Smart Technology for Wearable Electronics:

TPSiV® Thermoplastic Elastomers

Mike Rabideau
Gifford Shearer
Ted Hays
Michael Zhang
Yann Gradelet
Sylvain Boucard

Dow Corning Corporation, USA
Smart Technology for Wearable Electronics:

TPSiV® Thermoplastic Elastomers

Mike Rabideau
Gifford Shearer
Ted Hays
Michael Zhang
Yann Gradelet
Sylvain Boucard

Dow Corning Corporation

Table of Contents

TPSiV® materials for wearable devices .....................3
Thermoplastic silicone vulcanizate .........................4
TPSiV® product range ....................................4
Performance comparisons and testing ......................5
Other silicon-based solutions for wearables ...............7
Collaboration drives innovation .............................7
How Can We Help You Today? .............................8
Wearable electronics are one of the most compelling new technologies that present opportunities for added connectivity, enhanced productivity and enriched lifestyles. In many ways, these devices are an extension of the human body, expanding our capabilities and enabling us to communicate and interact with our environment and with others.

The established and emerging wearable technologies are being led by evolutionary devices that can spring off wireless networking and mobile computing to provide unique new human information interfaces or diagnostic functions. They also include disruptive, radically new technologies for apparel and textiles. Allied devices could involve skin-contact and portable or carried items. There are camera goggles, glasses with augmented reality, finger-worn scanners, sleep and heart monitors, x-y-z positional sensors, proximity sensors, child and pet trackers, wrist phones, UV-exposure detectors, and watches or wristbands that double as computers. Form, function and style are integrated for wearable electronics devices in glamor/fashion, entertainment, lifestyle computing, fitness and wellness, healthcare and medical, safety/security, and even industrial and military applications.

What are priority requirements of a typical wearable electronics device? First and foremost is reliability. The device must be able to perform its designed function or purpose – under widely diverse consumer use conditions – throughout its expected lifetime. While advanced electronics are key for functional reliability, device packaging also is a most critical consideration for securing long-term durability, toughness, human lifestyle compatibility, appearance, cleanliness and sensory comfort. These devices are getting thinner, lighter, more flexible, more fashion-conscious, more intuitive and livelier – demanding new thinking on fit-for-purpose electronics assembly materials.

**TPSiV® materials for wearable devices**

Drawing on its deep experience in the electronics industry and expertise in materials development, Dow Corning Corporation – a global leader in silicones, silicon-based technology and innovation – has a selection of specialty thermoplastic elastomer (TPE) materials that offer a combination of unique performance properties for wearable electronics. The hybrid materials are TPSiV® thermoplastic elastomers, which are proven to provide the nontacky, soft-touch feel of silicones along with the technical advantages of thermoplastic polymers.

Collaborating with a number of leading developers of wearable technologies, Dow Corning is qualifying TPSiV® thermoplastic elastomers for increasing use in wearable devices. These silicone-enhanced TPEs are part of Dow Corning’s extensive portfolio of high-performance material solutions that can help ensure device functionality and reliability. Other proven silicon-based innovations include semiconductor assembly and packaging materials, adhesives and sealants, medical-grade elastomers, potting and encapsulating materials, thermal management materials, and functional surface coatings for displays.

This white paper describes the basic science behind TPSiV® thermoplastic elastomers, highlights their key design-enabling features for portable and wearable electronics, identifies the current product range and material properties for selected requirements, details comparative performance testing, and notes other silicon-based solutions and ongoing innovation efforts that can contribute to the success of wearable electronics.

<table>
<thead>
<tr>
<th>Wearable Electronics Applications</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Glamour/Fashion, Communication</td>
<td>Lighting displays, earbuds, Bluetooth jewelry, headsets</td>
</tr>
<tr>
<td>Lifestyle Computing</td>
<td>Smartwatches, glasses, interactive gaming, learning</td>
</tr>
<tr>
<td>Sport, Fitness</td>
<td>Bio-activity monitors, GPS, smart shoes, apparel</td>
</tr>
<tr>
<td>Wellness</td>
<td>Sensor bands, interactive belts, bracelets, monitors</td>
</tr>
<tr>
<td>Medical</td>
<td>Biofeedback patches, drug delivery, sensors</td>
</tr>
<tr>
<td>Security/Safety</td>
<td>Handheld or worn scanners, GPS child/pet trackers</td>
</tr>
<tr>
<td>Industrial/Military</td>
<td>Location sensors, trackers, vision aids, wound detection*</td>
</tr>
</tbody>
</table>

**Thermoplastic silicone vulcanizate**

*TPSiV®* thermoplastic elastomers from Dow Corning involve a patented thermoplastic silicone vulcanizate, which offers a unique combination of properties and benefits from a hybrid thermoplastic polyurethane (TPU) and a fully crosslinked silicone rubber. Containing no plasticizers, *TPSiV®* materials have a very low odor and offer a nontacky feel that resists dirt pickup. They are available in customized grades with varying hardness levels and specialized, application-matched attributes.

The material technology combines silicone softness and UV/chemical resistance with the durability and processing ease of a thermoplastic. The dispersion of the silicone internal phase is produced by dynamic “vulcanization” or crosslinking of silicone polymers within the thermoplastic phase, resulting in a stable droplet-type morphology. The materials are supplied in ready-to-use pellet form for typical thermoplastic processes such as injection molding or extrusion. They also can be easily overmolded or co-molded onto different plastic substrates.

In various development projects for wearable devices, design-enabling *TPSiV®* thermoplastic elastomers are showing several significant application advantages. Silicone adds a soft feel and good environmental resistance to the typical TPU features of strength, strong bonding, processing ease and recyclability. The silicone reduces surface coefficient of friction while also adding better temperature stability without causing TPU stickiness. Precise *TPSiV®* formulations can meet a range of user specifications to provide:

- Performance properties such as abrasion resistance, different hardness levels, high mechanical strength, low compression set and good hydrolytic resistance
- Excellent stain resistance; skin contact safety; and silky, soft-touch haptic characteristics
- Specialty colors with very good UV color stability and color retention over time
- Easy overmolding with excellent bonding to a variety of substrates, including polycarbonates and ABS
- Laser-etching capabilities for distinctive features

**TPSiV® product range**

With durometer hardnesses ranging from Shore A 50 to 80, *TPSiV®* thermoplastic elastomers include the:

- **TPSiV® 4000 Series** – With excellent stability and good resistance to ultraviolet (UV) light, these materials can be used in applications requiring good aesthetics and environmental resistance, such as in glamour, communications and lifestyle wearable devices.

- **TPSiV® 4100 Series** – With superior compression set and mechanical strength properties, these materials can be suitable for wearable devices that will be exposed to rough handling or other harsh conditions, such as in sport, fitness and possibly industrial applications.

- **TPSiV® 4200 Series** – These materials provide product options for general-purpose uses that require superior chemical resistance and long-term durability, such as wearable devices for sport, health and wellness applications.

In addition to these established families of *TPSiV®* thermoplastic elastomers, Dow Corning also is developing a new “SR” product offering optimized scratch and stain resistance, high mechanical strength, flexibility (but resistant to stretching), and excellent durability. Customer sampling is available for:

- **TPSiV® 4200-75A SR elastomer** – This enhanced *TPSiV®* material provides the highest mechanical performance for black or dark-colored devices not needing UV resistance.
Performance comparisons and testing
Selective competitive comparisons and performance testing have been conducted to illustrate certain key advantages of TPSiV® thermoplastic elastomers for wearable electronics.

Softness vs. Feel: Plasticized TPEs can exhibit a sticky, tacky feel with limited softness capabilities, while a TPU resin might provide a relatively hard and dry feeling; the best combination of softness and a silky feel can be provided by TPSiV® thermoplastic elastomers. Some high-hardness polyurethane (PU) coatings can impart a silky feel (often called “soft-touch paint”). Liquid silicone rubber also can achieve a silky feel when coated. However, coating processes with polyurethanes or liquid silicones can be less efficient than molding or extruding a TPSiV® thermoplastic material. This is important, especially considering the high-volume production requirements of wearable electronic devices.

![Soft-feel performance of TPSiV®](image)

Prolonged Skin Contact Testing:
Selected TPSiV® TPEs have been shown to be nonirritating and nonsensitizing in skin contact applications, validating customer confidence in these materials for use in wearable electronics devices. Independent testing by certified laboratories was conducted according to United States Pharmacopeia’s (USP) General Chapter <88>, Biological Reactivity protocol, and ISO 10993-10 requirements.

The in vivo USP testing demonstrated that the specific TPSiV® elastomers were not cytotoxic, showed no indication of systemic toxicity and did not produce skin irritation. Additional ISO testing provided further evidence that the TPSiV® elastomers were not skin sensitizers.

<table>
<thead>
<tr>
<th>TPSiV® TPE Skin Contact Testing</th>
<th>Guideline/Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class V</strong></td>
<td>USP &lt;88&gt; Biological Reactivity</td>
</tr>
<tr>
<td>Intracutaneous reactivity</td>
<td>Determines biological response to four different extracts of article</td>
</tr>
<tr>
<td>Acute systemic toxicity</td>
<td>ISO 10993-5 Determines if article or extracts will cause cell death</td>
</tr>
<tr>
<td>Cytotoxicity</td>
<td>ISO 10993-10 (Sensitization test – Buehler method) Determines if article or extracts will elicit an allergic response</td>
</tr>
<tr>
<td>Skin sensitization (direct and extract)</td>
<td>ISO 10993-10 (Sensitization test – Buehler method) Determines if article or extracts will elicit an allergic response</td>
</tr>
</tbody>
</table>
Perceptual Mapping: Another relative comparison can be made involving important material attributes. TPSiV® 4000-60A TPE easily outperforms bondable TPV and a bondable TPU alloy in terms of tear strength, compression set, adhesion to PC, abrasion resistance, tensile strength and oil resistance.

Optimized “SR” TPSiV® Performance: Tests on optimized TPSiV® “SR” thermoplastic elastomers verified their enhanced durability with exceptional resistance to scratching. Using a well-known test method adopted from the automotive industry, the scratch visibility of TPSiV® 4200-75A SR TPE is significantly improved compared to standard TPSiV® TPEs. Further improvements in the area of color stability and improved stain resistance also are currently underway.

The new TPSiV® “SR” materials are well-suited to meet the demands and challenges of applications such as smartwatch bands and fitness- and wellness-tracking device straps. These unique TPEs offer a combination of soft, silky feel for comfortable wearing; toughness; durability; and resistance to various usage and environmental conditions and exposures.
Other silicon-based solutions for wearables

As a world-class materials technology developer, Dow Corning provides an extensive selection of electronics solutions for the wearables market. In addition to TPSiV® thermoplastic elastomers, three other silicon-based design materials are especially useful for wearable device manufacturing and assembly.

Liquid silicone rubber (LSR) elastomers provide excellent stretchability and elasticity in a range of durometer hardnesses for injection-molded devices and seals or for soft-touch overmolding applications. The LSRs can be transparent for high clarity or pigmented to custom colors. Their low viscosity promotes use in molding ultrathin membranes as well as complex shapes. Some of the LSR options are FDA-compliant for food contact, while specific medical or healthcare grades can offer increasing levels of medical protocol certifications. Dow Corning® QP1 LSRs are especially suited for short-term healthcare applications such as inserts, sensor pads, insulin pumps and implants.

Functional surface coatings can ensure “easy-to-clean” display glass and panel treatments. Chemical surface modification is achieved with spraying. Proven effective in handheld devices, the strong covalent bonding with increased hydrophobicity provides a smooth, slippery feel; enhanced resistance to sweat; and lasting good looks, with reduced fingerprinting, stains, abrasion, and dust and dirt attraction.

Silicone hot-melt adhesives are another emerging Dow Corning technology that can offer advantages for wearables design and development. Currently available for customer sampling, these innovative materials can provide strong, primerless adhesion on most common plastics and metals. Offering instant green strength and fast-curing with atmospheric moisture, they can form a flexible, water- and weather-resistant adhesive seal that can be easily reworked if needed.

Collaboration drives innovation

Looking ahead, the market for wearable electronics is expected to multiply many times over versus its present-day size, value and range of innovative devices. With in-depth experience, application expertise and global technical support, Dow Corning is ready to meet critical market trends, key design challenges and consumer “must-haves.” Working together in close collaboration with market leaders, Dow Corning is focused on continuing to innovate and enhance the performance of its TPSiV® thermoplastic elastomers, along with its other solutions for advanced wearable electronics.

New technologies are being commercialized at select customers, and these include TPSiV® elastomers with optimized scratch and stain resistance, more durability, and color stability. At the same time, continued developmental work pursues even more enhanced haptics – discovery initiatives aimed at improving characteristics such as feel, wearability and overall human-device interface comfort. Enhanced processing ease and economics, along with weight optimization for selected applications, are additional materials development goals.

At Dow Corning, patented TPSiV® thermoplastic elastomers are smart technology to help meet the requirements of wearable electronics. And, liquid silicone elastomers, functional surface coatings and new hot-melt adhesives are additional innovative solutions for the dynamically changing range of advanced devices and interactive applications.
How Can We Help You Today?

Tell us about your performance, design and manufacturing challenges. Let us put our silicon-based materials expertise, application knowledge and processing experience to work for you.

For more information about our materials and capabilities, visit dowcorning.com.

To discuss how we could work together to meet your specific needs, email electronics@dowcorning.com or go to dowcorning.com/ContactUs for a contact close to your location. Dow Corning has customer service teams, science and technology centers, application support teams, sales offices, and manufacturing sites around the globe.