MATERIALS FOR ADVANCED PHOTOVOLTAICS
LOW TEMPERATURE MATERIALS FOR THE NEXT GENERATION OF PHOTOVOLTAICS
# Introduction

**Henkel in Solar**

- Advanced Energy Solar Applications ................................................................. 3
- Sustainability ....................................................................................................... 3

**Electrically Conductive Adhesives**

- Electrically Conductive Adhesives Technology Leader ........................................... 5
- ECAs Custom Designed for Photovoltaics ........................................................... 6
- Technical Consultation .......................................................................................... 7
- Product Properties ................................................................................................ 8

**LOCTITE ABLESTIK ICP 8000 Series**

- Leading the Next Generation of Photovoltaic Module Design .............................. 9

**Back Contact Cells**

- Metal Wrap Through (MWT) and Interdigitated Back Contact (IBC) ....................... 10
- Heterojunction (HJT) and Third-Generation Photovoltaics ...................................... 11
- Building Integrated Photovoltaics (BIPV) ............................................................. 12
- Product Properties ................................................................................................ 13

**Solder** .................................................................................................................. 15

- Solder Paste ......................................................................................................... 16
- Solder Paste ......................................................................................................... 17
- Solder Wires ....................................................................................................... 18
- Henkel Process Capabilities ................................................................................ 19
At Henkel, we know that materials innovation is a primary catalyst for the widespread adoption of Renewable Energy. As the leading innovator of electrically conductive adhesives (ECAs), low temperature conductive pastes, printed inks for BIPV and third-generation PV, as well as novel solders and encapsulants, Henkel is facilitating the manufacture of next-generation solar technologies with the lowest total cost of ownership and lowest levelized cost of energy (LCOE).

Helping solar specialists deliver profitable results is at the core of Henkel’s development efforts, as our customers’ profitability is critical for the future of PV.

Leadership in sustainability is one of Henkel’s corporate values and our ambition is to achieve more with less. This means we create more value for our customers and consumers, for the communities we operate in, and for our company—at a reduced environmental footprint.

**FACTOR 3.**
www.sustainabilityreport.henkel.com

Our 20-year goal, set in 2010, is to triple the value we create for the footprint made by our operations, products and services by the year 2030. We call this ambition Factor 3— to become three times more efficient.
Sustainability at Henkel

Achievements

In 2017, we made significant progress toward the achievement of these interim targets (base year 2010):
**Electrically Conductive Adhesives Technology Leader**

Since inventing electrically conductive adhesives (ECAs) in the 1950’s, Henkel’s dominance in ECA innovation and global market share have remained unmatched. Our broad understanding of material formulation and in-use behavior has led to the development of over 300 commercial ECA products.

Highly-customized ECAs that are fit for purpose, combined with our expertise in the chemistry nuances of all ECA chemistry platforms including Acrylates, Epoxies, Silicones, Bismalimides and Hybrids; our customers realize success in the design, manufacture and performance of advanced photovoltaic (PV) systems.

In the solar market, Henkel’s comprehensive ECA toolbox is enabling the delivery of next-generation solar cell and module designs that are more efficient, more reliable and cost-effective.

**300+ Commercial ECA’s in 8 Chemistry Families**
Prioritizing performance, processability and cost as measured by $/W, Henkel’s portfolio of customized ECAs for solar applications deliver:

- **Lower Costs** – $0.005/W – $0.02/W ECA cost per panel
- **High Throughput** – 200 mm/sec. application speeds for all common application methods, full cure in under 10 sec.
- **High Yield** – High precision of alignment with < 300 µm deposition width in production settings
- **Expert Technical Support** – Loctite ECAs are supported by world-leading ECA engineering staff with open testing and characterization labs in all global regions
- **Reliability** – 100% silver solution ensures bankability, eliminating both high-volume production challenges and warranty risks of using copper-containing ECA’s
- **Optimization** – Customized material flexibility, adhesion, substrate compatibility, processing and curing mechanisms for any design requirement
- **Broad Material Selection** – Comprehensive range of Epoxy, Acrylate, Silicone and Hybrid solutions makes Henkel distinct in our ability to optimize ECAs specifically for each application
- **Quality Assurance** – State-of-the-art quality systems customized for ECA production
- **Fast and Flexible** – Solar ECA Production and R&D in all regions
- **Global Supply Chain** – End-to-end international compliance and global presence with employees in 120 countries removes regulatory challenges and concerns regarding frozen goods
Technical Consultation
Ensuring Productivity and Cost Targets are Met

For projects that demand a level of support beyond the boundaries of standard technical service, Henkel can provide complete engineering services. Utilizing state-of-the-art test labs in Europe and Asia, Henkel:

- Co-designs ECA materials and Processes – Supports testing and characterization work to validate and optimize production lines
- Formulates products to align with specific equipment sets and customer requirements – Engineering teams partner with customer technical specialists to collaboratively optimize materials and manufacturing processes
- Offers full-time production line support to ensure our mutual success
## ECA Product Properties

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Key Attributes</th>
<th>Tensile Lap Shear Strength (N/mm²)</th>
<th>Volume Resistivity (Ω • cm)</th>
<th>Glass Transition Temperature, $T_g$ (°C)</th>
<th>Storage Modulus, 25°C (Mpa)</th>
<th>Cure Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acrylate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE ABLESTIK CA 3556HF</td>
<td>Very flexible, snap cure, high adhesion applicable for print and dispense speeds at &gt; 150 mm/sec.</td>
<td>12</td>
<td>2.5 E-03</td>
<td>-20</td>
<td>800</td>
<td>&lt; 30 sec cure at 120°C, &lt; 10 sec. cure at 150°C</td>
</tr>
<tr>
<td>LOCTITE ABLESTIK ICP 8118</td>
<td>Low silver, jet, auger and time/pressure dispensable, snap cure with application speeds &gt; 200 mm/sec.</td>
<td>11</td>
<td>1.1 E-03</td>
<td>-20</td>
<td>300</td>
<td>&lt; 30 sec cure at 120°C, &lt; 10 sec. cure at 150°C</td>
</tr>
<tr>
<td>LOCTITE ABLESTIK ICP 8282</td>
<td>Low silver, screen and stencil printable snap cure with application speeds &gt; 250 mm/sec.</td>
<td>10</td>
<td>1.1 E-03</td>
<td>-20</td>
<td>300</td>
<td>&lt; 30 sec cure at 120°C, &lt; 10 sec. cure at 150°C</td>
</tr>
<tr>
<td>LOCTITE ABLESTIK ICP 8311</td>
<td>Sn and SnPb compatible, very stable contact resistance on non-noble metallization with print and dispense speeds above 180 mm/sec.</td>
<td>11.5</td>
<td>3.4 E-04</td>
<td>-20</td>
<td>200</td>
<td>&lt; 30 sec cure at 120°C, &lt; 10 sec. cure at 150°C</td>
</tr>
<tr>
<td><strong>Epoxy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE ABLESTIK CE 3103WLV</td>
<td>Very stable electrical performance and high adhesion on Ag, Sn, SnPb and Cu. Dispensable version.</td>
<td>13</td>
<td>8.0 E-04</td>
<td>114</td>
<td>4,500</td>
<td>&lt; 90 sec cure at 180°C</td>
</tr>
<tr>
<td>LOCTITE ABLESTIK CE 3104WXL</td>
<td>Very stable electrical performance and high adhesion on Ag, Sn, SnPb and Cu. Stencil and screen printable version.</td>
<td>9</td>
<td>7.0 E-04</td>
<td>114</td>
<td>4,500</td>
<td>&lt; 90 sec cure at 180°C</td>
</tr>
<tr>
<td>LOCTITE ABLESTIK 2030SC</td>
<td>Low stress, snap curable designed for high speed production applications.</td>
<td>2.7</td>
<td>2.0 E-04</td>
<td>28</td>
<td>3,300</td>
<td>&lt; 30 sec cure at 120°C, &lt; 10 sec. cure at 150°C</td>
</tr>
<tr>
<td><strong>Silicone</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE ABLESTIK ICP 4001</td>
<td>Good conductivity, low temperature cure and outstanding elongation performance.</td>
<td>&gt;1.7</td>
<td>4.0 E-04</td>
<td>-50</td>
<td>40</td>
<td>Lamination cure</td>
</tr>
<tr>
<td>LOCTITE ABLESTIK ICP 4015</td>
<td>Excellent conductivity, low temperature cure and outstanding elongation performance.</td>
<td>&gt;1.5</td>
<td>7.0 E-04</td>
<td>-50</td>
<td>40</td>
<td>Lamination cure</td>
</tr>
</tbody>
</table>
LOCTITE ABLESTIK ICP 8000 Series
Leading the Next Generation of Photovoltaic Module Design

Cell Interconnect Ribbon Bonding

- Enabling reliable tabbing with wafer thicknesses below 160 µm
- Designed for both Ag and Sn and SnPb ribbon
- $0.007/W – $0.02/W
- 1.2 N/mm+ peel strength on Ag, Sn and SnPb
- 200+ mm/sec. print speeds
- Fully cured before lamination improving throughput, in-line testing and yield
- < 30 sec. cure at 120°C, < 10 sec. cure at 150°C
- Compatibility with Heterojunction and third-generation cell architectures

Shingled Solar Modules

Enabled by Henkel’s Loctite Ablestik ICP 8000 series electrically conductive adhesives, shingled solar modules are the latest c-Si cell connection innovation, delivering better performance and reduced material consumption versus alternative designs.

- $0.005W – $0.018/W
- 200+ mm/sec. dispense and print speeds
- < 30 sec. cure at 120°C, < 10 sec. cure at 150°C
- Optimized on equipment vendor’s tool
- Complete Engineering Guides for all application methods
**Back Contact Cells**

**Metal Wrap Through (MWT) and Interdigitated Back Contact (IBC)**

Henkel began custom designing ECA’s for MWT designs in 2011. We have a suite of low cost ECA products tailored to both jet dispense and screen printing processes.

**Metal Wrap Through (MWT)**

- Screen, stencil printing or jetting with consistent dots and high planarity
- Highly flexible with high stress absorption
- Low and stable contact resistance on Copper

**Interdigitated Back Contact (IBC)**

- Low temperature, low-cost SnBiAg solder paste
- Low-cost solder paste formulated with SAC 0307
- Jettable solder paste
- Busbar metallization paste

**Thin Film Solar Modules**

The performance and reliability of Henkel’s thin film ECAs have been proven in the field for well over a decade. With multiple solutions for thin film interconnect and bussing, Henkel is uniquely positioned to support your requirements.
**Heterojunction (HJT) and Third-Generation Photovoltaics**

As one of the first companies to formulate low temperature metallization pastes, Henkel draws on the expertise founded in the company’s printed electronics market leadership and its knowledge base surrounding highly-filled, conductive, polymer systems. Custom formulations for heterojunction, perovskite or other third-generation cell architectures ensure Henkel helps customers achieve the lowest cost, highest efficiency solutions.

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Key Attributes</th>
<th>Ag loading</th>
<th>Volume Resistivity (Ω • cm)</th>
<th>180° Peel Strength on ITO (N/mm)</th>
<th>Print Height to Achieve Peel Strength (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silver Inks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE ECI 1802 E&amp;C</td>
<td>Busbar paste with very high peel strength on ITO/solder at low deposits, low silver loading and 200 mm/sec. print speeds.</td>
<td>70%</td>
<td>4.1 x 10⁻⁵</td>
<td>1.6</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Key Attributes</th>
<th>Contact Resistance on ITO (mΩ.cm²)</th>
<th>Volume Resistivity (Ω • cm)</th>
<th>Aspect Ratio (40 µm Line Opening)</th>
<th>Cure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silver Inks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE ECI 1803 E&amp;C</td>
<td>Ultra fine line capability down to 30 µm opening without line interuptions, ideal for smartwire HJT.</td>
<td>0.4</td>
<td>4.24 E-6</td>
<td>0.28</td>
<td>Dry (&lt; 10 min.) – cure (&lt; 20 min.) at 200°C</td>
</tr>
<tr>
<td>LOCTITE ECI 1800 FINGER PASTE SERIES</td>
<td>Balanced Line resistance and high volume printability to reduce 4 – 5 busbar HJT fingers down to &lt; 40 µm opening.</td>
<td>0.54</td>
<td>4.86 E-6</td>
<td>0.36</td>
<td>Dry (&lt; 10 min.) – cure (&lt; 20 min.) at 200°C</td>
</tr>
</tbody>
</table>
Building-Integrated Photovoltaics (BIPVs)

Henkel has developed a broad portfolio of printed inks that are ideal for embedding electronic circuitry of BIPV modules into windows and building facades. In particular, our rotogravure and flexographic conductive and dielectric inks are capable of meeting very high volume demands with exceptional manufacturability. Off-the-shelf conductive, dielectric and transparent inks lead the market in conductivity, processability, sheet resistance and cost : performance ratio.
## Product Properties

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Application</th>
<th>Key Features</th>
<th>Flex</th>
<th>Rigid</th>
<th>Sheet Resistance (Ω/sq/25 µm)</th>
<th>Processing</th>
<th>Substrates</th>
<th>Cure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silver Inks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE ECI 1006 E&amp;C</td>
<td>• Busbar support for ITO films • Digitizers • Flexible circuits • Membrane switches • Photovoltaic • Touch screens</td>
<td>• Halogen-free • Excellent fine-line and high resolution printability 50 µm lines and spaces attainable • Excellent adhesion to sputtered ITO and PET good electrical conductivity</td>
<td>X</td>
<td></td>
<td>&lt; 0.030</td>
<td>Screenprint</td>
<td>Treated and untreated PET, Kapton, ITO film</td>
<td>10 min. at 130°C</td>
</tr>
<tr>
<td>LOCTITE ECI 1010 E&amp;C</td>
<td>• Flexible circuits • RFID SmartCards</td>
<td>• High conductive with optimum mechanical performance • Compatible with LOCTITE EDAG 440A E&amp;C, LOCTITE EDAG 440B E&amp;C and LOCTITE EDAG PF 455B E&amp;C</td>
<td>X</td>
<td></td>
<td>&lt; 0.007</td>
<td>Screenprint</td>
<td>Treated and untreated PET, Kapton</td>
<td>10 min. at 120°C</td>
</tr>
<tr>
<td>LOCTITE ECI 1011 E&amp;C</td>
<td>• Flexible circuits • RFID SmartCards</td>
<td>• Appearance of the coating is very smooth and shiny</td>
<td>X</td>
<td></td>
<td>&lt; 0.003</td>
<td>Screenprint, Flexographic</td>
<td>Treated and untreated PET, Kapton, ITO film</td>
<td>10 min. at 120°C</td>
</tr>
<tr>
<td>LOCTITE EDAG 461SS E&amp;C</td>
<td>• Flexible circuits • Touch screens • Photovoltaic cells flexible</td>
<td>• Halogen-free • Good adhesion to sputtered ITO films and difficult to adhere to substrates • Low temp cure for heat sensitive substrates</td>
<td>X</td>
<td></td>
<td>&lt; 0.020</td>
<td>Screenprint</td>
<td>Sputtered ITO, PET, ABS</td>
<td>30 min. at 77°C</td>
</tr>
<tr>
<td>LOCTITE ECI 1802 E&amp;C</td>
<td>• Busbar support for ITO films • Digitizers • Flexible circuits • Membrane switches • Photovoltaic • Touch screens</td>
<td>• Halogen-free • Excellent fine-line and high resolution printability 50 µm lines and spaces attainable • Excellent adhesion to sputtered ITO and PET good electrical conductivity</td>
<td>X</td>
<td></td>
<td>&lt; 0.030</td>
<td>Screenprint</td>
<td>Treated and untreated PET, Kapton, ITO film</td>
<td>10 min. at 130°C</td>
</tr>
<tr>
<td>LOCTITE EDAG 451SS E&amp;C</td>
<td>• Flexible circuits • Flexo high speed</td>
<td>• UV cure • Smooth film • Compatible with LOCTITE EDAG silver and carbon inks</td>
<td>X</td>
<td></td>
<td></td>
<td>Screenprint, Flexographic</td>
<td>Untreated and print receptive polyester and polycarbonate film</td>
<td>0.3 to 0.7 J/cm²</td>
</tr>
<tr>
<td>LOCTITE EDAG PF 455B E&amp;C</td>
<td>• Flexible circuits • RFID • Medical electrodes • Biosensors</td>
<td>• Excellent humidity resistance • Excellent printability • Excellent adhesion • Good dielectric strength • UV cure</td>
<td>X</td>
<td></td>
<td></td>
<td>Screenprint</td>
<td>Treated and untreated polyester film</td>
<td>80 W/cm²</td>
</tr>
<tr>
<td>LOCTITE NCI 9001 E&amp;C</td>
<td>• Touch screens • Flexible circuits</td>
<td>• Minimal dielectric strength • Excellent flexibility • Resistant to abrasion • Primer coat for difficult to adhere to substrate</td>
<td>X</td>
<td></td>
<td></td>
<td>Screenprint, Flexographic</td>
<td>Flexible copper circuits, ITO sputtered polyester film, metals and glass</td>
<td>5 min. at 130°C</td>
</tr>
</tbody>
</table>

### Product Properties

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Key Attributes</th>
<th>Ag loading</th>
<th>Volume Resistivity (Ω cm)</th>
<th>180° Peel Strength on ITO (N/mm)</th>
<th>Print Height to Achieve Peel Strength (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silver Inks</strong></td>
<td></td>
<td>70%</td>
<td>4.1 x 10⁻¹</td>
<td>1.6</td>
<td>10</td>
</tr>
</tbody>
</table>

### Materials for Advanced Photovoltaics
### Product Properties – Continued

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Application</th>
<th>Key Features</th>
<th>Flex</th>
<th>Rigid</th>
<th>Sheet Resistance (Ω/sq/25 µm)</th>
<th>Processing</th>
<th>Substrates</th>
<th>Cure</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCTITE ECI 8000 E&amp;C</td>
<td>Heating elements</td>
<td>• Positive Temperature Coefficient (PTC) printable ink • Self regulating heater</td>
<td>X</td>
<td></td>
<td>1,700</td>
<td>Screenprint</td>
<td>Polyester, PEN, Kapton</td>
<td>10 min. at 120°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Description</th>
<th>Key Features</th>
<th>Print Mesh</th>
<th>Sheet Resistance (Ω/sq)</th>
<th>Transmittance (% at 550 nm)</th>
<th>Haze (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCTITE ECI 5005 E&amp;C</td>
<td>Highly conductive, screen-printable ink with excellent transparency and low haze</td>
<td>• Competitive to current market ITO materials • Excellent transparency and lowest haze of the ECI 5000 Series • Low-temperature cure • Additive process – No laser etching needed • Better flexibility than sputtered ITO</td>
<td>305/34</td>
<td>−55</td>
<td>−90</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>420/30</td>
<td>−75</td>
<td>−95</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Henkel's Solder Portfolio

With solder solutions that span diverse applications within numerous market sectors, Henkel is the solder technology market leader. A history of innovative formulations and market firsts – from high-reliability alloys to game-changing, temperature-stable solder pastes – continue to deliver the performance that electronics specialists require for today’s demanding assemblies.

Materials development ingenuity is at the core of every Henkel LOCTITE solder material – and has been for decades. Our multi-award-winning solder portfolio has earned the praise of industry experts and the trust of our customers. With a broad selection of solder pastes, cored and solid wires, liquid fluxes and multiple alloys, Henkel offers a total solution for current and future solder materials requirements.
Henkel's commitment to best-in-class solder performance, printability, reflow and reliability is unyielding. This, in combination with our focus on enabling a sustainable future, has led to some of the industry's most advanced formulations. Henkel's halogen-free solder paste materials have set the bar high for environmental compliance. With zero deliberately added halogens and integrating the purest raw materials available, we can assure our customers that Henkel's halogen-free formulations are, indeed, halogen-free. We take our obligation to advanced materials development so seriously that Henkel has pledged to ensure all future solder paste formulations are either halogen-free, temperature stable or both.

**SOLDER PASTES**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DESCRIPTION</th>
<th>ALLOY*</th>
<th>PARTICLE SIZE DISTRIBUTION*</th>
<th>IPC J-STD-004B CLASSIFICATION</th>
<th>OPTIMAL SHELF LIFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Stable, Halogen-Free</td>
<td>Ultra-low voiding, temperature stable solder paste. Designed to improve transfer efficiency for fine-pitch components such as 01005s and 0.4mm CSPs, the material's slump resistance at higher soak temperatures allows for thorough fluxing action on challenging surface finishes such as Cu OSP and ImSn.</td>
<td>SAC305</td>
<td>Type 3, 4</td>
<td>ROLO</td>
<td>12 months up to 26.5°C</td>
</tr>
<tr>
<td>LOCTITE GC 18</td>
<td>High tack, low voiding, RoHS-compliant solder paste with excellent fine pitch coalescence and extended stencil life and abandon time. Designed for medium to large boards and compatible with many Pb-free alloys. Suitable for vacuum soldering.</td>
<td>965 SAC305</td>
<td>Type 3, 4</td>
<td>ROLO</td>
<td>6 months at 0 – 10°C</td>
</tr>
<tr>
<td>LOCTITE HF 212</td>
<td>RoHS-compliant solder paste designed for use with low-temperature, Pb-free alloys. Formulated to provide excellent dispensability, printability and solderability in various reflow profiles.</td>
<td>Bi58</td>
<td>Type 2.5 (2A)</td>
<td>ROLO</td>
<td>6 months at 0 – 10°C</td>
</tr>
<tr>
<td>LOCTITE LM 100</td>
<td>High activity, soft residue, colorless solder paste with pin-testable flux that displays resistance to high temperature and humidity environments. Suitable for a large range of assembly processes, including Rheometric Pump, Proflow, large and high-density.</td>
<td>Sn63</td>
<td>Type 3, 4</td>
<td>ROLO</td>
<td>6 months at 0 – 10°C</td>
</tr>
<tr>
<td>LOCTITE MP 218</td>
<td>High activity, soft residue, colorless solder paste with pin-testable flux that displays resistance to high temperature and humidity environments. Suitable for a large range of assembly processes, including Rheometric Pump, Proflow, large and high-density.</td>
<td>Sn63</td>
<td>Type 3, 4</td>
<td>ROLO</td>
<td>6 months at 0 – 10°C</td>
</tr>
</tbody>
</table>

**SOLDER PASTE REFLOW PROPERTIES**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>SUITABLE ATMOSPHERE</th>
<th>ALLOY</th>
<th>MELTING POINT (°C)</th>
<th>TIME ABOVE LIQUIDUS, LINEAR (SECONDS)</th>
<th>TIME ABOVE LIQUIDUS, SOAK (SECONDS)</th>
<th>SOAK TEMPERATURE (°C)</th>
<th>SOAK TIME (SECONDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCTITE GC 18</td>
<td>Designed for air; Suitable with nitrogen</td>
<td>SAC305</td>
<td>217</td>
<td>37 – 105</td>
<td>60 – 120</td>
<td>150 – 200</td>
<td>60 – 200</td>
</tr>
<tr>
<td>LOCTITE HF 212</td>
<td>Air and nitrogen</td>
<td>SAC305</td>
<td>217</td>
<td>217</td>
<td>15 – 99</td>
<td>20 – 78</td>
<td>161 – 179</td>
</tr>
<tr>
<td>LOCTITE LM 100</td>
<td>Air and nitrogen</td>
<td>Bi58</td>
<td>138</td>
<td>138</td>
<td>30 – 60</td>
<td>30 – 60</td>
<td>100 – 120</td>
</tr>
<tr>
<td>LOCTITE MP 218</td>
<td>Air and nitrogen</td>
<td>Sn63</td>
<td>183</td>
<td>30 – 75</td>
<td>30 – 75</td>
<td>130 – 165</td>
<td>30 – 120</td>
</tr>
</tbody>
</table>

* Example of process guidelines
Henkel has developed a variety of liquid flux formulations to facilitate Pb-free and SnPb wave soldering processes, rework operations and laser soldering. No-clean, low-residue, VOC-free, halide-free and halogen-free flux formulas provide manufacturers with several options for specific manufacturing requirements, delivering high-performance, defect-free soldering and excellent throughput. Henkel’s liquid flux technologies are environmentally responsible and align with sustainable manufacturing approaches.

**LIQUID FLUXES**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DESCRIPTION</th>
<th>SOLID CONTENT (% BY WEIGHT)</th>
<th>ACID VALUE (mg KOH/g)</th>
<th>APPLICATION</th>
<th>IPC J-STD-004B CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Halide-Free, No-Clean</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE X33-04</td>
<td>Superior second generation no residue halide-free fluxes from the pioneers of &quot;no clean&quot; technology. Unique patented formulation. Fast soldering on conventional leaded and SMD components – no bridges or icicles.</td>
<td>1.6</td>
<td>15</td>
<td>Foam, Spray or Wave</td>
<td>ORMO</td>
</tr>
<tr>
<td>LOCTITE X33-08i</td>
<td>Resin-free, no-clean, halide-free liquid flux for surfaces with poor solderability from the pioneers of &quot;no clean&quot; technology. Fast soldering on conventional leaded and SMD components - shiny joints; no bridges or icicles. Sustained activity for maximum process window.</td>
<td>1.6</td>
<td>17.5</td>
<td>Foam, Spray or Wave</td>
<td>ORLO</td>
</tr>
</tbody>
</table>

*Solid content can be further reduced with additional solvent, please see Henkel TDS for additional information
SOLDER WIRES

Available in both solid and cored versions, Henkel's LOCTITE brand solder wire products have been enabling rework and hand soldering operations for decades. Award-winning multiple flux core technology in our cored wire options distributes flux evenly throughout the solder wire, offering fast wetting and high solder joint reliability. LOCTITE cored wire is available in Pb-free, SnPb and halogen-free formulas. For assemblers who prefer a non-cored option for selective soldering applications, LOCTITE solid wire products are offered in both Pb-free and SnPb options.

CORED WIRES

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DESCRIPTION</th>
<th>APPROXIMATE FLUX CONTENT (% BY WEIGHT)</th>
<th>DIAMETER RANGE (mm)</th>
<th>ALLOY Pb-FREE</th>
<th>ALLOY SnPb</th>
<th>IPC J-STD-004B CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCTITE C 400</td>
<td>Halogen-Free, No-Clean Clear residue, cored solder wire with increased flux content for improved wetting on challenging surfaces. Features the award-winning multiple flux core technology that ensures consistent distribution of flux throughout the solder wire. Suitable for manual and robotic soldering.</td>
<td>2.2</td>
<td>0.38 – 1.63</td>
<td>SAC305</td>
<td>Sn60</td>
<td>RLO</td>
</tr>
</tbody>
</table>

CORED WIRE OPTIONS

Flux content dependent on alloy, diameter and number of cores

<table>
<thead>
<tr>
<th>NUMBER OF CORES</th>
<th>FLUX CONTENT (% BY WEIGHT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5% – 1.0%*</td>
</tr>
<tr>
<td>3</td>
<td>1.0% – 2.5%</td>
</tr>
</tbody>
</table>

*Other flux content available upon request

SOLID WIRES

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>ALLOY</th>
<th>SILVER CONTENT (% BY WEIGHT)</th>
<th>DIAMETER* (mm)</th>
<th>ROHS COMPLIANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb-Free</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE SWR SAC305</td>
<td>SAC305</td>
<td>3.0</td>
<td>3</td>
<td>Yes</td>
</tr>
<tr>
<td>SnPb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCTITE SWR SN63</td>
<td>Sn63</td>
<td>0</td>
<td>3</td>
<td>No</td>
</tr>
</tbody>
</table>

*Other diameters for certain products available upon request
Global Footprint and Broad Industry Partnerships

We have invested in state-of-the-art solar testing capabilities in facilities in Europe and China, as well as test and characterization labs and dedicated engineering staff in Korea, Japan, Taiwan, Europe, the U.S. and China. Henkel’s collaborative technology partnerships with global research institutes and solar cell and module OEMs are driving the next generation of solar devices. Equipment suppliers, manufacturers and organizations seeking research and development alliances with Henkel can e-mail:

Jonathan Burke | Market Manager, Alternative Energy | Henkel Electronic Materials LLC
jon.burke@henkel.com