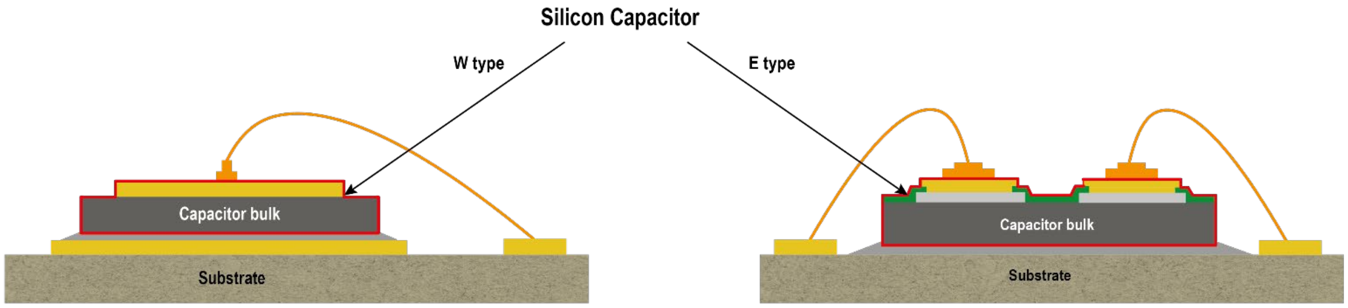
Assembly Note Silicon Capacitor

Assembly by wirebond

Rev. 1.0

This document describes the attachment techniques recommended by Murata Integrated Passive Solutions for their wire-bondable capacitors on the customer substrates. Two wire-bondable capacitor types are available, vertical caps for wirebond (W type) and horizontal caps for wirebond (E type). This document is non-exhaustive. Customers with specific attachment requirements or attachment scenarios that are not covered by this document should contact Murata.



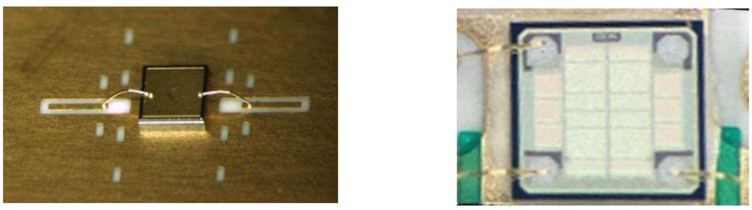


Figure 1: Examples of typical assembled capacitors, W type on the left, E type on the right

Table of contents

1. Handling Precautions and Storage

Silicon dies must always be handled with precaution in a dedicated environment for assembly. Regarding silicon capacitors, after opening of the packing, the remaining quantities have to be repacked immediately after any process step, in the same conditions as before the opening (ESD bag + N2 is usually preferred).

Avoid storing the capacitors in the following conditions:

- Ambient air containing corrosive gas (Chlorine, Hydrogen sulfide, Ammonia, Sulfuric acid, Nitric oxide, etc.)
- Ambient air containing volatile or combustible gas
- In environments with a high concentration of airborne particles
- In liquid (water, oil, chemical solution, organic solvents, etc.)
- Under direct sunlight
- In freezing environment

For specific storage conditions, please refer to the dedicated Application Note « Storage and shelf life conditions».

To avoid contamination and damage like scratches and cracks, our recommendations are:

- Die must never be handled with bare hands
- Avoid touching or scratching the active face with tools that are not adapted
- The mechanical pressure has to be limited
- Do not store and transport die outside protective bags, tubes, boxes, sawn tape
- Work only in ESD-controlled environments

Plastic tweezers or a soft vacuum tool are recommended to handle our Silicon dies.

For more information about handling, please refer to the dedicated application Note "Recommendation to handle bare dies".

Standard packing is tape & reel but silicon capacitors can be provided within waffle pack, gelpak or sawing frame. Please contact Murata for drawing and references (mis@murata.com).

2. Capacitor Shape and pad Information

2.1. Capacitor segregation and shape

Differentiation between W type and E type is required to correctly follow this assembly note.

2.1.1. For Vertical caps (W type)

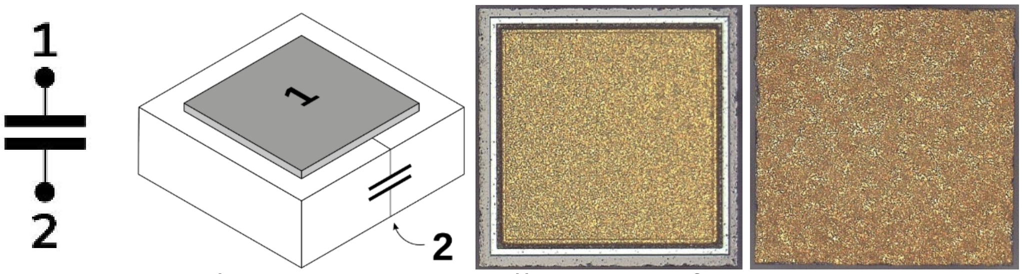


Figure 2.1: Schematic, isometric view, top and bottom pictures of a W type capacitor

Multiple pads or a single pad covering a large area of the component, also including the middle of the component.

Electrodes are located on top side (one or multiple pads) and a single electrode on bottom side.

2.1.2. For Horizontal caps (E type)

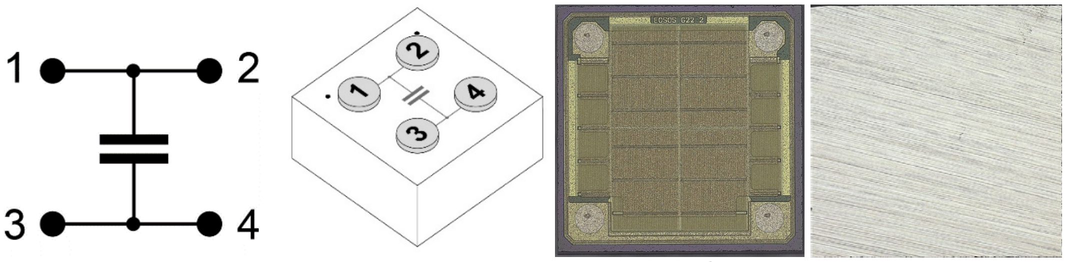


Figure 2.2: Schematic, isometric, top and bottom pictures of an E type capacitor

Pads are located on the corners of the component, and neither pad nor bondable area is located in the middle of the component.

Electrodes are located on top side of the capacitor (minimum two pads for two electrodes).

2.2. Pads identification

With respect to previous figures, this section explains how to correctly identify capacitor's orientation and pads.

2.2.1. For Vertical caps (W type)

As vertical components, we will consider in this document electrode 1 as top electrode and electrode 2 as bottom electrode. Electrode 1 is easy to recognize as it's finishing will not cover the entirety of the top surface as explained in each product datasheet. Electrode 2 and it's finishing, however, will cover the entirety of the bottom surface.

The capacitive part is located between electrode 1 and electrode 2, in a vertical way, inside the component.

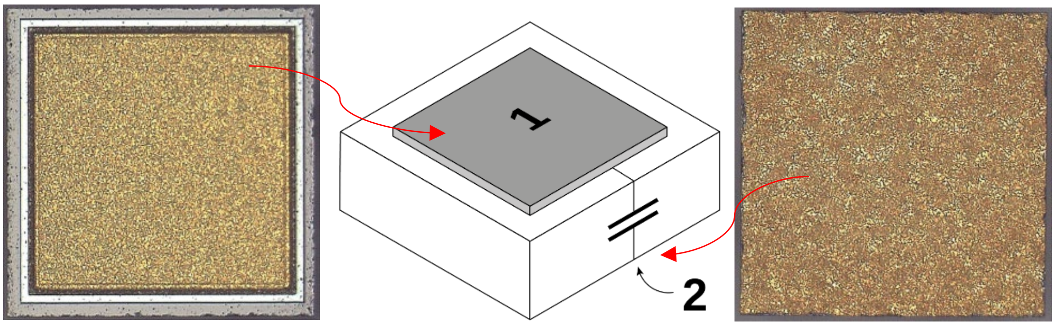


Figure 2.3: W type capacitor: electrode 1 (top electrode) and electrode 2 (bottom electrode)

2.2.2. For Horizontal caps (E type)

For E type Si-caps, first, please identify electrodes 1 and 2 and their respective pads P1 and P2. Please refer to the component datasheet to determine their position. For most of the components P1 and P2 are visible with dots on their corners, please look at the previous figures. P3 and P4 pads, corresponding to electrodes 3 and 4 are located on the opposite side, with P3 in front of P1 and P4 in front of P2.

Electrodes 1 and 2 are connected together. Electrodes 3 and 4 are connected together as well. The capacitive part is located between electrodes 1/2 and 3/4.

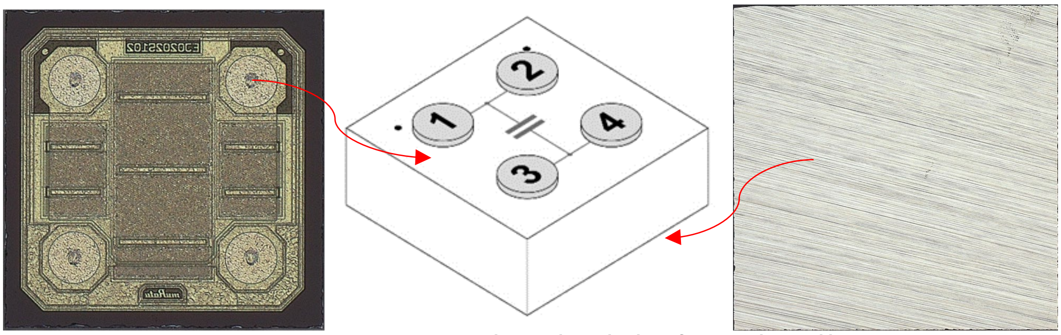


Figure 2.6: E type capacitor: top view with 4 pads with identification dot and bottom view.

Please note that for some specific capacitor arrays or for older versions, pad identification may be different from explained above. You may always refer to the component datasheet or contact Murata for more information.

2.3. Pad finishings

Murata regularly delivers such capacitors with below finishings:

Capacitor type	W type	E type
Top electrodes (either one or multiple)	Ti/W/Au* (Au 3µm) recommended for Gold wire Al/Si/Cu** 3µm recommended for aluminum wire NiAu (ENIG) Electroless Nickel Immersion Gold)	Al/Si/Cu** 3µm recommended for aluminum wire and for gold wire below 125°C
Bottom electrode	Ti/Ni/Au*** Al/Ti/Ni/Ag****	N/A

Table 1: Standard finishings for top and bottom electrodes

* Ti/W/Au means Titanium/Tungsten (0.03µm) / Gold (3µm)
** Al/Si/Cu means Aluminum (98.96%) alloy with 1% of Silicon and 0.04% of Copper
*** Ti/Ni/Au means Titanium (0.1µm) / Nickel (0.3µm) / Gold (0.2µm)
**** Al/Ti/Ni/Ag means Aluminum (0.3µm) / Titanium (0.1µm) / Nickel (0.3µm) / Silver (1.0µm)

Other finishings (thinner gold, Ti/Cu/Ni/Au, Copper…) are available as options upon request. Please contact Murata. Please have a look at section 5 for die bonding and at section 6 for more details on wirebond.

3. Landing Pad Opening

Landing pad dimensions for wire-bondable capacitors will vary upon the viscosity and type of attachment material in usage. Please look at part 5, for extensive details about recommendations on die bonding. Here, we will give general recommendations for landing pad design as well as some troubleshooting guidelines.

For liquid or semi-liquid (low viscosity) conductive material, in order to limit the risk of glue creeping (please also see section 5.1), the distance between two capacitors on the same pad should be greater than 100µm on each direction.

100µm is also the minimal keep-out we advise in each direction between a component and the edge of the landing pad, whether it is materialized by solder mask or not.

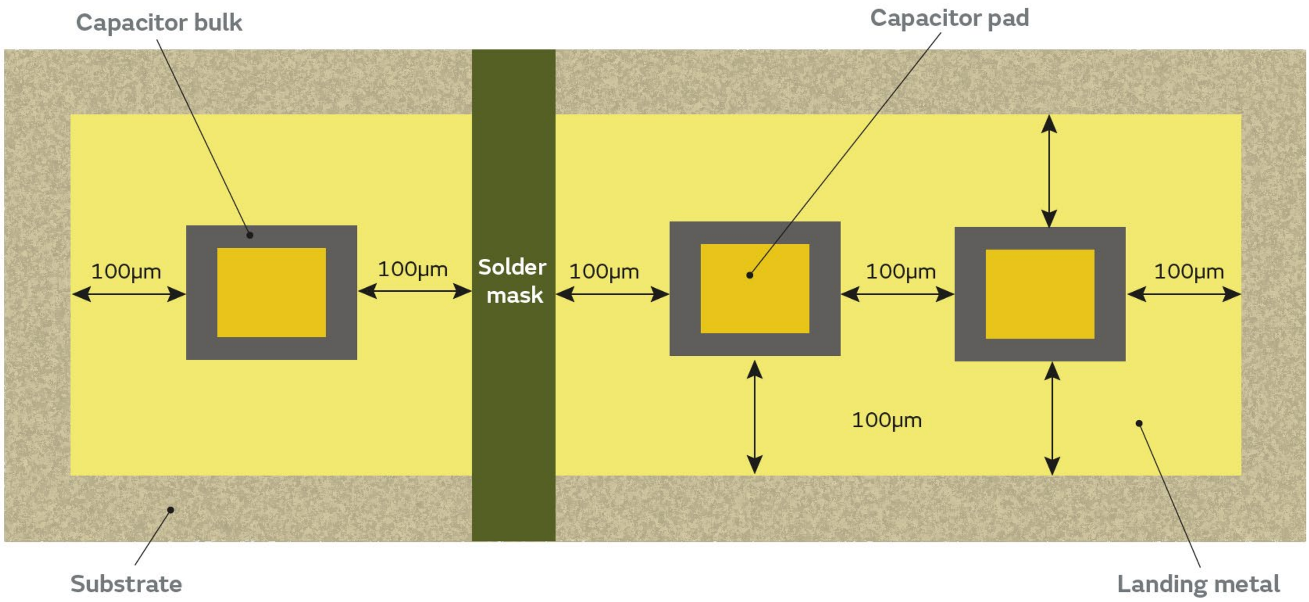


Figure 3.1: Recommended land pattern openings for liquid or semi-liquid conductive attachment

By substrate, we consider any kind of board or lead frame on which components can be assembled, with or without landing pads. This also include several substrate materials, not exhaustively FR4, aluminas, ceramics, metal frames…

Using die-attach foil or non-conductive epoxy will release some constraints. We shall remain at 100µm between two caps on the same pad, but in any other direction the keep-out can be reduced to 50µm.

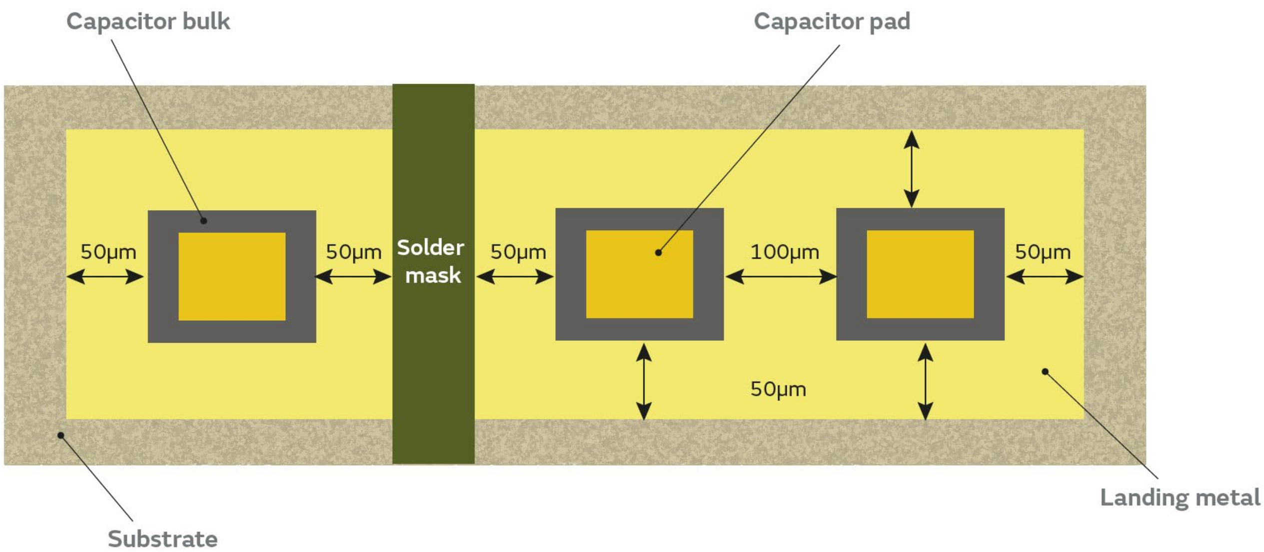


Figure 3.2: Recommended land pattern openings for non-conductive attachment or non-viscous conductive attachment

These design distances are minimum recommendations. Please use your proper design and assembly rules if stricter.

If you need to reduce the creep, the first advice is to reduce the amount of attachment material. For instance, Si-cap's better flatness allows to use slightly less Silver paste or solder paste than for other components in ceramic. If this does not solve your issue, you may enlarge all the distances shown above, especially the distance between two caps. Please see section 5.1 for more information about acceptable creep.

4. Die picking (pick and place)

The most common approach is with automatic equipment using vision inspection to correct die positioning after picking and before placement on substrate. Manual picking can also be carried out for prototyping. Use of a soft tip (like rubber or Torlon®) is strongly recommended for the die picking. A metal tip can damage the capacitor.

Please look at the dedicated Application Note "Recommendations handling bare dies".

If automatic equipment is used, it is best to use the same tool as for picking. The placement force will depend on the die size. A minimum placement force is required in order to cover all the die back side with glue. Too much force can damage the die.

Suggested forces with recommended glue/solder paste for a minimum capacitor thickness of 100µm:

Silicon Capacitor Type	Capacitor size (µm²)	Placement force (grams)
W0101	250 x 250	100
W0101+	294 x 294	100
W015015	380 x 380	150
W0202	500 x 500	200
W0303 or W0502	800 x 800 or 1250 x 500	300
W0402 or W0802	1000 x 500 or 2000 x 500	350
W0504	1250 x 1000	450
W0505 and above	1250 x 1250 and above	500

Silicon Capacitor Type	Capacitor size (µm²)	Placement force (grams)
E0201M	600 x 400	75
E0202	580 x 580	100
E0302	850 x 580	200
E0404	1000 x 1000	250
E0505	1250 x 1250	250
E0605	1520 x 1520	300
E1208	3000 x 2000	300
E1612	4000 x 3000	400
E1616	4000 x 4000	450
E2016	5000 x 4000	500

Table 2: Recommended placement force for wire-bondable Si-caps

Placement force should always be adjusted based on solder material viscosity, chip thickness and chip size. For dies thicker than 250µm, placement force can be increased.

5. Die bonding

Die bonding process is dependent on the die attach material. In this document are described two kinds of die attach: epoxy glue (including both conductive and non-conductive) and solder paste. Other attachment materials can be used, like Die Attach Foils, Conductive Foils or Sintering. For more information, please contact Murata. Please refer to the following table to check what die bonding type is suitable for each capacitor type. Please also look at section 3 for landing pad design advice and consider looking at MIL-STD-883 method 2010.14 for more acceptance criteria.

Bonding type	Capacitor type	
	W type	E type
Conductive glue	Suitable (section 5.1)	Suitable (section 5.1), with caution*
Non-conductive glue	Not suitable	Suitable (section 5.1)
Solder paste	Suitable (section 5.2)	Not suitable

Table 3: Attachment selection table in function of type

* For E type, MIS advice is to use non-conductive glue, but if conductive glue is necessary, it is mandatory to have the substrate board bonding pad either at no voltage or at the same voltage as electrodes 3 and/or 4 of the capacitor. Please also refer to product datasheet and to section 5.1.2.

5.1. Using conductive or non-conductive glue

General outlines for die bonding process with conductive or non-conductive glue are the same. Please always refer to the specific parameters of your material supplier.

By conductive glue, we refer to any epoxy material that creates both a mechanical and electrical joint between the substrate board and the capacitor. For instance, silver pastes or conductive underfills, not exhaustively, come into conductive glue types.

By non-conductive glue, we refer to any epoxy material that creates only a mechanical joint between the substrate board and the capacitor, but electrically isolates the component and the substrate. Epoxies and underfills with no conductive particles in them can be considered as non-conductive glues.

The critical point in using conductive material to assemble Si-caps is to control the creep along Si-caps' sides, avoiding it to reach the top layer and cause a short between top and bottom of the capacitor. This is true for both W and E types and for every kind of liquid or semi-liquid conductive attachment material (Silver paste or other conductive glue, solder paste...)

An acceptable creep is less than half of capacitor height or 100µm whichever the lower.

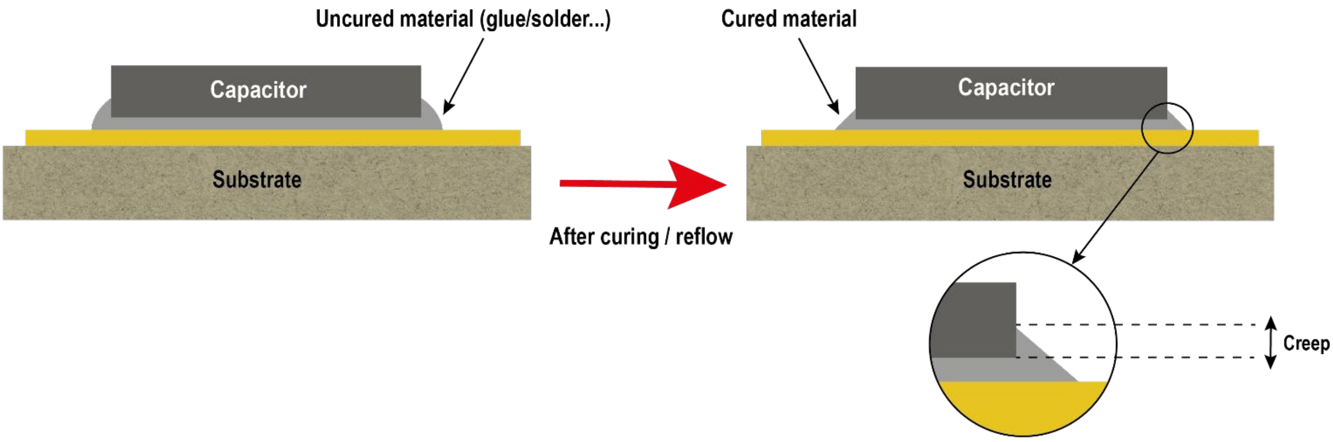


Figure 5.1: Creep generation process and creep visual definition

5.1.1. Process flow for glue

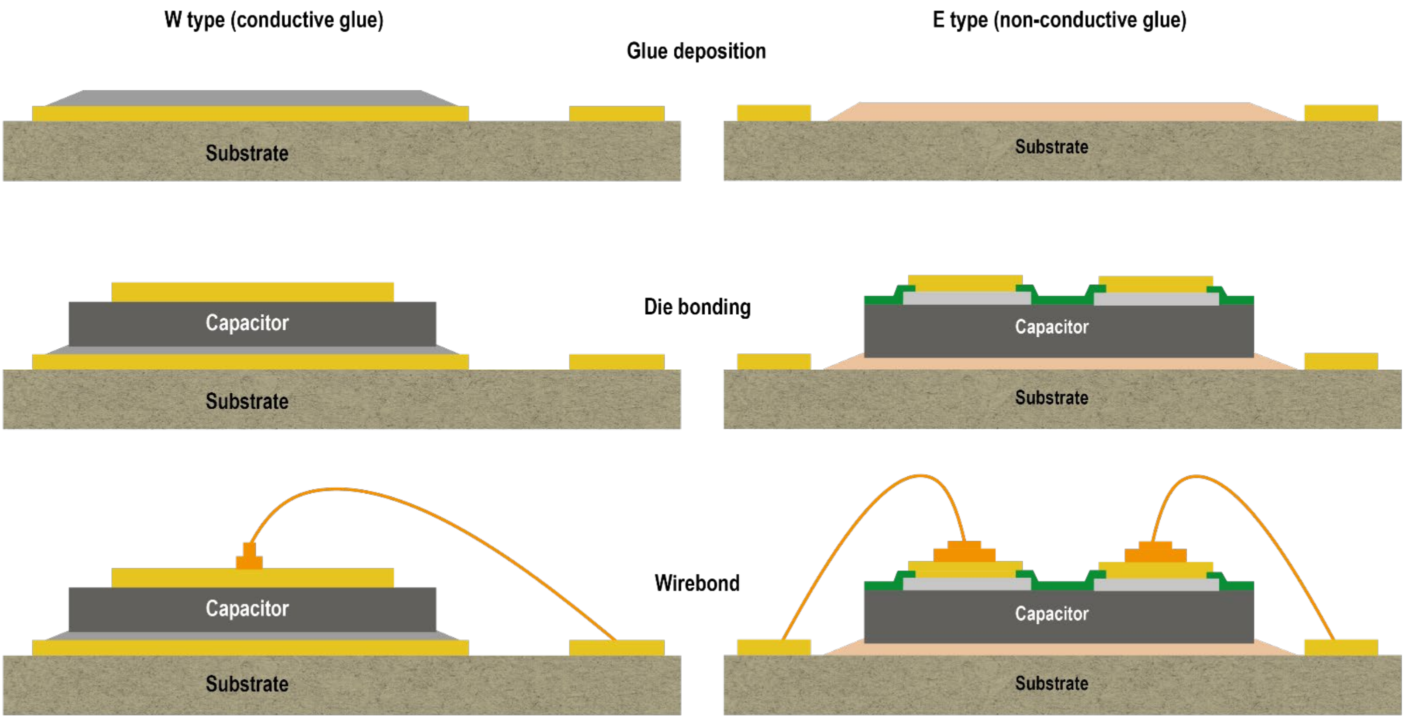
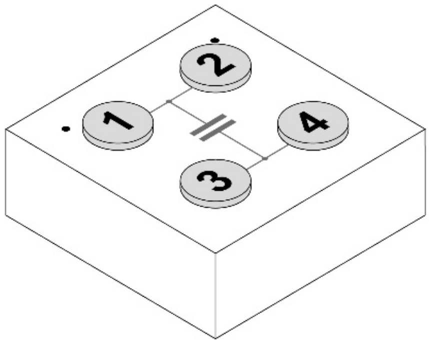


Figure 5.2: Process flow with glue attachment

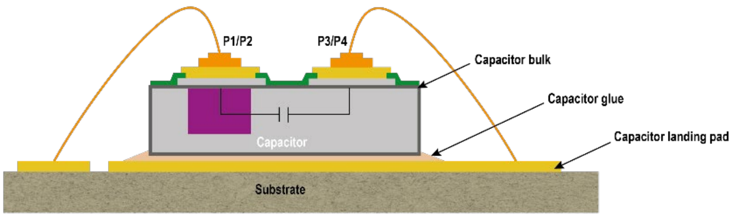
5.1.2. For E type assembled on a metal landing pad with conductive glue

For E type, MIS advice is to use non-conductive glue, but if conductive glue is necessary, it is mandatory to have the substrate board bonding pad either at no voltage or at the same voltage as electrodes 3 and/or 4 of the capacitor. Please refer to product datasheet and to section 2 to correctly identify the electrodes.



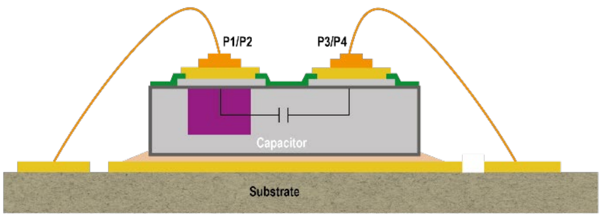
E type Si-caps have their electrodes 3 and 4, respectively pads P3/P4 electrically connected together to the capacitor bulk. This means the voltage connected to the silicon bulk has to be either the same as voltage at P3/P4 or floating to avoid shorts through the bulk.

For specific wire pattern of E type Si-caps, please look at section 6.



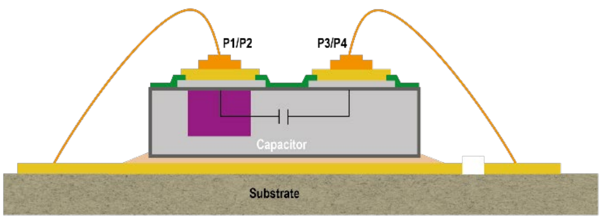
- Capacitor bulk at same voltage as P3/P4 is OK
- No risk of short
- Take care for the conductive glue not to touch wire bonding pad

Correct Assembly



- Capacitor bulk at floating voltage is OK
- No risk of short
- Naturally the floating pad which the capacitor is assembled on will be polarized at the same voltage as P3/P4 through the bulk and the conductive glue

Correct Assembly



- Capacitor bulk at any other voltage (here connected to P1/P2) is not OK
- The bulk is connected to both P3/P4 and to P1/P2 through the capacitor landing pad, a short occurs

Incorrect Assembly

Figure 5.3: Specific landing pad design requirement for E type attachment with conductive glue

5.1.3. Recommendations considering glue

Murata uses a large variety of conductive and non-conductive glues. We advise to use mid to high viscosity in order to control the flow and the creep.

Both UV curing and temperature curing types are suitable for Si-caps. As well, it is possible to use bi-component glues. Basically, every glue suitable for general ICs will be suitable for Si-caps. Please always refer to the datasheet of your bonding compound.

Please find below the recommended dispensing processes and patterns depending on capacitor size and for glue dispensing.

Silicon Capacitor Type	Capacitor size (µm²)	Recommended glue dispensing process	Recommended pattern
W0202 or E0202 or smaller	Smaller than 580 x 580	Stamping/jetting	DOT
W0303 or E0302	850 x 850 or 850 x 580	Stamping/time pressure valve/jetting	DOT
W0402 and above or E0404 to E0605	From 1000 x 500 to 1520 x 1520	Stamping/auger/time pressure valve	DOT/CROSS
E1208 and above	Bigger than above	Auger	CROSS

Table 4: Recommended glue dispensing process depending on capacitor size

Please consider that Si-caps' backside surface is smoother than some other capacitors. This may slightly change the way the glue is flowing out of the backside. This is a normal behavior.

5.2. Using solder paste

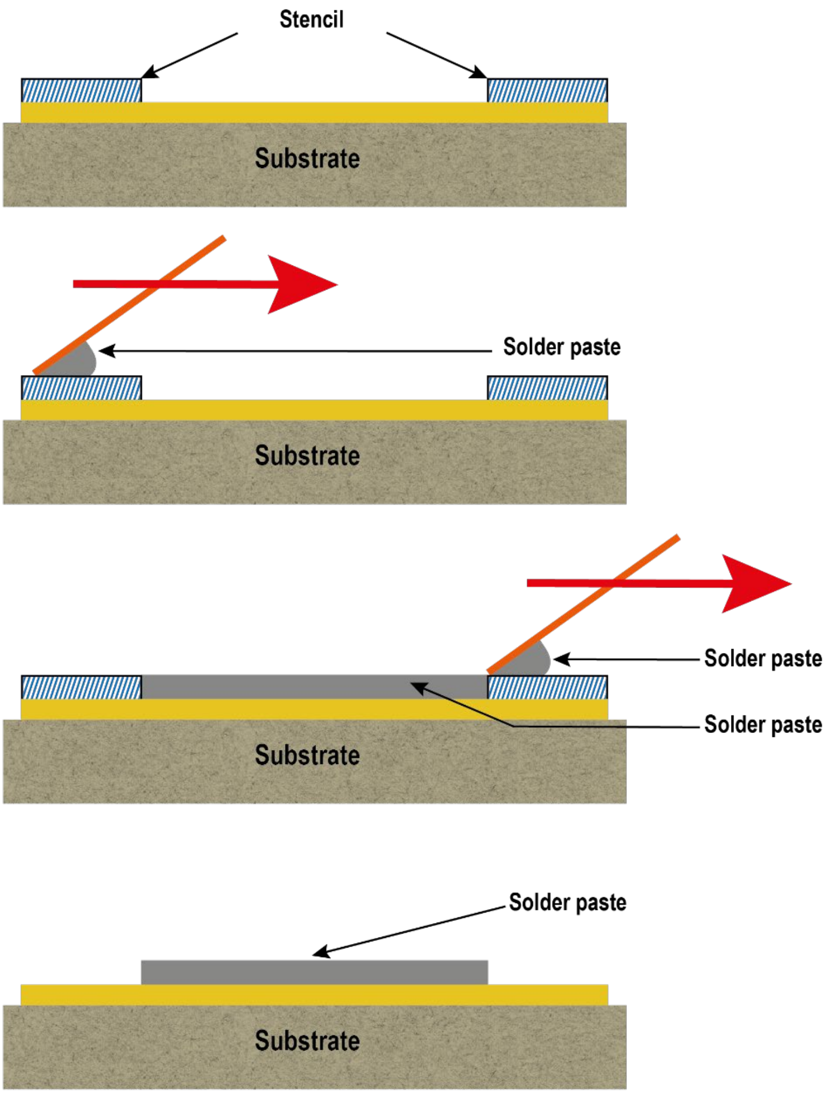
By solder paste, we refer to any mix of metallic particle and flux suitable for reflow process. Typical solders include SAC305, lead-free high-temperature solders like eutectic AuSn as well as lead-free low-temperature bonding solders. Lead solders are not recommended for environmental reasons though are also suitable for reflow of our capacitors. Please always read and follow your solder paste supplier information for temperature and process requirements.

Please note that only W type capacitors can be used with reflow soldering as their backside is metallized. E type capacitors cannot be assembled using reflow soldering.

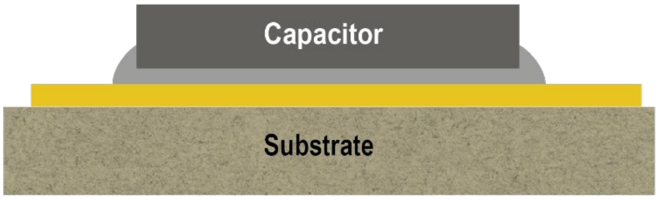
5.2.1. Process flow for solder paste

Here, will be described the solder deposition by stencil. Solder dispense is also possible. In that case, the process is similar to the conductive glue one (part 5.1) but conductive glue is replaced by solder paste.

Step A – Solder Printing :



Step B - Die Bonding :



Step C – Reflow soldering :

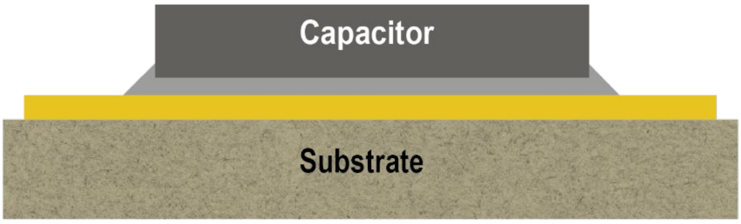


Figure 5.4: Process flow for solder paste attachment

5.2.2. Recommendations considering solder paste

SAC305 is commonly used and recommended but other materials compatible with the die pad finishing are also possible. Please contact Murata.

Murata recommends using a type 6 powder size, especially for small components. Type 5 can be used depending on the customer PCB design and application. Depending on the die pad size, powder size can be adjusted. However, type 6 compared with type 4 limits the risk of tilting of the capacitor for smaller pad dimensions.

Alloy	Composition	Solidus	Liquidus	Comments
SAC305	Sn 96.5%, Ag 3%, Cu 0.5%	217°c	217°c	Eutectic
Sn63	Sn 63%, Pb 37%	183°c	183°c	Eutectic Only for allowed applications
AuSn	Au 80%, Sn 20%	280°c	280°c	Eutectic - High temperature
SnPb	Sn 5%, Pb 95%	308°c	312°c	High temperature Only for allowed applications

Table 5: Solder print materials selection table for reflow

Murata recommends convection reflow but vapor phase reflow and infrared reflow could be also used.

The reflow process must be carried out in accordance with the JEDEC J-STD-020-E standard for low temperature reflow like SAC305. Please look at the dedicated Assembly Note “Silicon Capacitors assembly by reflow” for this application. For higher temperature solder pastes, like AuSn, please refer to the dedicated Application Note “Silicon Capacitors assembly by reflow with high temperature soldering material”.

For flux cleaning recommendations, please refer to section 7 of this document.

5.3. Stencil design rules in function of its grade

Murata advises in every case that the width of the stencil opening (referred as ‘W’) should be larger than 5 times the average powder size of your soldering material. This, in order to correctly fill the stencil pocket.

Murata follows the IPC-7525 standard and quantifies the stencil grade based on ratio between stencil’s area ratio (AR), aspect ratio (AS) and thickness. Please look at the following formulas and tables to find the stencil grade we recommend.

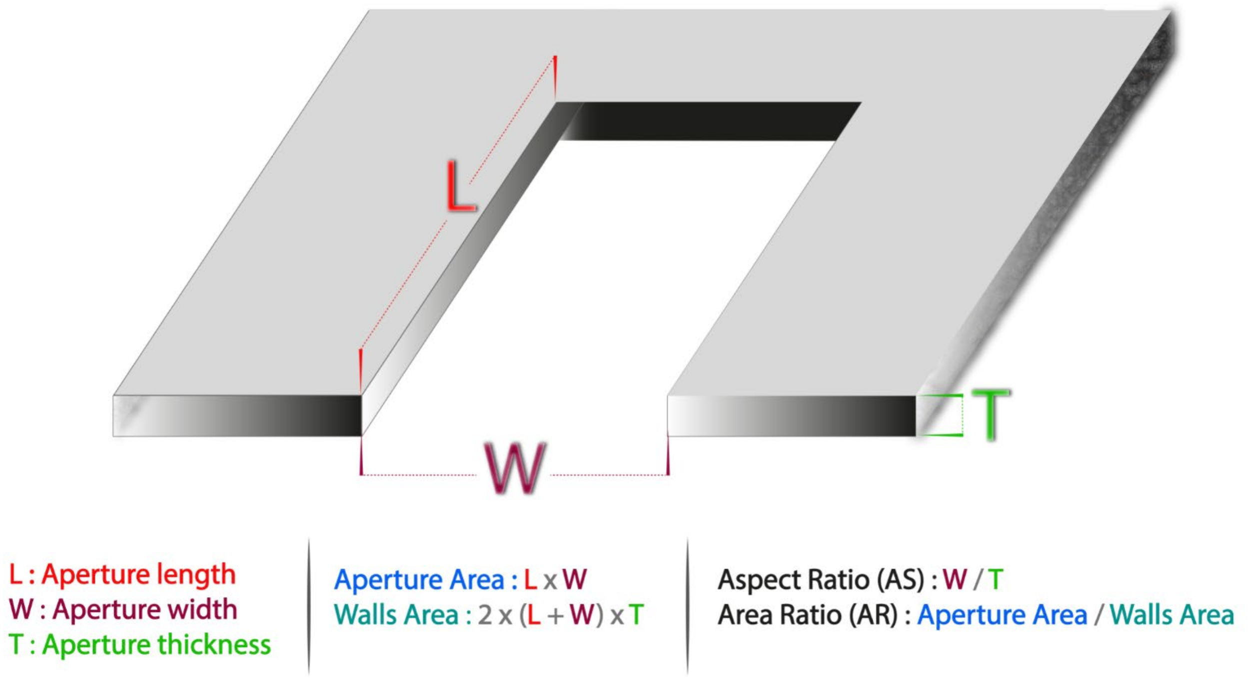


Figure 5.5: Definitions for stencil aperture

Please compare your stencil's desired thickness, aspect and area ratio with the following tables to define which grade we advise. Please consider the highest grade you will find from each of the three criteria.

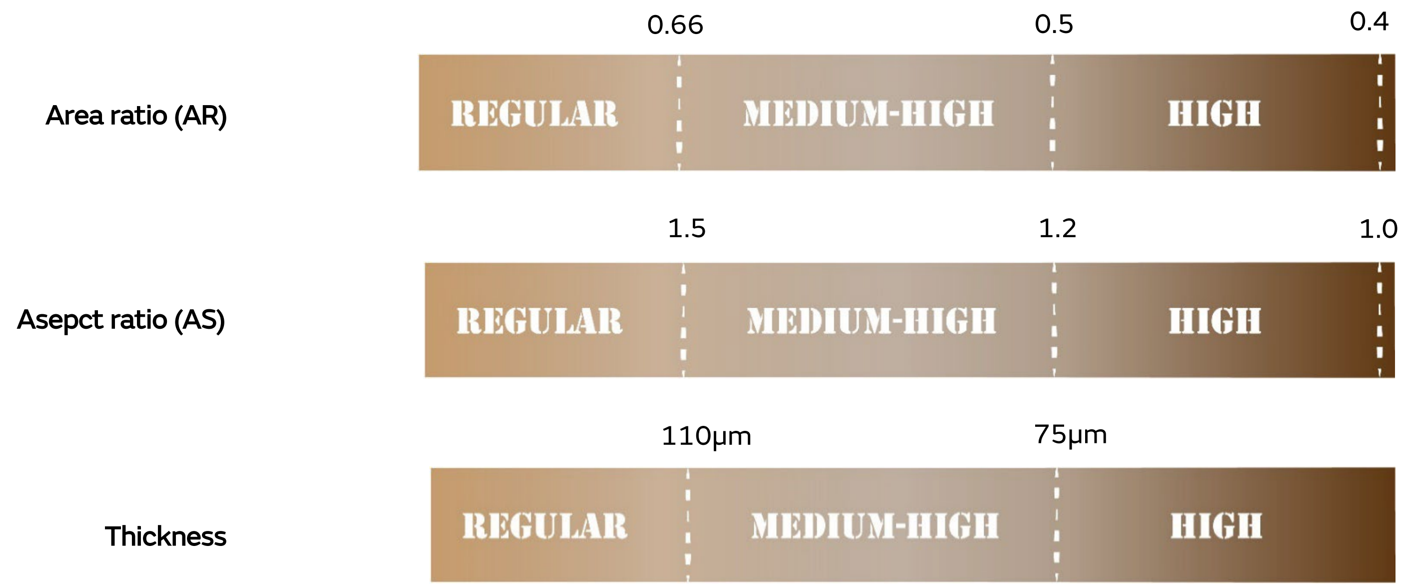


Table 6: Stencil grade selection criteria per Area ratio, Aspect ratio and Thickness

Examples of medium-high grade stencils include electroformed or laser-cut technologies.

Examples of high grade stencils include plasma or medium-high grade with surface treatment technologies.

For SAC305, a solder joint thickness of 40 µm +/-10 is targeted to limit the risk of contact between the solder paste and the side of the capacitor. Limiting solder joint thickness will also avoid an excessive tilting of the capacitor, especially for small components. Please contact Murata for other soldering materials and thinner solder joints.

For example, below are some stencil designs advised by Murata (SAC305 type 6 with 50% of flux by volume):

Table 7: stencil W type

Silicon Capacitor Case Size	Stencil opening size (in µm)	Stencil thickness (in µm)	Stencil grade (roughness and opening profile)
W0101	220 x 220	100	medium high
W0101+	260 x 260	100	medium high
W015015	300 x 300	100	medium high
W0202	400 x 400	125	regular
W0303	640 x 640	125	regular
W0404	800 x 800	125	regular
W0504	1000 x 800	125	regular
W0505	1000 x 1000	125	regular
W0502	1000 x 400	125	regular
W0802	1600 x 400	125	regular

Advised designs for

Note: sizes are to adjusted to flux and type

Opening be according content used.

For components with different sizes, especially custom components, similar rules can be considered as a base. Please contact Murata for additional support.

6. Wire bonding

This section refers to all assemblies with bonded wires. Please note that wire material can be specific to capacitor type and finishing. Wire-bondable Si-caps are designed to be assembled with bonding wires on the top side of the capacitor. For any other assembly method, please contact Murata.

For W type capacitors, it is expected to have at least one wire on top of the capacitor.

For E type capacitors, it is expected to have at least one wire connected to either S1 or S2 and one another wire connected to either S3 or S4. It's of course possible to have both S1 and S2 on the one side and/or S3 and S4 on the other side connected with bond wires. To identify pad location, please look at section 5.1.2.

6.1. Wire types and specifications

Materials used and bonding method:

- Wire material: gold or aluminum
- Wire diameter: Murata advises to use wires from 20 to 25 microns. For reference, Si-caps are also suitable for larger wires for specific applications if pad is big enough. Please contact Murata for more information.
- Wire bonding methods: Ball bonding or wedge bonding
- Wire bonding temperature for gold wire bonding: 150 to 200°C
- Please check there is no major impact on die pad metallization prior to bonding

Wire structure specifications:

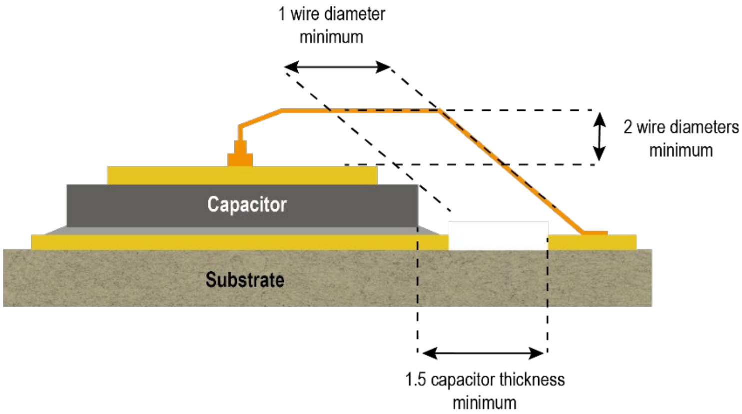


Figure 6.1: Wire structure specifications

Ball bonding specifications:

- The gold ball diameter must be between 2 and 5 times the wire diameter.
- The wire exit must be completely within the periphery of the ball.

- 100 % of the ball must be on the die pad metallization.
- For second bond, called sometimes stitch or crecent, please look at wedge bonding specifications considering the circle/lunar shape as the wedge.
- Please also consider the MIL-STD-883, method 2010.14 for more details.
- Multiple balls are possible as long as the preceding rules are fulfilled.

Wedge bonding specifications:

- For gold wire, the wedge bond width (W) must be between 1.2 and 3 times the gold wire diameter.
- For aluminum wire, the wedge bond width (W) must be between 1 and 3 times the aluminum wire diameter.
- The wedge bond length (L) must be between 1.5 and 6 times the wire diameter.
- The tool impression on wedge bond must cover the entire width of the wire.
- 100 % of the wedge (tail not included) must be on the die pad metallization.
- Please also consider the MIL-STD-883, method 2010.14 for more details.
- Multiple wedges are possible as long as the preceding rules are fulfilled.

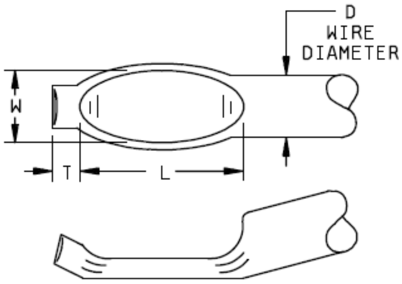


Figure 6.2: Wedge bonding specifications (image extracted from MIL-STD-883 method 2010.14)

6.2. Bondable area

The bondable area is clearly notified in the product datasheet for each product. Please carefully look at the product datasheet for detailed information.

Please note that the area outside the bondable area has no finishing suitable for wire bond. This means it's not possible to bond outside of the bonding pad. Si-caps are not designed to be fully metallized and are not suitable for wedges nor balls on the edge of the component. However, Si-caps' finishings are flat enough to the extremity of the bonding pads to allow bonds all over the dedicated pads.

For W type capacitors

For E type capacitors

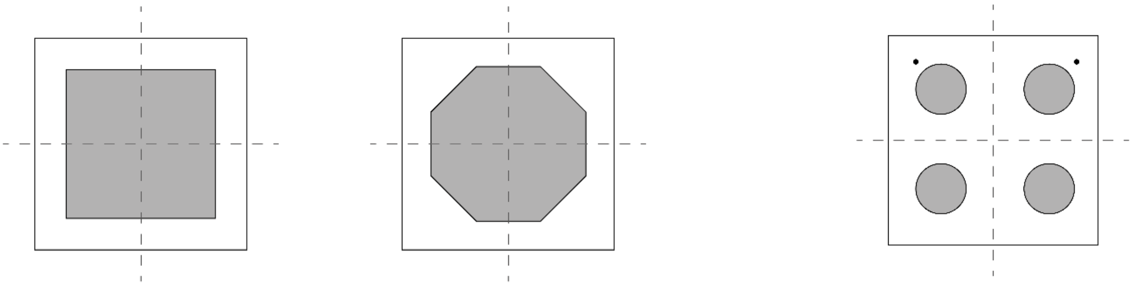


Figure 6.3: Bondable areas examples for W and E types

Bondable areas are represented in grey on above pictures. For the W type, are represented to pad types: On the left a square pad, covering a large portion of the Si-cap's top side and on the right an octagonal pad. For the E type, the 4 gray circles represent the 4 circular pads.

6.3. Multiple wires

W type Si-caps are suitable for multiple wires as long as the bonding pads are large enough to accept several wires. Also, each wire should respect the specifications mentioned above. Please also consider the MIL-STD-883 method 2010.14 for more information.

E type Si-caps are for the majority designed with octagonal pads with a diameter of 150µm. Such Si-caps are suitable to receive two 25µm wires per pad in either wedge or ball. Few E type Si-caps are designed with 100µm diameter pad, only suitable for one 25µm wire.

It is also possible to assemble Si-caps with BSOB or double bond per ball. Using multiples is a common way to reduce ESL and improve current capability of the system. Continuous Capilary Wedge Bonding (CWB) is also demonstrated to be suitable with our Si-caps as well. For more information on such bonding pattern, please contact Murata.

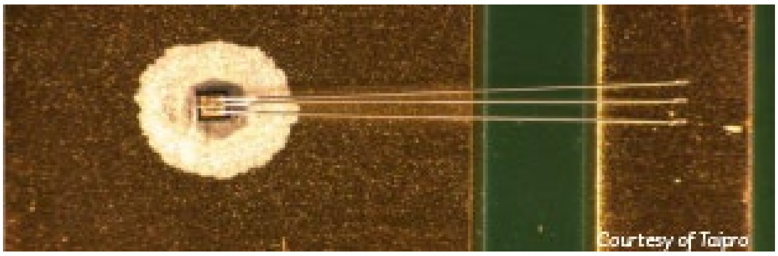


Figure 6.4: W0101 capacitor assembled with three long gold wires in wedge bonding (photo courtesy of Taipro Engineering SA)

6.4. Wire bonding parameters

Wire bonding parameters will be adjusted in function of the tool and the wire references, as well as the type of equipment. These data are given to help our customers to define the parameters area.

Wedge bonding with aluminum wire (25 µm) example:

Al wedge (25µm)	Bonding parameters
Bonder	BJ820
US	20 to 25% (400-460 mW)
Bonding force	15 to 25 cN
Bonding time	10 to 20 ms
Deformation	25 to 35%
Temperature	Ambient

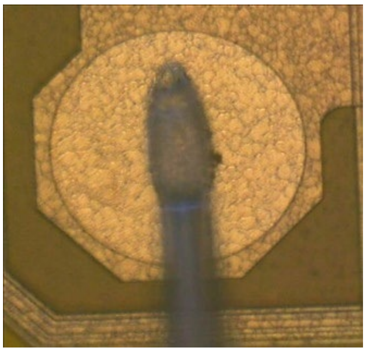


Table 8: Recommendations for Aluminum wedge bonding

Wedge bonding with gold wire (25 µm) example:

Au wedge (25µm)	Bonding parameters
Bonder	BJ820
US	20 to 30% (420-600 mW)
Bonding force	20 to 30 cN
Bonding time	20 to 25 ms
Deformation	25 to 35%
Temperature	115°C

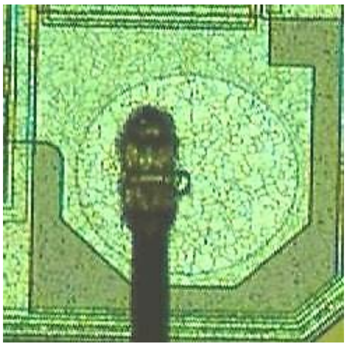


Table 9: Recommendations for Gold wedge bonding

Ball bonding with gold wire (25 µm) example:

Au ball (25µm)	Bonding parameters
Bonder	Bondtec 5810
US	215 to 230 mW
Bonding force	30 to 40 g
Bonding time	20 to 30 ms
Temperature	125°C

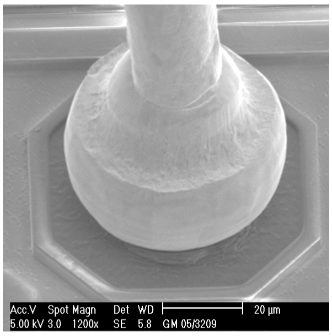


Table 10: Recommendations for Gold ball bonding (first bond/ball)

Second (stitch/crecent) bonding with gold wire (25 µm) example:

Au stitch (25µm)	Bonding parameters
Bonder	Bondtec 5810
US	220 to 250 mW
Bonding force	20 to 25 g
Bonding time	20 to 30 ms
Temperature	125°C

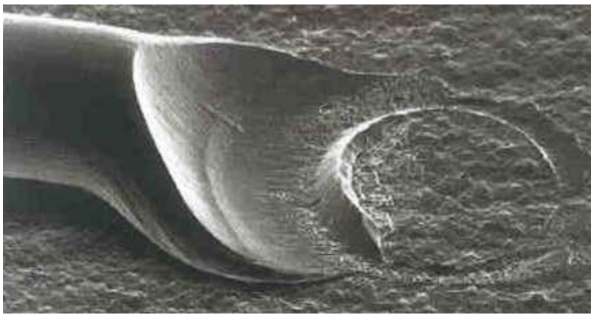


Table 11: Recommendations for Gold stitch bonding (second bond/stitch/crecent) (photo courtesy of Taylor Electronics Services)

7. Cleaning after reflow

For appropriate removal of residual flux, proper cleaning equipment, conditions and solvent must be used. This prevents any residual flux or other foreign substances causing deterioration of electrical characteristics and the reliability of the capacitors.

Water soluble and no clean flux can be used. In case of water-soluble flux, please refer to the solder paste supplier for the cleaning and flux removal. For optimum results, it is recommended to remove the flux immediately after reflow to avoid a potential issue of current leakage or short circuits

However, Murata does not recommend to use excessive conditions for ultrasonic oscillation, water or air pressure during cleaning which can cause reliability issues. Before starting your production process, please test your cleaning system.

Revision history

Revision	Date	Description	Author
1.0	20/04/2023	Document Creation	C. Muller/ K. Dubois

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These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Murata customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Murata for any damages resulting from such improper use or sale.

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