkable to allow a large assembly to be salvaged if a bad connection or component is located during final testing. Other package attributes include, testability, standardization, ease of automatic handling, miniaturization, performance enhancement, and heat management. Photonics, MEMS and MOEMS add more layers of requirements.

PACKAGE CLASSES and their MATERIALS

Full Hermetic

The full-hermetic package, developed about 150 years ago, has admirably served the electronics and optoelectronics industries. The cathode ray tube (CRT), demonstrated by Braun in the 1800's, used a glass enclosure to seal out the atmosphere and maintain a vacuum. It is the original hermetic package. Later, electronic vacuum tubes were developed in the form of the Fleming diode quickly followed by the De Forest triode amplifier tube, the first active electronic device. These early opto- and electronic devices required a vacuum to operate because the flow of electrons through free space was an inherent element of their mechanisms. But today, only a very few systems actually require a vacuum even though this century-old tradition of the full-hermetic sealed enclosure continues. The early packaging glass evolved to ceramics and metal and the principle of making a near-perfect gas-tight enclosure persists today.

Non-Hermetic Plastic Package (Plastic Encapsulated Microelectronics; PEM)

Plastic packages became mainstream products with the breakthrough introduction of the dual-in-line package (DIP) although plastics were used earlier for discrete transistors. The IC (Integrated Circuit) is typically connected to a metal lead frame (MLF) by wire bonding followed by transfer overmolding with EMC. Molding compound is a mix of solid epoxy resins, hardeners, fillers, and additives that is easily liquefied by modest heating to allow the melt to be forced into a mold that holds the lead frame assembly. The heated thermoset EMC polymerizes to a permanent solid. The molding compound comes into direct contact with the IC, wire bonds and MLF. The BGA (Ball Grid Array) style package can use a similar overmolding method but an organic (plastic) substrate typically is used in place of the MLF. Since MEMS devices have moving parts, direct contact by encapsulant is not an option unless specially pre-capped MEMS chips are used. While wafer-level capping is being used on inertial sensors, this is one of the few MEMS classes that can tolerate this technique since access to the outside world is required for most other classes. But overmolding of capped MEMS can stress-degrade their performance due by epoxy shrinkage around the device. Some capped MEMS products have moved away from thermoset overmolding to thermoplastic cavity packages.

Near-Hermetic Package (NHP)?

The component packaging industry has really only offered these two extremes, the costly full-hermetic and the economical non-hermetic package. But an intermediate package would be valuable[2,3] and might be refer to as the Near-Hermetic Package (NHP). While there is not yet a definition[4,5], several have sought to develop the Near-Hermetic Package - a design that is "good enough" and "cheap enough" for the intermediate packaging needs that have been requiring the industry to use the full hermetic package with its market-limiting costs. For now, it will suffice to say that the NHP should provide a sufficient barrier so that the packaged device and interconnect will meet the customer's performance criteria. The NHP will therefore have product-specific performance. Success for the NHP will require identifying suitable materials and processes. A MEMS gyroscope appears to be the first MEMS device to utilize a NHP.

BASIC ELECTRONIC PACKAGING MATERIALS

Metals

Metal provides the ultimate gas and moisture barrier that can convey lifetime values predicted to be more than 100 years. Although raw metals can be quite inexpensive, the fabrication methods used for packages generally add substantial cost. So while metal is the *gold standard,* this is unfortunately reflected in the price. But, metal packaging, because it is typically electroplated, can release contaminants such as hydrogen; devices that are sensitive to hydrogen may use hydrogen getters within the metal enclosure. Metal and metal composites are presently used as the electrical conductors for devices, packages and PCB interconnects, but this could change in the future as nanotechnology and organic conductor advance. A process called injection molding metal (IMM) might offer some savings to metal packaging, but the electrical conductivity of enclosures, regardless of how they are made, requires insulation and special processes that add cost.

Ceramics

Ceramic continues to be a popular material for hermetic and certain non-hermetic packages that need the following attributes; good planarity, smoothness, extreme mechanical stability, high thermal conductivity, and excellent temperature stability. Ceramic materials and processes continue to be more expensive than organic technology although cost-reducing processes are still evolving. Ceramic is presently the favored platform for large CPUs and the preferred cavity type enclosure for MEMS, MOEMS and some RF devices. But ceramic is being replaced by plastic materials wherever possible for cost reduction and manufacturing simplicity.

Plastics

Plastic packaging, primarily based on thermoset materials, accounts for perhaps 95% of the world packaging market because of low cost, versatility, and easier automation. But there are issues. The common EMCs have limited shelf life, must be kept in cold storage to extend useful life, and can produce variable properties depending on age and temperature history during processing. EMC materials can have surprises as happened when material that appeared to be good, resulted in failures of a large number of products in 2000-2001 that triggered a host of expensive lawsuits and settlements. The complex mixture nature of EMCs and its multiple polymerization reactions can make quality control difficult.

Thermosets, once polymerized, cannot be melted for reuse and become scrap. Worse yet, EMC is generally classified as hazardous waste making disposal increasingly difficult. Many EMC's contain bromine flame retardant compounds that are destined to be regulated into extinction just like lead solders. Some bromine compounds fall under pending RoHS rules and others will almost certainly be restricted in the future. Replacement of bromine with dubious choices like phosphorus as a flame retardant will only add more uncertainties. Reformulating will require retesting and a "reset" of the learning curve. Epoxies are also relatively poor gas and moisture barrier materials although chip passivation has allowed most devices to work well enough to bring success to the plastic package. What are the plastic material alternatives?

Impending regulations and the need for better performance have thrust thermoplastics into the center stage of consideration. Thermoplastics can be cheaper, environmentally friendly, reusable, recyclable, and boast near-hermetic properties far superior to non-hermetic epoxies. One of the best thermoplastic packaging candidates only contains carbon (C), hydrogen (H) and oxygen (O), yet passes flammability specs and survives lead-free solder temperatures (over 260^{o}C). Thermoplastic properties are controlled and confirmed by the resin manufacturers who complete the polymerization reactions and deliver 100% polymer. Conversely, thermosets will vary from run to run since the end user is the *polymer manufacturer* who affects the final properties by carrying out *in situ* polymerization. Thermoplastics are much simpler and have more predictable chemistry than epoxies. Epoxies start as mixtures and typically undergo dozens of competing reactions during polymerization to form a myriad of intermingled structures that can be difficult to quantify. Issues with their complexity was perhaps demonstrated by the 2000-2001 epoxy packaging failure epidemic where allegedly bad material was not discovered until complete systems had been assembled that failed in the field. But the increasing need for lower cost cavity packages may be the driver for developing the new class of packaging based on thermoplastics. MEMS, MOEMS, some RF (radio frequency), and OE (opto-electronics), have created an escalating demand for lower cost **free-space** enclosures that might be best satisfied by modern thermoplastics. Thermoplastics are also finding increasing favor as circuit dielectric materials, but mostly in the flexible circuitry domain that is also the fastest growing PCB segment.

PLASTIC MATERIALS AND PROCESSES

Polymers are long-chain molecules that occur naturally, but are now mostly synthesized. Plastics are arguably, the most important materials of today. Materials have been so important to civilization that entire eras have been named for them; the Stone Age, Bronze Age, etc. From a materials perspective, we are still in the Plastics Age and the day will come when we have plastic (organic) electronic devices in polymer enclosures on plastic circuits in plastic housings. Ironically, many who worked with polymers 20 or 30 years ago were told, and many believed, that the golden age of polymers had passed *because all of the basic polymers had been invented*. How wrong! Fundamentally new polymers continue to be invented, innovative processes are still being implemented and imaginative new products come to the market every month. Much of emerging Nano-electronics is based on organic, polymer-like structures that may some day replace wires and silicon transistors. Although electronics has been considered the leading edge of technology, this field is far behind in the adoption of modern polymers except for the housing, cases and enclosures that hold the electronics products.

Thermosets vs. Thermoplastics

Thermoset plastics, like epoxies, are produced when monomers react to form long chains that are interlinked (cross-linked) to create mega-molecules. Epoxies were the first broadly successful organic packaging materials and continue as the most widely used materials today. They are also used to make organic circuit laminates like FR4 and BT. Since epoxies are thermosets, they are "set" by polymerization when heated to about 150^{o}C or higher (ambient cure is also possible but properties will be different). The other major polymer class is thermoplastics, polymers that can be melted and remelted by heating since there are no confining cross-links. The key distinction between thermosets and thermoplastics is the cross-link. A cured epoxy part is more or less one giant molecule that can't melt. It was the non-melting characteristic that made them a good choice for packages and circuit boards that needed to withstand the high temperatures of soldering. Early thermoplastics would soften and deform at solder temperatures, but there is no problem for today's advanced materials.

Many now feel that the thermoset class of polymers, especially epoxies, has reached a plateau and will continue to fall short as packaging and PCB requirements increase. Relatively high moisture absorption is an increasing concern and so is the need to add flame retardants. But epoxies are still the dominant polymer for electronics and are used in plastic packages, encapsulants, underfills and circuit boards. While epoxies are notable for their balance of properties, they don't really excel in any particular area. In fact, without a significant level of fillers and modifiers, epoxies can't be used in electronics. Substantial amounts of organic bromine compounds have been added to pass flammability standards. Encapsulants and underfills typically contain more filler than epoxy resin to tame the high CTE (Coefficient of Thermal Expansion) that ranges around 80 – 90 ppm/^{o}C. And when it comes to water absorption, they are a "sponge" compared to many other commercial polymers. Epoxy-based circuitry laminates require a substantial level of glass reinforcement to control their dimensional-instability as well as bromine for flame retardancy.

Transfer Molding Thermosets

The transfer molding process has been used for about 50 years to encapsulate electronics and is the *de facto* standard. The steps are straightforward: a chip is attached to a lead frame that is normally a strip or an array of chip bonding sites. Polymer adhesive is the usual die attach material and it can be dispensed at the wire bond station. Once the adhesive is quickly hardened by heating, wire bonds are made between the chip pads and the corresponding lead frame bond sites. The "loaded" array (or strip) is now placed into the molding tool. The transfer mold consists of a heated chamber that is separated from the cavities but connected to each through a system of runners and gates. The process begins by closing the loaded mold. EMC in the form of solid pre-heated preform (called a puck), is moved into the chamber and heated to melting. An auxiliary ram then pushes the liquefied material through the runner and gates into the cavities, completing the transfer process and encapsulating the chip and lead frame. Post heating may be required to fully-polymerize the epoxy.

Thermo-shaping of Thermoplastics

Thermoplastics also have long chains but they are <u>independent</u> (not cross-linked) so that thermal energy will cause a transition from solid to liquid state, while cooling returns the material to the original solid with virtually no intrinsic property changes. Thermoplastics can therefore be reshaped because of this reversible phase change and this is the basis for injection molding and other thermoforming processes. Plastic thermoforming is a very large world-wide industry that is highly diversified. Today's thermoplastics are superior to EMCs in critical categories and can take the abuse of lead-free soldering, can have an order of magnitude better moisture resistance, are rapidly shaped into precise 3D structures, and many pass flammability standards without adding halogens, phosphorus, nitrogen compounds, or hydrates.

Injection Molding

The Injection molding (IM) press first softens the plastic resin, injects it into a metal mold that can have 100 or more package-shaped cavities, and then finally ejects finished parts. The cycle is repeated. A complete IM cycle for a package array takes about 10 seconds. The hot molten plastic is quickly cooled by the mold to form a tough solid part that will not melt during soldering. IM, one of the most ubiquitous manufacturing processes, is used around the world to produce very large and near-microscopic parts for every industry, including automotive and electronics. One drawback is that large, multi-cavity molds can be expensive. Plastic injection molding is well-suited for electronics and several companies now offer molded cavity style packages made from high-temperature plastics such as LCP (Liquid Crystal Polymer) or PPS (Polyphenylene Sulfide). The thermoplastic shaping processes have also kept pace. Injection molding can produce tens of thousands of packages in an hour – all automatically. Micro-molding has advanced to a level where precision parts can only be identified under a microscope. One of the most valuable features of IM is that it can readily produce complex 3D cavity style package structures. Injection molding can form a strip or array of cavity BGA packages at high-volume and low cost using economical engineering plastics like LCP. This polymer class is not new but has been recently popularized as a new flexible circuitry substrate. Any waste, such as mold runners, can be remelted and reused.

Although thermoplastics can be used for overmolding and contact encapsulation, this is probably not a good option for this class of materials. Since thermoplastics must be heated to their melting points that must be high enough to withstand solder reflow, the chip and interconnect would be exposed to very hot and often viscous melt. Only a few discrete devices are overmolded with thermoplastics today. The best fit for thermoplastics is pre-molded packages. Although post-molded packaging is the norm, pre-molded designs can have good economics while offering much greater versatility.

DESIGNING THERMOPLASTIC PACKAGES

MEMS Special Requirements

Microelectromechanical devices can have exceptional requirements depending on their mechanical motion classification. MEMS devices move, or cause motion in materials. The obvious requirement for MEMS devices with motion is "free-space", or "head room". When free space is required, thermosets become less practical since a cavity is more difficult to produce using transfer molding. However, plastic injection molding is an ideal method for producing cavities, ports, or various 3-dimensional precision structures. MEMS may have one additional requirement and that is a controlled atmosphere. Many of these devices are affected by the relative humidity; stiction, wear, and corrosion rates are strongly influenced by relative humidity. Therefore, the package may need to contain a specific internal atmosphere that is modified by getters, anti-stiction agents and even vapor phase lubricants. Optical MEMS, or MOEMS, has the extra requisite of a light path; window or fiber port.

Thermoplastic Concepts for Cavity Packages

The most common molded packages use a metal lead frame that is stamped, or etched out; the form factor is a strip or an array or chip sites for increased productivity. The MLF strip or array is positioned into the injection mold cavity similar to the method used for transfer molding. But the MLF is not pre-loaded with chips and the mold is designed to create cavity shapes instead of flooding the plastic over the surface of the frame. The mold closes under high clamping pressure measured in tons; press ratings are often in clamping force. Next, the injector screw forces melted plastic into the mold cavities under high pressure. The mechanical action of the screw helps reduce plastic melt viscosity. The mold is usually cooled (but held above ambient) using a jacket connected to a chiller to maintain temperature by recirculating water or a heat-transfer fluid. The cooling plastic solidifies in seconds, the mold opens and ejector pins push out (eject) parts from the mold. The process is repeated and is usually automated. Figure 1 shows the insert molding process that can be used to make packages and hundreds of other products.

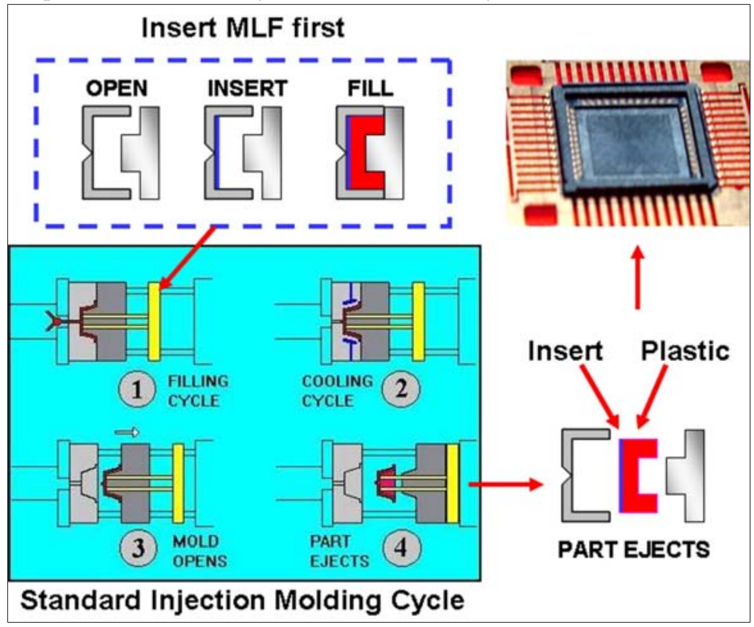

Figure 1 – Insert Molding Process

There are several injection-molded packages that are being developed today and some are in low-volume production. They are based on insert-molded lead frames just described and are shown in Figure 2. But there is a simpler design using thermoplastic materials if we chose to heed Einstein's famous axiom, "Everything should be made as simple as possible but not simpler"[6]. The simpler approach is to insert-mold discrete metal connectors. Let's look more closely at thermoplastic materials for moving onto design details.

Table 1 compares the most ideal thermoplastics from the view of packaging requirements and all can withstand the thermal abuse of the lead-free soldering processes. The packaging industry has mostly ignored thermoplastics, but the need for low cost cavity packages could force an entry point. The Liquid Crystal Polymer (LCP) class of thermoplastics appears to have the best properties for packages. Commercial liquid crystal resins are so named because their polymer chains orient into orderly crystalline structures even in the liquid state. These C-H-O based molecules are superb environmental materials that pass the V-O flammability rating without additives because of their efficient molecular alignment. The efficient molecular packing also results in a high melting point and good barrier properties. LCPs have been used for some time to make precision, moisture-resistant, dimensionally-stable parts like optical connectors and there is a wealth of knowledge available. Commercial LCPs have about 10 times better gas barrier performance than epoxies and behave more like glass when it comes to moisture. This appears to be the right moment in time and technology, and higher environmental attentiveness, to adopt thermoplastics into packaging. These resins are reasonably priced and widely available.

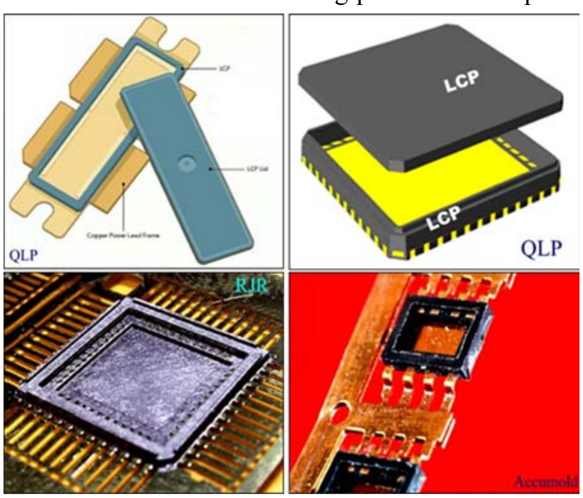

Figure 2 – Plastic Cavity Packages

Table 1 – Thermoplastics for Packaging

PLASTIC	water abs. %	MP	UL94	CTE/30% glass
LCP	**0.02 - 0.10 %**	**280 - 352°C**	**V-0**	**0 - 12 ppm**
PEEK	0.15%	340°C	V-0	16 ppm
PPA	0.15 - 0.29 %	310 - 332 °C	H-B V-0	22- 40 ppm
PPS	0.01 - 0.04 %	280°C	V-0	19 – 27 ppm

LCP = Liquid Crystal Polymer; PEEK = Polyetheretherketone
PPA = Polyphthalamide; PPS = Polyphenylene Sulfide

The next step is to select the interconnect to mate with the thermoplastic. The sphere is the most natural and universal shape and therefore one of the easiest and cheapest forms to manufacture. Natural attractive forces at both atomic- and macro-levels readily form spheres. Industry produces hundreds of spherical products ranging from BGA solder balls to silica filler.

Spheres are easy to handle since they are perfectly symmetrical. Billions of metal spheres are used in ballpoint pens, for example, making them a low cost commodity. All of this leads to metal spheres for conductors as the optimum choice. But since solder would melt at the molding temperature of more than 300^{o}C, the candidates must be non-fusible metals. Copper and nickel are reasonable choices, but copper has more advantages. Copper balls can be pre-plated with Ni followed by palladium for solderability and wire bonding compatibility. Palladium over nickel has been used on lead frames for decades by Motorola and others. Palladium is very suitable for wire bonding and does not degrade solders. Gold over Ni is another option but there could be potential solder contamination problems. The Ni/Pd finish is lead-free and compatible with L-F solders. Pd tends to be readily wet by polymers and could improve adhesion. We can select a size, such as 30 mils for the spheres and a package thickness of 10 mils (1/3) to permit the ball to protrude through the package bottom and into the cavity. The metal ball is really the analog of the pin for a PGA with an optimum manufacturability shape.

The electrical interconnect structure can be thought of as a lead frame that is not initially maintained in a pattern. This "lead frame" pattern is determined by the mold tool that has tiny curved depressions, or dimples, to accommodate and hold the metal balls. So our lead frame inventory is a container of metal balls in standard sizes. We can even use mold inserts to "program" and change the I/O pattern. The metal balls are automatically placed into mold cavities using a vacuum pick-up similar in concept to the BGA solder ball placers. The entire package can be manufactured automatically in a molding machine with a "ball placer". The packages can be molded in a multiple array of several dozen or even a hundred parts for efficient handling and throughput. Small plastic connecting tabs can be used to hold parts together for chip loading and testing. The packages can then be singulated by punching, cutting, lasing, or snapping the tabs. Testing can be carried out while packages are still in array since the ball conductors are isolated. Conventional lead frames must be excised or singulated. The balls protruding inside the package can be coined flat to aid wire bonding and to insure a tight seal and this is shown in lower left of Figure 3. The copper is easily shaped and no damage to the plating has been observed.

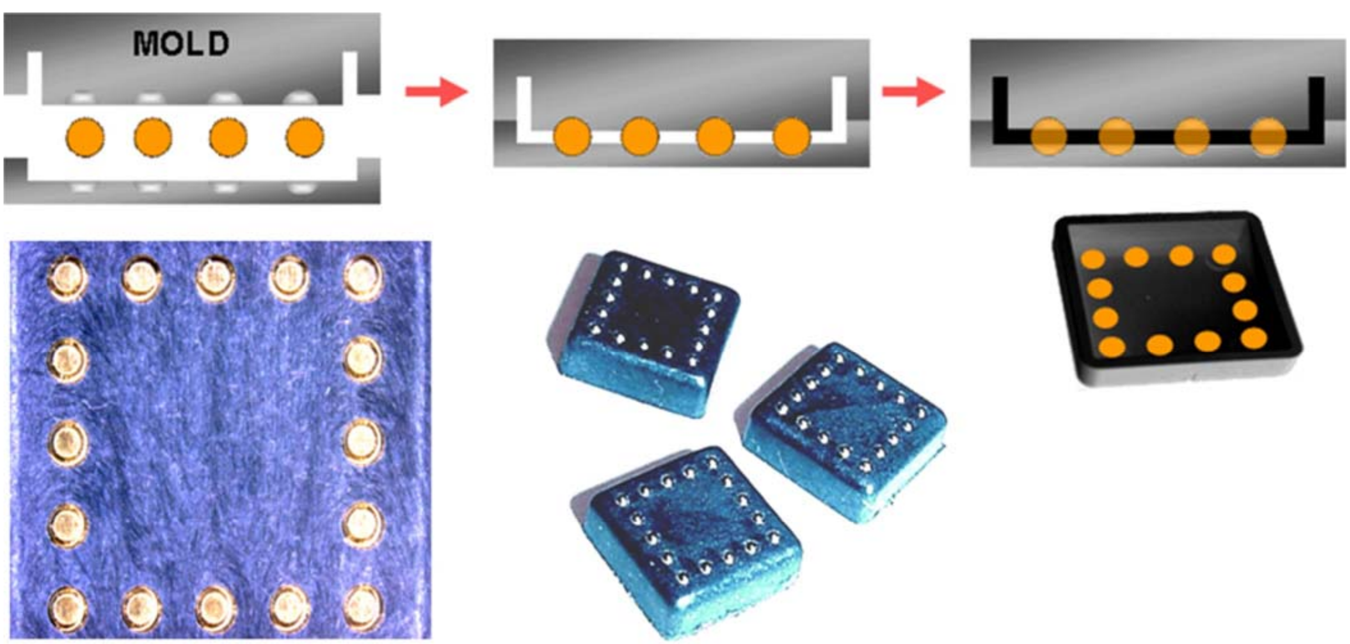

Figure 3 – Injection Molded Prototype Packages

Assembly for all pre-molded packages involves chip attachment and wire bonding that can be run on a conventional line if the array of packages is laid out to a standard configuration to accommodate chip assembly lines. Once chips are assembled, the lids can be bonded to seal the package. This can be done with individual lids or sheets of plastic material. Glass lids can be used for optical devices but plastic is adequate for MEMS. LCP can be used, as well as other plastics including optically clear materials. The lid sealing can be accomplished with any of several bonding methods including adhesives, thermosonic and laser welding[7]. The sealed packages can be tested and singulated. If lids are a sheet, this can serve as a carrier for test and burn-in. The ball array type package can be socketed for test/burn-in without deformation that can occur with solder balls since the balls are made of Cu or Ni. The singulated Near-Hermetic Package is ready for standard SMT assembly. Solder paste is applied to the PCB by stenciling, without any additional steps since paste is needed for the other SMDs anyway. LCP packages are still at an early stage but some have already passed the helium fine leak test and JEDEC Level-1.

Injection-Molded Package Tests
A mold was designed as a 2-up (2 identical cavities) and each had an array of 16 concave depressions in the base and top sections to accommodate the 16 metal balls. The .030" balls were placed with a manual vacuum pick-up array from a vibratory bowl. A magnetic pick-up might be feasible for nickel balls. Once loaded with balls, the mold halves were closed and LCP resin was injected at about 340^{o}C. The mold was opened and parts ejected. High volume production would utilize a tool with multiple cavities and the packages would be connected together in a standard assembly array by small tabs. The mold could be designed so that the ball capture dimples were made shallow or even eliminated on the inner package side for coining. We decided to coin, or flange, the balls after molding since this would produce a compression fit as the ball profile became more elliptical and did not require mold modification. Matrix Inc. (Providence, RI) designed the mold, fabricated the tool and produced prototype parts.

Lids and Sealing
Once a die is attached and wire bonded, the package can be sealed. The lid can be made from almost any conductive or insulator; metal, ceramic, glass, or plastic. Lid sealing to plastic is thoroughly described in the literature and includes adhesive bonding, ultrasonic sealing and laser welding. A search of the literature showed that the idea of using lasers for sealing plastic-to-plastic goes back to the 1960's when lasers were first being explored for industrial use. More recent literature indicates that the concept of using a laser to seal glass lids to LCP molded packages is a known art and apparently in the public domain; free of patent encumberment. A recent Kodak patent describes a molded LCP package for CCDs where the glass lid can be bonded using any of numerous conventional means including adhesive, heat sealing, ultrasonic welding, or laser welding"[7]. Although LCP is the best moisture barrier plastic, it is still permeable like all plastics. However, barrier coatings could create a full-hermetic plastic package in the future by borrowing technology from the lighting industry.

APPLICATIONS
A thermoplastic injection-molded package is being used for capped MEMS today. Some MEMS bare die devices will probably use similar packages in the future. But the ability to insert metal into the plastic can lead to valuable designs for other areas such as power devices and high-intensity LEDs that need extra heat dissipation. Figure 4 shows concepts where heat could be transferred from the chip to the circuit board and to a heat sink. The area under the die could be populated with metal balls for heat removal. Since they are coined flat, there would be a good interface with the die. But if a higher heat transfer was needed, a metal slug could be insert-molded as shown. If even more heat removal was needed, a heat sink lid could be added and a thermal fluid or gel could be introduced into the cavity as shown. Metal thermal inserts can also be formed with using MLF designs; the heat spreader can be part of the MLF. The optical component area also appears to be a good target for thermoplastic parts. The in-molded ball design might also be amenable to simple stacked package designs as shown in Figure 5.

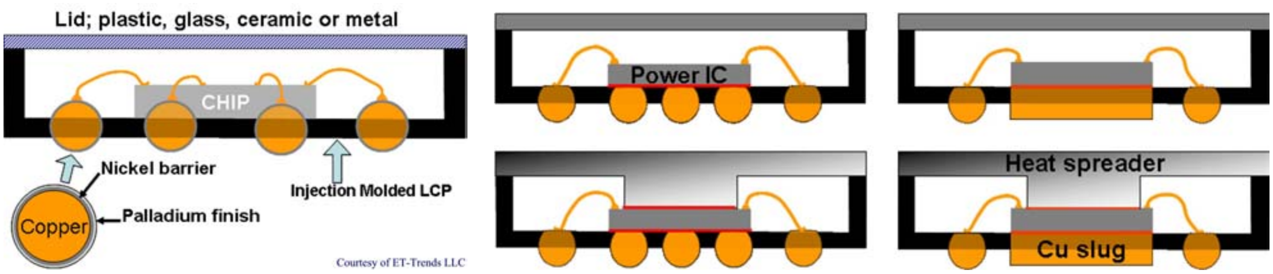

Figure 4 – Thermoplastic

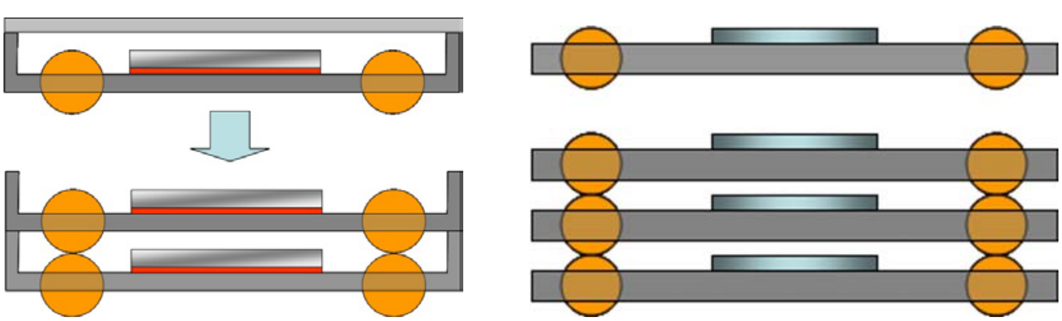

Figure 5 – Stackable Packages

CONCLUSION AND THE FUTURE

This is the right time to consider thermoplastic materials for packaging since the industry is at a crucial stage that requires significant change. Thermoplastics, like LCP, excellent properties for component packaging including high temperature tolerance, low moisture absorption, low flammability, and manufacturability using trouble-free precision molding. Cavity packages can be readily injection molded from LCP using metal lead frame insert molding. A simpler and potentially lower cost concept was developed where metal balls are insert-molded into the package to protrude into the package base and exterior bottom to accommodate wire bonding and SMT assembly. Early results indicate that both metal lead frame and in-molded ball package can be useful for MEMS and other devices such as power and optical. Injection molding is a highly versatile plastic shaping process that could also be used to make more complex packages including multi-chip and stackable types. Future Nanoelectronics devices and systems may use thermoplastics for packaging because of versatility and fine-feature capabilities[8].

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