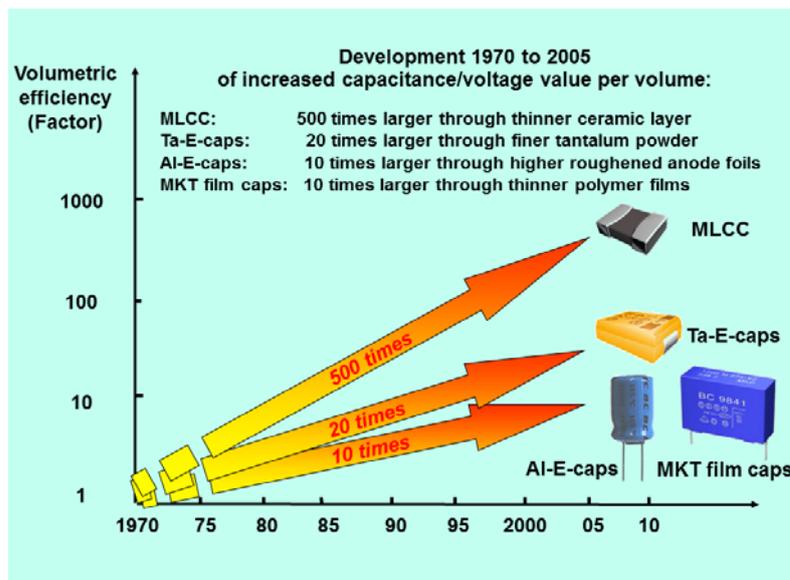


## Challenges and Solutions for Bonding Ultra-Small Ceramic End-Terminated Capacitors

Electronic components and packages continue the trend of miniaturization which drives demand for cost-effective assembly solutions for smaller components and packages. This is happening in end markets in Telecom/Datacom, Aerospace & Defense, Medical Devices, Computers and Peripherals, and Industrial.

Moore's Law is the observation made by Intel co-founder Gordon Moore that the number of transistors on a chip doubles every 18 months. As with transistors, the volumetric efficiency of multilayer chip capacitors (MLCC) continues to make dramatic improvements. Volumetric efficiency of capacitors is a measure of the performance of electronic function per unit volume. For capacitors, the volumetric efficiency is denoted by the "CV product." CV is the product of the capacitance (C) and maximum voltage rating (V) and divided by the volume. As shown in the following graph, volumetric efficiencies have improved dramatically for MLCC. (Graph is courtesy of Wikipedia.) The result is increased use of ultra-miniature capacitors.

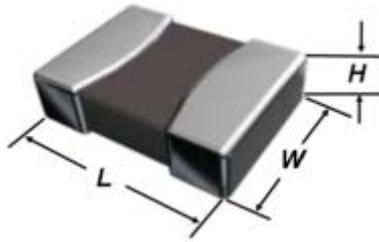


Ultra-miniature capacitors present challenges to high-volume manufacturing for small complex electronic packages such as optical components and military hybrids. The proliferation of IoT (Internet of Things) devices is also accelerating this trend. This article explores the solutions available on MRSI die bonders to meet these challenges with a focus on 01005 (0.016" x 0.008") and 0201 (0.024" x 0.012") EIA Inch Code case sizes.

### Shrinking MLCC Case Sizes

Referring to capacitor case sizes can be confusing as several standards exist. The same capacitor size can have different case size references in EIA inch code and IEC/EN metric code as the following chart shows. This article will use EIA Inch Code case size as a reference. One thing that is not in question is that capacitor

size continues to shrink thus increasing the magnitude of the assembly challenges.



Dimensions L×W×H of the multi-layer ceramic chip capacitors

EIA inch code	Dimensions L × W inch × inch	IEC/EN metric code	Dimensions L × W mm × mm
1005	0.016 × 0.0079	402	0.4 × 0.2
15015	0.016 × 0.016	404	0.4 × 0.4
201	0.024 × 0.012	603	0.6 × 0.3
202	0.02 × 0.02	505	0.5 × 0.5
302	0.03 × 0.02	805	0.8 × 0.5
303	0.03 × 0.03	808	0.8 × 0.8
504	0.05 × 0.04	1310	1.3 × 1.0
402	0.039 × 0.020	1005	1.0 × 0.5
603	0.063 × 0.031	1608	1.6 × 0.8
805	0.079 × 0.049	2012	2.0 × 1.25
1008	0.098 × 0.079	2520	2.5 × 2.0
1111	0.11 × 0.11	2828	2.8 × 2.8
1206	0.126 × 0.063	3216	3.2 × 1.6
1210	0.126 × 0.10	3225	3.2 × 2.5
1410	0.14 × 0.10	3625	3.6 × 2.5
1515	0.15 × 0.15	3838	3.81 × 3.81

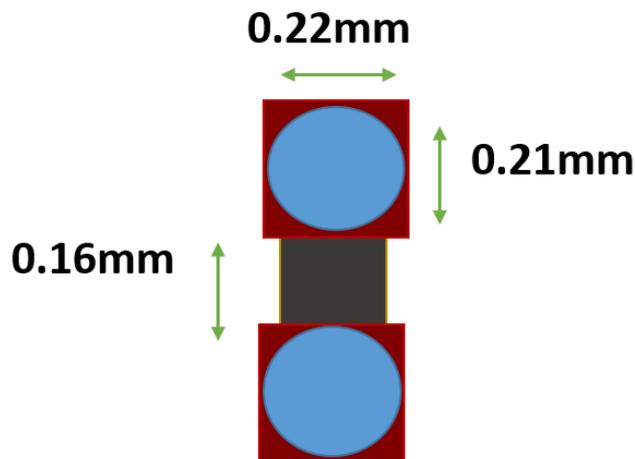
*Table of the dimension codes and the corresponding dimensions of MLCC chip capacitors (Source: Wikipedia)*



## Adhesive Deposition – Challenges and Solutions

Depending on the application and process flow, capacitor terminations are connected with either solder or conductive epoxy. Generally, solder is used for the interconnect with SMD devices and SMT processes on PCBs. Epoxy is used to attach capacitors on substrates with bare die for advanced packaging applications. MRSI Systems die bonders are used primarily with the epoxy process in advanced packaging applications.

The smallest and thus most difficult case size of 01005 (.016" x .008") requires the smallest board pads. Common pad dimensions for 01005 capacitors is 0.21 x 0.22 mm with 0.16 mm separation (see diagram).



#### *Example of Pad Design Parameters*

For each of the two end termination pads, a single highly repeatable dot with a 0.2 mm (200 micron) diameter is required. The dots must be placed with excellent volumetric repeatability and ultra-accuracy to avoid shorting and silver migration and for good mechanical properties.

#### **Epoxy Deposition Methods**

End terminated capacitor pads are small and consequently require very small epoxy dots for successful epoxy attach. The smallest components such as 01005 capacitors require very small volumes of conductive epoxy. Control of the volume is critical. The right volume enables epoxy coverage with no voiding and controlled thin bond lines. This is important to maximize electrical connections and mechanical strength while minimizing stresses. Squeeze-out must be controlled to prevent shorting or bridging. The epoxy must be placed in precise locations to maximize yield.

Stencil and Jet printing are common when solder is used for interconnect in conjunction with SMD devices and SMT processes on PCBs. For advanced packaging applications using conductive epoxy, the most common two methods for applying epoxy to accomplish the task described above include stamping (pin transfer or daubing), and syringe dispensing. The selection of the deposition method largely depends upon the properties of the epoxy used and the minimum

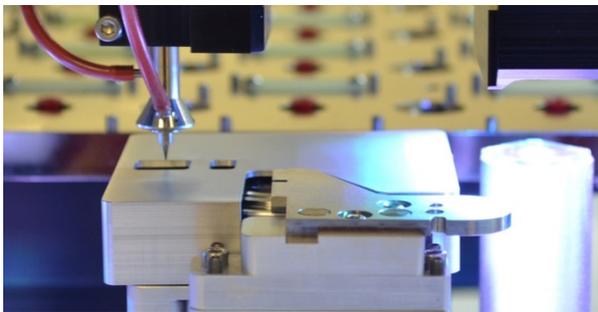
dot size required. Factors such as silver grain size, material viscosity, thixotropic index, and packaging methods all influence the decision of the material deposition method. Often the best solution is stamping because the process requires dots smaller than 0.2mm.

Stamping is used to create very small epoxy dots by touching down in epoxy at the stamping well and then transferring the material onto the substrate. Dot size is determined by the epoxy thickness at the well and the stamp tool profile. In the stamping process, a reservoir of epoxy is presented in a grooved well. The well is rotated so that the material is passed under an adjustable height wiper blade. The height of the wiper blade should be precision adjustable using a micrometer adjustment. The rotating stamping well can have multiple grooves to accommodate multiple types of epoxy.

Stamping does not have to be limited to the transfer of single dots. Gang-arrayed (multiple) stamping tools can be employed to transfer an array of dots simultaneously. These gang stamp tools have multiple points that place the same pattern of dots with each touchdown. This is useful for increased throughput and for precise control over the pattern. Stamp tools can be designed for specific case sizes to place the dot for each terminated end at the same time.

Tool profile is another critical factor of stamping to consider. Tools can be designed with a spherical tip or a flat tip depending on the shape and size that is desired for the dot. When combined with good control of epoxy thickness in the well, the right stamp tool can produce repeatable dots of a very specific height and diameter.

Syringe fluid dispensing is an alternative to stamping. The feature typically includes high-resolution servo driven, positive displacement pumps, for the most accurate dispensing of dots, lines and areas. A precision time/pressure pump can also be used depending on the application, materials and process requirements. Material flow is enhanced by a chamfered design in the needles inside the wall, with the chamfering toward the needle tip. This reduces surface tension, provides for more precise control, and also reduces clogging.



*Epoxy Stamping Well*

### **Assembly Process - Feeding of MLCC Capacitors**

Solutions to meet the challenges of the assembly of 01005 capacitors must include the presentation method and the ability to accurately pick and place the

components onto substrate pads. Presentation methods include tape and reel waffle pack and Gel-Pak with tape and reel being the most common.

Traditional 8 mm tape and reel feeders are not designed to be able to reliably feed the ultra-small MLCC case sizes. MRSI offers specialty 8 mm tape feeders for small case sizes < 0402. These specialty feeders have better indexing resolution to enable small tape sprocket moves.



*8 mm Tape Feeder Bank*

The use of programmable closed-loop force feedback, is required to enable successful handling of these devices. Ultra-miniature capacitors must be picked and placed with controlled forces to avoid mishandling that can result in tombstoning. Specialized vacuum collets are used to maximize the contact area.

### **High-precision placement at high speeds**

When placing ultra-miniature capacitors placement accuracy is a basic requirement. Throughput is only meaningful with achieved accuracy. High yield is only achieved with a high-precision, stable machine. The epoxy and capacitor placement location must be controlled for high yield. Placement accuracy as low as 3 microns at high speeds is needed and is achieved through the use of linear motors and encoders combined with a thermally and mechanically stable platform.

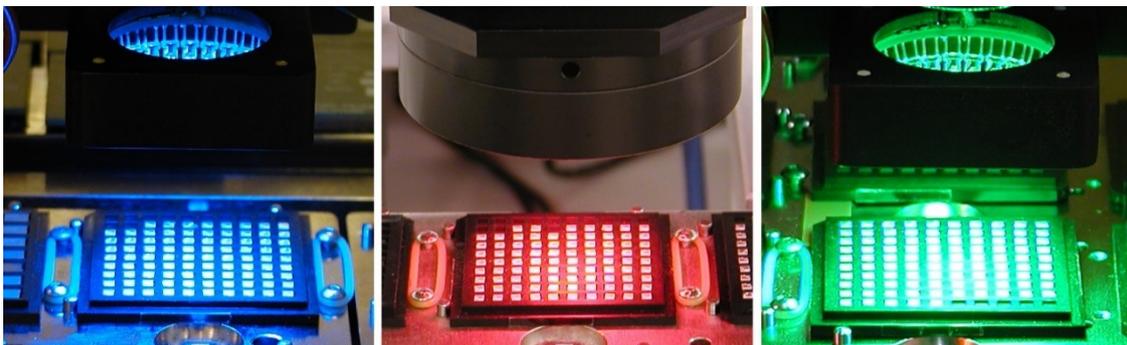
Parallel processing is used to achieve high speeds. Parallel processing examples include multiple pick-and-place heads, "on-the-fly" tool changing, parallel vision alignment, material handling, and multiple bonding stages with parallel loading and unloading.

### Advanced vision and lighting

Another major feature of MRSI's Die Bonders is machine vision, a critical factor for accurate placement and ultra-miniature capacitors. The vision system must align the capacitor outline to substrate pads or fiducials ensuring repeatable and precise placement.

Machine vision is required for alignment of the capacitor outline. This can be done with either with a downward facing camera prior to pick-up or with an upward facing camera that captures the image of the capacitor on the vacuum collet prior to placement.

Optimal lighting conditions are needed for capacitor recognition and for alignment. Multi-color lighting is required to successfully image process a wide range of materials and enable optimum imaging of low-contrast components. Multi-colored (i.e., red, green and blue) ring lighting is a powerful tool when processing challenging alignment surfaces. Lighting intensity must be programmable and include both ring and collimated lights for a complete lighting solution. It also must be possible to individually program optimal light settings for each die and substrate fiducial alignment.



*Multi-colored Lighting*

### Summary

This article reviewed the required die bonder features for successful assembly of ultra-miniature MLCC capacitors for small complex electronic packages such as optical components, and military hybrids. For each of the two end termination pads a single highly repeatable dot of 200 micron diameter is required, with excellent volumetric repeatability, and ultra-accurate dot placement to ensure good mechanical and electrical performance and avoid shorting and silver migration. The ultra-miniature MLCC capacitors must be placed accurately through the use of accurate presentation in special 8 mm feeders combined with machine vision and lighting, force control, and a highly accurate machine platform.

By combining the features described, an application specific die bonder will deliver a flexible solution, which maximizes product yield, throughput, and process control, to ensure a successful solution for ultra-miniature MLCC capacitors. This standardized approach also results in fast machine delivery times which are important to scale production rapidly.

### **Contact MRSI Systems**

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