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Solving 5G Ecosystem Challenges with Silicones

Silicones have an attractive balance of properties, support high-volume manufacturing, and enable high-speed connections. They solve challenges with adhesion, encapsulation, coating, and EMI shielding.

The 5G ecosystem includes consumer devices, telecommunications equipment, cloud computing, and data centers. Across this ecosystem, new designs are disrupting existing technologies because 5G's greater power densities produce increased levels of heat *(Fig. 1)*. In addition to thermal management, electronic designers need shielding against electromagnetic interference (EMI) due to crosstalk between numerous adjacent circuits. Environmental sealing also is required because many 5G devices and equipment are exposed to outdoor weather conditions.

1. Silicones can protect data-center electronics from 5G's higher heat density.

For electronic designers, the challenges include adhesion, encapsulation, coating, and molding. Materials that can meet 5G's tough requirements are in demand, but not all chemistries have the right balance of properties.

Material Selection and Electronics Protection

Many available protective materials provide advantages that come with significant tradeoffs. For example, acrylics cure rapidly for efficient electronic assembly but soften at high temperatures. Urethanes and polyurethanes are very hard and resist mechanical wear; however, these materials do not provide sufficient relief from the stresses caused by rapid and uneven heating and cooling.

Then there are epoxies that can resist humidity but are more prone to cracking, potentially causing adhesives, sealants, and coatings to fail. Parylene is chemically inert but supports only limited throughputs during electronic assembly. That's a limitation for mass-produced products like smartphones and laptops.

By contrast, silicones have an attractive balance of properties and support high-volume manufacturing. These elastomers resist moisture, chemicals, and contamination while remaining soft and flexible. Their hydrolytic stability is especially important because 5G will mean installing more towers, base stations, and transmitters in locations with high humidity, rain, or snow *(Fig. 2)*.

Importantly, silicones can resist 5G's higher temperatures while providing longer-lasting heat resistance without a significant loss in properties. With their low modulus, silicones also can relieve some of the stress that results when materials expand and contract at varying rates because of their different coefficients of thermal expansion (CTEs).

In addition, silicone resins provide good adhesion to many substrates, often without the use of a primer for greater production efficiency. On top of that, silicone adhesives, sealants, coatings, encapsulants, and EMI shielding are able to support automated dispensing and more efficient curing systems. Silicones that cure at room temperature can eliminate the need for ovens, reducing energy expenses and supporting larger sustainability initiatives.

Silicone resins with low levels of volatile organic compounds (VOCs) also can meet regulatory requirements and address environmental health and safety (EHS) concerns. From 5G smartphones to advanced driver-assistance systems (ADAS), these elastomers support consumer devices.

2. Silicone sealants and adhesives are used with antenna covers in 5G networks.

5G Consumer Electronics

Smartphone designers specify silicones because these materials reliably dissipate chip heat and have anti-cracking, stress-relieving, and shock-damping properties to protect against wear and tear. Silicones also combine resistance to high and low temperatures with low cure shrinkage, an important consideration for smartphone displays where air gaps between the display panel and cover require waterproof sealing.

With their excellent optical density, some silicones are used with light shields to help block unwanted illumination *(Fig. 3)*. Other silicones are employed with light guides because they combine high luminous transmittance, low haze, and low scatter with resistance to ultraviolet (UV) light. Silicone adhesives for flexible, foldable displays can be applied directly to thin metal surfaces and form an elastic layer, or inner hinge, that helps to protect the display from damage caused by folding and unfolding.

Other silicone applications target smartphone accessories and 5G smartwatches. For example, silicone thermal adhesives are used inside smartphone chargers, which tend to quickly heat up. Reliable bonding for waterproof smartphone connectors is in demand, too.

With silicones, bonding and sealing for cable connectors can combine primer-less adhesion with instant green strength for better adhesion and good reworkability for less waste. These features are important for 5G smartwatches—compact devices with chips that produce significant heat and may require rework or removal of residues during product assembly. For environmental sealing, high-consistency rubber (HCR) that's platinum-catalyzed arrives ready-to-use. Liquid silicone rubber (LSR) for smartwatch bands supports high-volume molding and has excellent processing performance as well as short cycle times.

Other 5G devices that can benefit from the use of silicones are true wireless stereo (TWS) earphones. They need charger protection that meets UL 746C for ignition characteristics and UL 94 V-0 for vertical burning. Because they're worn outdoors and compressed repeatedly, TWS earphones also require environmental sealing with resistance to compression set.

Designers of virtual-reality and augmented-reality (VR/AR) products like how silicones are lighter than glass and can have high luminous transmittance and low haze and scatter for use with optically clear lenses. In drones, silicone thermal gels dissipate heat without post-cure oil contamination. Unmanned vehicles can utilize silicone adhesives that combine EMI shielding with good mechanical properties for strong bonds to a variety of substrates.

3. Optically clear silicones support electronic displays that are bright, sharp, and rugged.

4. Silicone adhesives that provide EMI shielding are often applied in automotive safety systems.

The 5G consumer electronics market includes advanced driver-assistance systems (ADAS) for automobiles. Silicone conformal coatings have the abrasion resistance and toughness that's needed to protect rigid or flexible printed circuit boards (PCBs) from scratches. When EMI-shielding adhesives are required, electrically conductive silicones support flexible joints and have high elongation to avoid breaking *(Fig. 4)*. ADAS designers also can choose silicone adhesives for assembling larger modules.

Silicone sealants provide module-level protection. Component-level solutions are used in electric-vehicle (EV) battery packs and ADAS sensors for light detection and ranging (LiDAR) and radar. Because of their good dielectric properties, silicone pottants help protect connectors, power suppliers, sensors, transformers, amplifiers, and high-voltage resistance packs.

Inside of computer laptops, silicones are used at the PCB level to help dissipate high heat from central processing units (CPUs) and graphics processing units (GPUs). They're also used with other board-mounted electronics and heat sinks. Silicone thermal greases support lidless die designs for closer component packaging and resist pump-out that can impede dispensing.

Silicone adhesives for metal laptop frames have a viscosity that makes it easy to apply them to the etched areas of thin stainless-steel sheets used beneath foldable displays. Molding with liquid silicone rubber (LSR) produces keypad domes with longer fatigue life. Through compression molding or vacuum lamination, silicone encapsulants protect a laptop's light-emitting diodes (LEDs) and resist both high heat and scratching.

Ultimately, 5G's greater reliability may be even more important than its higher speed and larger capacity. To become the network of everything, 5G requires a level of service that can support always-on technologies ranging from the safety systems in self-driving cars to seamless video downloads from flexible, foldable computers.

With consumer electronics, silicones already support greater reliability at more than just the device level. From thermal management and EMI shielding to adhesion, coating, and encapsulation, silicones also protect the sensitive electronics that form the backbone of cellphone and data carrier networks.

Carrier Networks and Heat Dissipation

Millimeter-wave (mmWave) networks for 5G-enabled devices and equipment need to support high-frequency communications plus 2G, 3G, and 4G mobile-phone services at 800 to 2100 MHz. As more 5G networks become available, demand for 3.3- to 5.0-GHz communications will increase as existing 5G-enabled devices begin to use previously unavailable features.

mmWave networks will provide more bandwidth, but 5G's higher data rates are offset by its limited connection range. Consequently, carrier networks will need many small cells or mini base stations to ensure coverage. Furthermore, carrier networks will require large cells or macro base stations to provide basic broad coverage using either 4G or 5G.

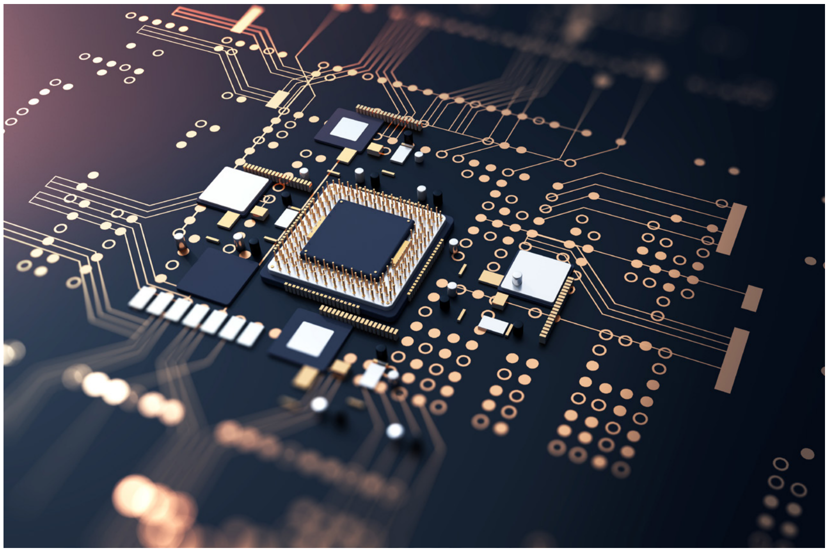
In addition, carrier networks must meet the demands of digital beamforming and massive MIMO. Unlike traditional multiple-input, multiple-output (MIMO), massive MIMO adds many antennas to a base station. Because these antennas may have up to 256 channels, it's especially important for designers to use smaller components and consider both energy efficiency and thermal management. With high levels of semiconductor integration, a single module may contain a transceiver, power amplifiers (PAs), filter, and antennas.

Today, a common design approach is to use a low-loss substrate combined with a flip-chip device and on-module EMI shielding. Silicones filled with metal or metal-coated particles can provide reliable shielding along with dependable electrical conductivity.

The architecture of carrier networks presents another design challenge. With their large antenna arrays and remote radio heads (RRHs), active antenna units (AAUs) have large power outputs that generate significant amounts of heat. Baseband units (BBUs), centralized units (CUs), and distributed units (DUs) also require effective heat dissipation. For electronic designers, more optical module connections and more server demands must be considered, too. Silicones are commonly used to coat optical fibers, but these elastomers have many other optical applications.

In optical transceivers, for example, silicone thermal gels are used to dissipate potentially damaging heat. As thermal-management materials, they transfer heat from the transceiver's core components to a metal shelter that serves as a heat sink.

Typically, the transceiver's heat-generating components include a microcontroller (MCU), transmitter optical subassembly (TOSA), tunable laser, integrated circuit (IC), and signal processor. During module assembly, silicone adhesives are able to combine strong bonds with both reliable EMI shielding and controlled levels of VOCs. Silicone encapsulants for optical splitters can resist the formation of microcracks caused by environmental stresses and that propagate over time.



5. Silicone conformal coatings help protect PCBs from 5G's higher chip heat.

Radio Access Networks and Core Networks

Designers of radio access networks (RANs) also must overcome thermal management, EMI shielding, and other reliability and performance challenges. In addition to providing dependable access, RANs need to coordinate network resources among many wireless devices regardless of frequency.

At mmWave frequencies, 5G's data-carrying capacity is extreme. At lower frequencies, 5G still provides significantly higher data rates than 4G. WiGig, a type of wireless local area network (WAN) that uses mmWave frequencies, offers significantly greater speeds than Wi-Fi but will require many small cells. With the proliferation of so many mini base stations, electronics manufacturers will need materials that support high-volume assembly.

The 5G AAUs for RANs have significantly greater power outputs than with 3G and 4G equipment. Silicone thermal greases can provide effective heat dissipation, and two-part curable silicones gels are a good choice for both AAUs and remote-radio-unit (RRU) power modules. For EMI shielding, softer silicones are used in gasketing because of their compressibility.

Silicone thermal gels with high thermal conductivity (TC) provide thermal management for base stations. They're used with power-supply rectifier modules, power amplifiers, the RRU, or an AAU chipset, and between BBU chips and the heat sink. Silicone sealants and adhesives are applied to antenna covers, and silicone conformal coatings are used with AAU PCBs *(Fig. 5)*.

The 5G core network uses a cloud-aligned, service-based architecture (SBA) that spans all functions and services, including security. In terms of design considerations, a core network is characterized by network slicing, software-defined networking (SDN), network function visualization (NFV), and multi-access edge computing (MEC).

With network slicing, radio resources are allocated across slices with specific quality-of-service (QoS) characteristics. NFV virtualizes core network functions to support different slices, such as a smartphone and car. To achieve low latency and cost savings, some functions of the core network are deployed closer to the MEC.

Silicone thermal greases are used with MEC equipment and servers. These heat-dissipating greases are also applied in the design of lidless CPUs and GPUs. Reworkable thermal gels for Ethernet switches and routers can use bare dies to support package size reductions and improve power management. The benefits of bare dies include more reliable operation at extreme temperatures and greater mechanical ruggedness. Silicones are also employed with switch-on-a-chip (SOC) technology for faster speeds.

The Evolving 5G Ecosystem

As the 5G ecosystem continues to evolve and expand, silicone elastomers will play an even larger supporting role. Electronic designers have a choice of materials, but silicones provide an attractive balance of properties and can address challenges, such as thermal management, which are particularly important to successful 5G deployments. By choosing the right partner, designers and electronic manufacturers can find the right solutions as they continue to grow with the larger 5G ecosystem.

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