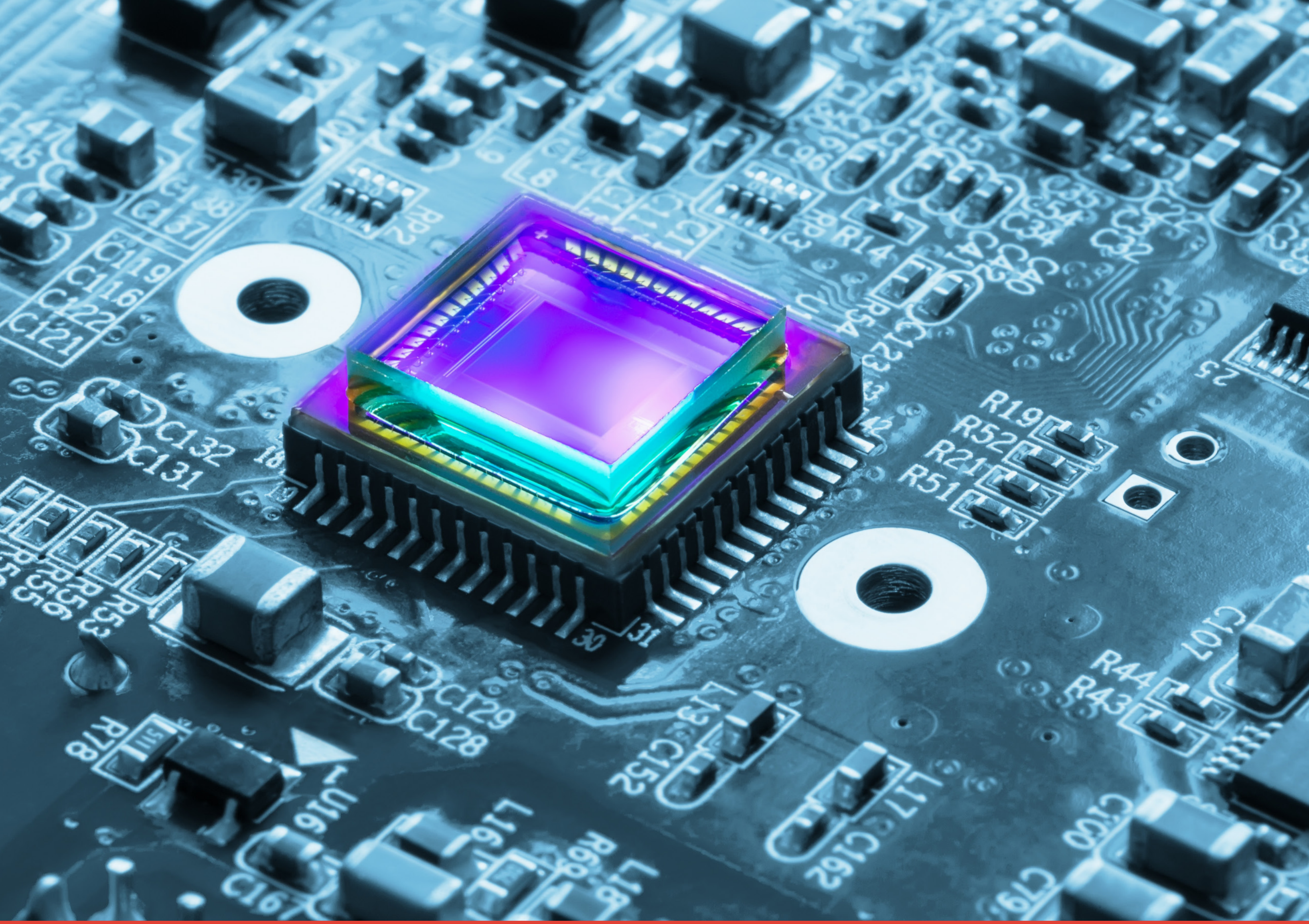

Adhesives for Sensor Applications

Case Studies Based on Publications in Peer Reviewed Scientific Journals and Patents

MASTERBOND®
ADHESIVES | SEALANTS | COATINGS

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Adhesives for Sensor Applications

Epoxy and silicone compounds play a fundamental role in the diverse sensor devices underlying the internet of things (IoT), smart products and advanced systems in a wide range of industry segments. By bonding and protecting sensor components, these compounds help simplify sensor fabrication and ensure continued performance of these devices.

Role in sensor systems

Sensors are the backbone of a digitized society, measuring a broad range of physical characteristics in every type of application from everyday consumer products to mission critical systems in aerospace, automotive, industrial, medical, optical and every other application that relies on smart, sensor-based devices. Sensor manufacturers offer sensors that are able to measure every type of fundamental physical quantity like temperature and pressure as well as dynamic characteristics like acceleration and rotation.

For each type of measurement, product developers can find sensors with the required dynamic range, sensitivity and accuracy. Combined in single packages and modules, highly integrated solutions incorporate multiple sensors with signal conditioning chains, processors and even optical subsystems to support more complex measurement modalities such as biometrics, inertial measurement, and diverse monitoring capabilities. Active chemical biosensors go even further, embedding molecules in a matrix or membrane composed of epoxy resin that immobilizes the molecule without degrading its ability to interact with molecules of interest. In fact, epoxy and silicone compounds play a vital role in sensors of all types.

Whether based on simple junction devices, advanced microelectromechanical systems (MEMS) devices or even biosensing membranes, sensors are expected to deliver accurate data reliably despite rough handling, harsh environments and continued stress from thermal, chemical, or mechanical factors through any combination of adverse operating conditions. Indeed, their performance and longevity depend critically on advanced manufacturing methods that combine multiple materials into precision assemblies. Within these assemblies, epoxy and silicone compounds serve a critical role as adhesives, underfill encapsulants, potting compounds, or conformal coatings needed to stabilize, bond, and protect sensor components during fabrication and continued use in their target applications. In fulfilling their role, these compounds need to support a combination of strict requirements that is unique to every application.

Meeting broad performance and processing needs

Suitable adhesive systems are readily available with characteristics fine-tuned through the use of filler materials that are combined with the base compound in different loading factors. Using different fillers, manufacturers can create adhesive compounds that are optimized for specific combinations of performance characteristics like electrical or thermal conductivity, chemical resistance, and stability as well as processing characteristics like viscosity, work time and cure time.

Other types of specialized epoxy and silicone compounds are designed to ensure compatibility with key standards in medical, aerospace, and other industries. Engineers developing more sophisticated sensors designed for implant or placement on the skin have already taken full advantage of biocompatible adhesives compounds to provide a protective interface between instruments and tissue. These specialized compounds not only provide the necessary thermal and electrical conductivity characteristics but also meet requirements for biocompatibility specified in USP Class VI and ISO10993-5 standards.

Similarly, engineers working on assemblies for aerospace systems or other applications with sensitive electronics can find adhesive compounds that meet ASTM E595 and NASA requirements for low outgassing. Using these compounds helps ensure that optical systems, sensitive electronics or other surfaces remain free from contamination from volatile compounds sometimes exuded by adhesives even after cure.

CASE STUDIES

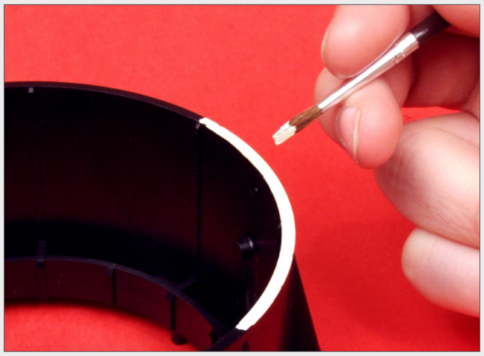
HONEYWELL CORP. - *Bonding MEMS temperature sensors*

Requirements: Thermal conductivity and low CTE

For devices intended for temperature sensing applications, manufacturers can take advantage of available compounds that exhibit the high thermal conductivity needed to avoid compromising measurements. For example, to improve accuracy of temperature measurement, developers at Honeywell International bonded a MEMS temperature sensor directly to an application-specific integrated circuit (ASIC) that generates measurement data from the MEMS device output.[1]

Honeywell's approach eliminates heat dissipation—and compromised temperature measurements—that arise in conventional assemblies that place temperature sensors on the underlying printed circuit board (PCB). Yet, this approach brings its own set of requirements. For Honeywell's design, the bonding compound needed to provide high thermal conductivity and high electrical resistivity to ensure accurate measurements during sensor operations as well as suitable handling characteristics during fabrication. In bonding the sensor and ASIC, the compound needed to exhibit a suitable coefficient of thermal expansion (CTE) to ensure continued bond integrity despite expansion and contraction of the two different substrates with temperature changes. For this assembly design, Honeywell chose Master Bond EP30LTE-LO, which offers the required high thermal conductivity and low CTE.

EP30LTE-LO TWO PART EPOXY



Key Features

EP30LTE-LO is ideal for bonding, coating, sealing and encapsulation applications. It has a low coefficient of thermal expansion and exceptionally low linear shrinkage.

- ✓ Excellent dimensional stability
- ✓ NASA low outgassing approved
- ✓ Low viscosity
- ✓ Electrically insulating and thermally conductive

Performance Properties of EP30LTE-LO

Thermal conductivity, 75°F	8-10 BTU•in/ft²•hr•°F [1.1538 to 1.4423 W/(m•K)]
Viscosity, 75°F	Part A: 35,000-70,000 cps, Part B: 290-500 cps
Volume resistivity, 75°F	$>10^{15}$ ohm-cm
Coefficient of thermal expansion, 75°F	$15\text{-}18 \times 10^{-6}$ in/in/°C
Tensile strength, 75°F	>6,000 psi

REQUEST A TDS for EP30LTE-LO

GL SCIENTIFIC - *Bonding temperature sensors*

Requirements: Thermal conductivity and cryogenic serviceability

While an essential requirement for temperature sensor assemblies, high thermal conductivity can play a vital role in other types of sensor systems. In aerospace and astrophysics applications in particular, both thermal conductivity and cryogenic serviceability can be critical requirements. Engineers at GL Scientific needed to develop a module to house infrared sensor chip arrays to be used in an adaptive optics imager instrument for a telescope.[2]

Among design objectives, the ability to control temperature of the module baseplate and imager focal plane within 0.1 kelvin (K) using a combination of cryogenic and heat cycling to achieve thermal stability. In this design, temperature sensors and heaters would be bonded to the focal plane and baseplate to monitor and control thermal cycling. Consequently, the design required an electrically insulating bonding compound with high thermal conductivity, and ability to withstand thermal cycling down to cryogenic temperatures while maintaining bonding strength as well as thermal and structural stability. Furthermore, the bonding compound needed to reliably form strong bonds with dissimilar materials. In this case, the focal plane was constructed from titanium-zirconium-molybdenum (TZM) and molybdenum and finally plated with gold; the baseplate was constructed from aluminum and nickel plated. For this application, the GL Scientific engineering team selected Master Bond EP37-3FLFAO—an epoxy system with high thermal conductivity, excellent electrical insulation properties, and good physical strength while retaining mechanical flexibility across temperatures ranging from 4K to 250°C.

EP37-3FLFAO TWO PART EPOXY

Key Features

EP37-3FLFAO has superior resistance to vibration, impact, shock and thermal cycling. Low exotherm minimizes the stress on sensitive electronic components.

- ✓ Excellent flowability
- ✓ Cryogenically serviceable down to 4K
- ✓ Electrically insulative
- ✓ Long working life and low exotherm

Performance Properties of EP37-3FLFAO

Thermal conductivity, 75°F	9-10 BTU•in/ft^2•hr•°F [1.30-1.44 W/(m•K)]
Viscosity, 75°F	Part A: 6,000-11,000 cps, Part B: 7,000-12,000 cps
Volume resistivity, 75°F	>10^{15} ohm-cm
Dielectric constant, 75°F, 100Hz	4.9
Coefficient of thermal expansion, 75°F	60-65 x 10^{-6} in/in/°C

REQUEST A TDS for EP37-3FLFAO

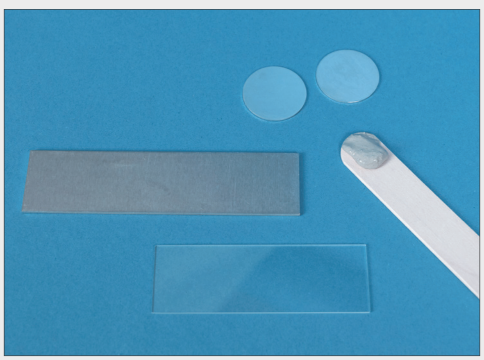
UNIVERSITÀ DI FIRENZE, ITALY - *Bonding dissimilar substrates in pyroelectric sensors*

Requirements: Electrical conductivity and workability

In many applications, sensor fabrication often involves bonding of significantly different materials. For example, the availability of ferroelectric polymer (PVDF, which typically needs to be chemically etched for good adhesion) in thin foils, permits design of specialized pyroelectric sensors. Pyroelectric sensors are highly sensitive to radiated energy across a very broad spectrum ranging from ultraviolet through visible and infrared to millimeter wavelengths. By assembling PVDF foils with substrates in multilayered structures, sensor developers can create highly specialized pyroelectric detectors able to provide accurate laser energy output measurements required for precision instruments. In fabricating sensors based on these flexible foils, however, manufacturers face a challenge in creating a reliable electrical connection between the foil and a PCB or other substrate.

In studying the laser pulse detection capabilities of pyroelectric sensors, researchers at Università di Firenze, Italy, created sensor arrays by bonding PVDF film between two PCBs to create a rigid structure.[3] For this application, the researchers required a conductive bonding compound able to form reliable electrical connections between the film's gold pads and the PCB's copper pads. A further requirement for the bonding compound related directly to the fabrication process. In this case, the researchers used a programmable robot designed to dispense the bonding agent, requiring a compound with consistent viscosity to ensure a uniform flow in building the assembly. Here, the research team selected Master Bond EP21TDCN epoxy for the bonding compound. The research team found that Master Bond EP21TDCN epoxy met both performance and manufacturing requirements, noting that after two years, this bonding system continued to function reliably with no change in performance.

EP21TDCN TWO PART EPOXY



Key Features

Two component nickel conductive epoxy adhesive featuring high peel strength, superior toughness and low volume resistivity.

- ✓ Convenient handling
- ✓ Good electrical conductivity
- ✓ Withstands thermal cycling
- ✓ Bonds well to many substrates

Performance Properties of EP21TDCN

Volume resistivity, 75°F	5-10 ohm-cm
Thermal conductivity, 75°F	11 BTU•in/(ft² •hr•°F) [1.59 W/(m·K)]
T-peel strength, 75°F	15-20 pli
Hardness, 75°F	80-90 Shore D
Service temperature range	-100°F to +275°F [-73°C to +135°C]

REQUEST A TDS for EP21TDCN

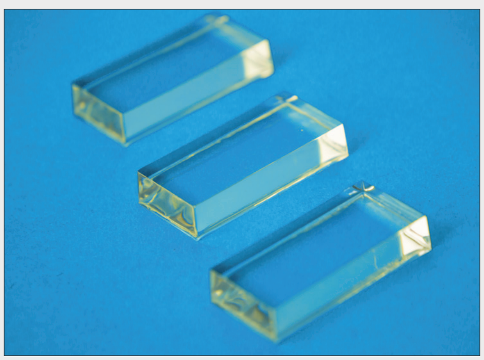
CARNEGIE MELLON UNIVERSITY - *Coating interconnects*

Requirements: Electrical insulation and handling

The specific performance and handling characteristics of a bonding compound can vary dramatically from application to application. Few applications demonstrate the wide range of requirements facing bonding compounds that are found in biochemical or biophysical applications. In a series of experiments, researchers at Carnegie Mellon University (Pittsburgh, PA) used photolithographic techniques to create microscopic electrode arrays designed to measure changes in impedance of cells exposed to various drugs. Because this method can be readily automated, it can help laboratories dramatically speed the throughput of drug screening, providing a critical capability for healthcare.

Because of the sensitivity of this approach, the research team needed to ensure that the measurement signal chain remained free of artifacts that could alter the results. In this case, the team needed a compound able to coat exposed portions of the electrode array to reduce parasitic capacitance that could significantly alter the measurements. At the same time, the compound needed to remain neutral to the biochemical environment to avoid affecting the biological target. For this application, the researchers chose Master Bond EP30HT—an epoxy system with excellent electrical insulation characteristics and superior chemical resistance. Here, the research team used Master Bond EP30HT to coat interconnect about 150 μm away from the electrodes, successfully reducing parasitics between the interconnect and liquid medium bathing the living cells used for this impedance-based bioassay method.

EP30HT TWO PART EPOXY



Key Features

EP30HT features outstanding dimensional stability, excellent chemical resistance and has extremely low shrinkage upon cure. It is a superb electrical insulator and can be used for small encapsulations.

- ✓ Minimal weight gain after 85°F/85% humidity testing for 1,000 hours
- ✓ Conforms to FDA section 175.105 for indirect food applications
- ✓ Cures rigid

Performance Properties of EP30HT

Viscosity, 75°F	Part A: 55,000-110,000 cps, Part B: 250-500 cps
Hardness, 75°F	80-90 Shore D
Coefficient of thermal expansion, 75°F	40-45 x 10^{-6} in/in/°C
Volume resistivity, 75°F	>10^{15} ohm-cm
Service temperature range	-60°F to +400°F [-51°C to +204°C]

REQUEST A TDS for EP30HT

UNIVERSITY OF TENNESSEE - *Sensor encapsulant in prosthetic device*

Requirements: Low viscosity and biocompatibility

Total knee arthroplasty is a widely popular application of joint replacement. The procedure alleviates arthritic knee joint pain by capping the ends of the bones that form the joint and kneecap with metal and plastic. Microcantilever-based sensors are the key to creating an accurate yet computationally efficient data map. Optimizing sensor quantity and size are significant challenges to the success of the application. The sensors must record accurate information without carrying a prohibitive computational cost. The sensors need to be encapsulated with medical grade adhesive to both protect them from damage and to form an appropriate interface between the implanted device and the bone tissue. Researchers tested a few epoxies[5] for suitability of sensor encapsulation to select the most advantaged product to record the optimal amount of data.

Among the epoxies tested, EP30Med proved to be the best choice of the four epoxies evaluated due to several factors: its low viscosity, a non-rapid cure time, and a minimal amount of air bubbles present in the mixed epoxy during the curing process, creating a durable, homogenous consistency. Despite initial challenges due to epoxy shrinkage, the researchers found6 that embedding microcantilever sensors in epoxy is an effective, though labor-intensive, method to create a medical monitoring device suitable for post-operative total knee arthroplasty. They cited EP30Med as the optimal epoxy choice for this application due to its low viscosity and its high-integrity cure.

EP30Med TWO PART EPOXY

Key Features

Forms high strength rigid bonds to a wide variety of substrates including metals, glass, ceramics, wood and many plastics. EP30Med has exceptionally low linear shrinkage upon cure.

- ✓ Room temperature curing
- ✓ FDA CFR 175.105 certified for indirect food contact
- ✓ Superior chemical resistance particularly to sterilants
- ✓ Withstands 1,000 hours 85°C/85% RH

Performance Properties of EP30Med

Viscosity, 75°F	Part A: 900-1,500 cps, Part B: 280-500 cps
Volume resistivity, 75°F	>10^{14} ohm-cm
Tensile lap shear strength, aluminum to aluminum, 75°F	2,600-2,800 psi
Tensile strength, 75°F	8,000-9,000 psi
Service temperature range	-60°F to +250°F [-51°C to +121°C]

REQUEST A TDS for EP30Med

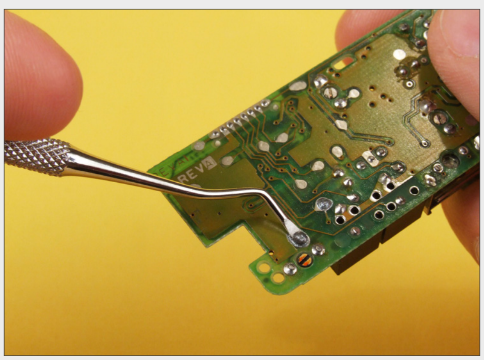
MIT - *Microchannel array for prosthetics*

Requirements: Electrical conductivity and biocompatibility

Recent advances in robotics have been used to improve the functionality and utility of prosthetic devices for persons with amputations (PWA). Despite the advancements, the integration of upper and lower limb prostheses still faces many challenges in enabling truly biomimetic functionality between the user and the prosthetic device.[7] An ideal prosthesis would possess bidirectional neural communication—existing neural signals from the user could be interpretated and sent to the device resulting in actuation while sensors present on the device itself would send signals back to the user's nervous system providing sensory feedback. Long-term efficacy also requires that the device have a high biocompatibility, enable nerve regeneration, and impart limited pathology to the remaining nerve fibers and surrounding tissues. The authors, Maimon et al, sought to devise and test a novel microchannel array with 16-20 channels and assess the extent of nerve regeneration that is critical to the long-term efficacy of these devices.

Master Bond EP3HTSMed, a silver-filled conductive epoxy meeting USP Class VI requirements, was used to secure and seal the electrical connections with the through-holes of the ribbon cable. Pin-grid array (PGA) techniques were used to connect the microchannel array, bond pads and the ribbon cable with all connections being done with Master Bond EP3HTSMed with the final interface being embedded in silicone. In addition to the USP Class VI requirements for biocompatibility, an epoxy system used in this type of application must have a high degree of conductivity to provide a sound electrical connection. Master Bond possesses exceptionally low volume resistivity of <0.001 ohm-cm.

EP3HTSMed ONE PART EPOXY



Key Features

EP3HTSMed's adhesion to metals, glass, ceramics, vulcanized rubbers and many plastics is excellent. The cured adhesive/sealant is a superior electrical and thermal conductor.

- ✓ Single component system; no mixing prior to use
- ✓ Rapid cure schedules at elevated temperatures
- ✓ Broad service temperature range of -60°F to 400°F
- ✓ Thixotropic paste

Performance Properties of EP3HTSMed

Viscosity, 75°F	Thixotropic paste
Volume resistivity, 75°F	<0.001 ohm-cm
Tensile lap shear strength, aluminum to aluminum, 75°F	>1,000 psi
Tensile strength, 75°F	>5,000 psi
Service temperature range	-60°F to 400°F [-51°C to 204°C]

REQUEST A TDS for EP3HTSMed

Sensor trends and adhesive technologies

Sensor technology continues to advance rapidly, keeping pace with advances in material science and manufacturing engineering. Advanced strain sensors based on single-walled carbon tube nanocomposites or highly sensitive heat detectors using the pyroelectric properties of emerging gallium nitride (GaN) devices promise to drive novel applications using these nanosensors to detect subtle phenomena. Other sensor technologies bring similar benefits to a wide range of sensing modalities. Destined to be woven into textiles, painted on surfaces or fabricated with 3D printing methods, new types of sensors will enable development of smart products able to access more comprehensive measurement data. More than ever, these emerging sensors will require adhesive compounds able to meet specific requirements for conductivity, biocompatibility, and manufacturing. As with sensors, new compounds will continue to emerge, using new materials and methods for fillers based on advanced materials such as graphene, carbon nanotubes, nano-silicates, and more.

DISCUSS YOUR APPLICATION

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