WHITE PAPER

EVOLUTION OF CERAMIC CAPILLARY

To meet the needs of the ever-changing semiconductor market, the design of ceramic capillaries continues to evolve.

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INTRODUCTION

Changes in semiconductor assembly processing, including the introduction of copper wire, have pushed and accelerated the development of new textures and finishes among ceramic capillary suppliers. Copper wire has increased the level of difficulty to achieve proper welding between the wire and the semiconductor package surface and device.

BACKGROUND

The ceramic capillary was invented by Gaiser Tool Company (now CoorsTek) in the late 1960s and soon became the tool of choice for the ever-growing semiconductor market.

Since its inception, the geometry of the capillary has remained constant to present day with few exceptions aimed at addressing specific challenges, though in general the basic shape has remained the same.

See figs. 1 and 2

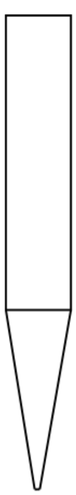


Fig. 1

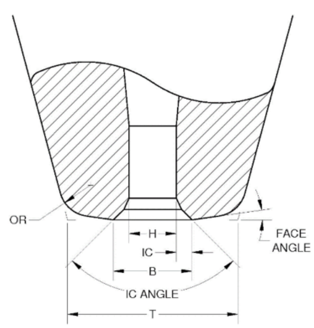


Fig. 2

Basic chemistry of the early capillary was limited to choices such as pure Alumina, single crystal ruby, and quartz.

It was not until the early 1980s when the development of the copper (Cu) wire bonding process began challenging ceramic capillary geometry and its tip surface finish.

The first solution for addressing this new wire bonding challenge was the matte finish. Along with some geometrical capillary tip modifications, such as the double internal chamfer (IC), these changes proved Cu wire to be a reliable substitute to gold (Au). However, while the welding requirements were achieved, the tool's resistance to wear deteriorated. This was expected as the hardness of Cu wire is almost twice that of Au wire.

As part of the research and development to improve Cu wire bondability to bare Cu packages, Gaiser began developing a ceramic thermal etching process with the goal of increasing roughness beyond the matte finish. This process proved a good alternative for Cu wire bonding. In parallel, a chemical etching process was developed at a major semiconductor design and manufacturing facility in Texas, USA.

Both of these methods provided levels of roughness necessary to wire bond even the most difficult package or plating. Unfortunately, neither method met the benchmark cosmetic criteria for shape and form of the second bond (stitch bond). So the processes were considered non-compliant and archived, delaying the transition to Cu wire bonding.

The 1990s brought additional material changes to the ceramic capillary. Zirconium (Zr) was added to the Alumina as a strengthener to improve resistance to capillary damage and wear. During this period Chromium (Cr) was introduced as a base agent for adding color to a new line of ceramic capillaries.

By the late '90s, experimentation and evaluations of Cu wire bonding resumed, but it was not until 2004-2005 that the process reached its peak with formal manufacturing implementation—marking the beginning of new capillary solutions including material improvements, geometrical changes, and surface finishes.

Surface Finish

Ceramic capillary suppliers focused their attention on two basic changes: surface roughness and ceramic composition. These were the two major drivers in achieving a common goal—improving second bond (stitch bond) quality, reliability, and repeatability.

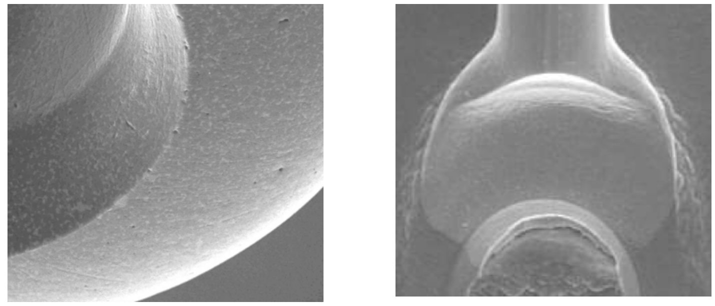
At this time, the old, forgotten thermal etching process was revitalized and presented as a new innovation by some suppliers, and a resurrection for others. Different levels of thermal etching roughness were introduced, all showing good improvements to Cu wire bonding.

As the Cu wire bonding process matures, attention has been focused on tool life durability and performance. Material chemistry has again evolved to create a new array of colors and improved physical properties.

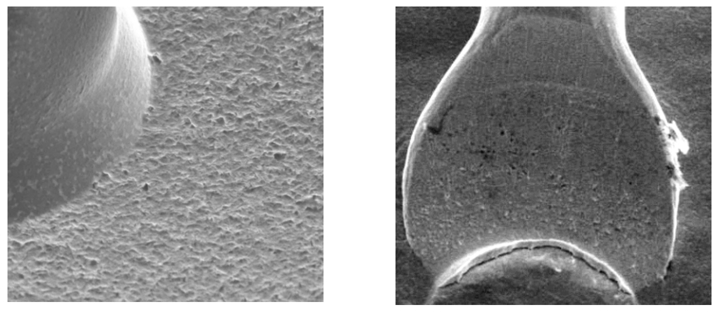
The ever-changing semiconductor industry continues to bring new challenges to the Cu wire bonding process as miniaturization, cost, and performance demands increase. These changes have begun to exhaust the capability of existing finishes and ceramic compositions, forcing suppliers to be creative in finding new and better solutions.

Based upon a combination of texture and geometry, CoorsTek Gaiser has designed a patent-pending finish to address these demands. This engineered design concept has proven effective even under the most severe wire bonding conditions, resulting in a more consistent and reliable bond than current finishes and geometries provide.

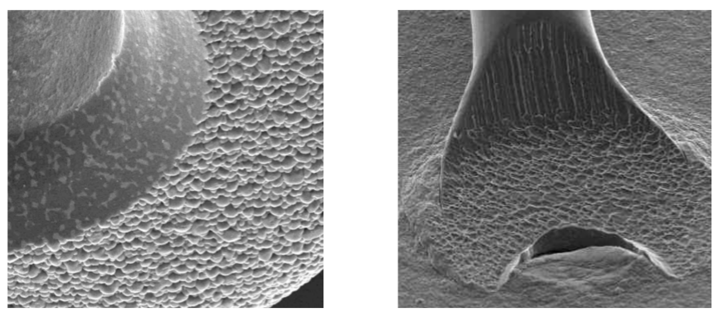
The following pictures show the differences between existing capillary tip surface finishes and the corresponding second bond (stitch bond) achieved when the wire is welded to the semiconductor packaging. This capillary texture and geometry is capable of achieving Cu wire bonds up to twice as reliable, with no additional wear.



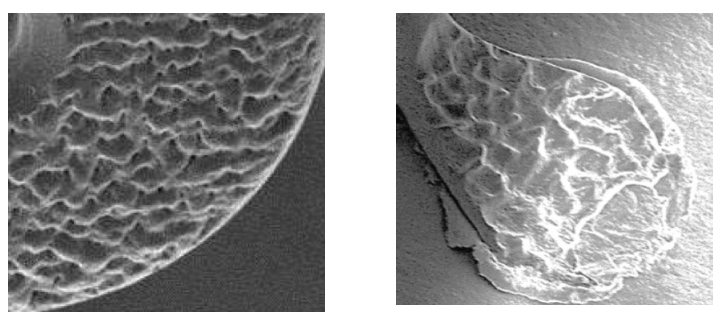
Polished finish and resulting stitch bond



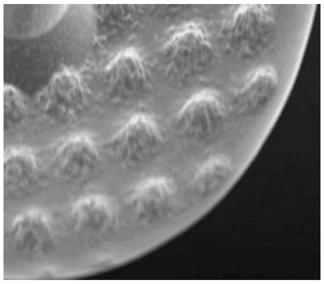
Matte finish and resulting stitch bond

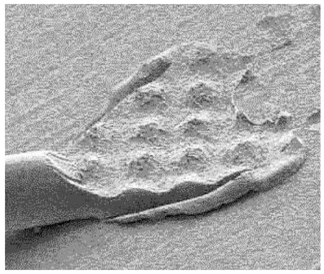


Thermal granular finish and resulting stitch bond



Fused surface finish and resulting stitch bond





Patent Pending finish and resulting stitch bond

CONCLUSION

Chemical, physical, and geometrical properties of the ceramic capillary contribute to the overall control of the energy transferred to the interface of the wire bond, but as packaging challenges increase surface texture is becoming a key element in the success or failure of the wire bond process.

The future of capillary technology has not yet reached its limits. The CoorsTek Gaiser group continues to innovate and engineer solutions for the evolving semiconductor market.

