High Performance mmWave Ribbon Bonding using 1x20 mil Gold Ribbon

David J Rasmussen
Hughes Circuits, Inc
546 S Pacific St
San Marcos, CA 92078 USA
Ph: 760-759-2806
Email: RavidR@HughesCircuits.com

Abstract

With the current trend to higher power and higher frequency used in mmWave (and microwave) applications there is a need to improve the performance of the interconnects. We all know that at higher frequency the skin effect of the interconnect is the primary mode. We have therefore been utilizing ribbon bonding for these interconnects where the skin area of a ribbon wire is much larger on a ribbon than a similar cross-sectional conductor area round wire. We have been using 0.5x2 for many of our small bond pad applications. For the higher power requirements, we have gone to 1x10 mil gold ribbon which represents an upper limit for most fine wire thermosonic wedge bonders on the market. Going to a larger ribbon does have significant advantage for even higher power use.

I have developed a process with the help of Deweyl Tool and TPT Wire Bonders to utilize 1x20 mil gold ribbon which has significantly larger skin area (~42 mil^2) than the ~5.4mil equivalent round wire (~15.8 mil^2) or even 2x10 mil ribbons (24 mil^2). The benefits of a single 1x20 ribbon over two 1x10 mil ribbons is fewer points of failure, narrower bond pad requirements, and consistent loop shapes.

Key words

mmWave, Microwave, Ribbon Bonding, Military, Radar, 5G.

I. Introduction

There is a growing need for higher power and higher performance mmWave 5G and Radar applications. The wider adoption and deployment of phased array Radar with advanced capability to track more objects simultaneously and be immune to jamming is of immense importance in the defense industry. Because of these requirements we need to provide for higher power and higher frequencies. These then lead to the ability of the device interconnects safely handle these requirements.

II. Motivation for study

We are now pushing the limits of the processes used to date with the upper limit of 1x10 mil gold ribbon on most wedge bonders on the market. This limitation is currently being addressed by using multiple 1x10 ribbons placed either adjacent to each other or one ribbon over the other ribbon.

The drawback for these two options:

1) *Both options require four wedge bond attachments (potential failure points).*
2) *The adjacent ribbons require a wider bond pad to allow some space between the ribbons.*
3) *High reliability military electronics requires 100% non-destruct pull testing. thus doubling the pull test time.*
4) *The stacked ribbons are each of different length (affecting signal performance) which is unacceptable in many applications*

For this study we proposed using a single 1x20 gold ribbon with the advantages of just two bond attachments, narrower bond pad width requirement and a single loop profile for consistent signal performance. 1x20 ribbon has significantly larger skin area (~42 mil^2) than the ~5.4mil equivalent round wire (~15.8 mil^2) or even 2x10 mil ribbons (24 mil^2).

We used our TPT HB-16 Wedge Bonder with its 90 deg vertical ribbon feed for this application.

The application that utilized this process on allowed for either two adjacent 1x10 mil ribbons or a single 1x20 mil ribbon. The materials are AlN substrates with gold bond pads and Rogers 6010 PWB with ENEPIG plated finish. We first built these assemblies with the standard two 1x10 adjacent ribbon approach shown below. The problems with this approach became obvious when we tried to place the ribbons as close to each other as possible. The wedge tool disturbed the ribbon loop if we got too close as well as the wedge tool foot impacting the adjacent ribbons bond.

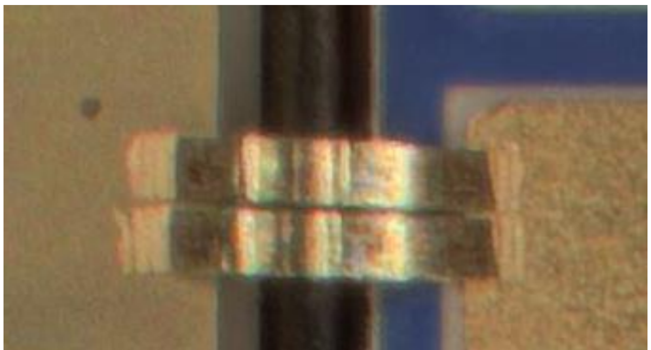

Figure 1 Two adjacent 1x10 mil gold ribbons - good condition

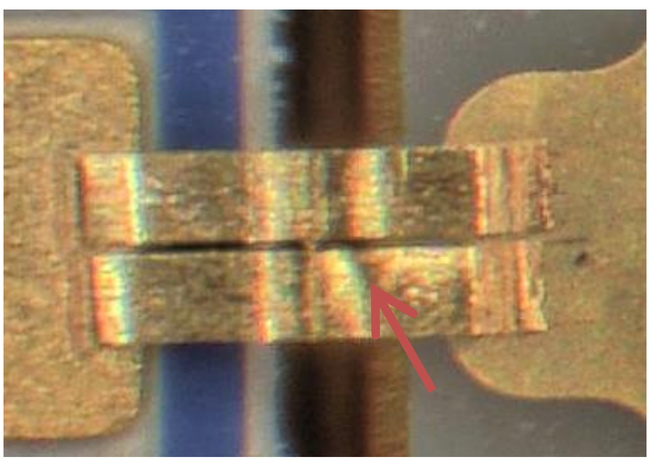

Figure 2 Lower ribbon has disturbed loop - arrow

We then started exploring the possibility of using a single 1x20 ribbon and found the ribbon available from California Fine Wire (though other sources have stated they also have this ribbon size available). Then we tried to find a wedge bond tool that could handle this size ribbon. David Pasfield of Deweyl Tool worked with us to design a tool that would fit this size ribbon. We started with a cross-groove design. But when enough ultrasonic energy was applied to achieve a bond we sometimes got some thin gold strands extruded to the sides of the bond at the groove.

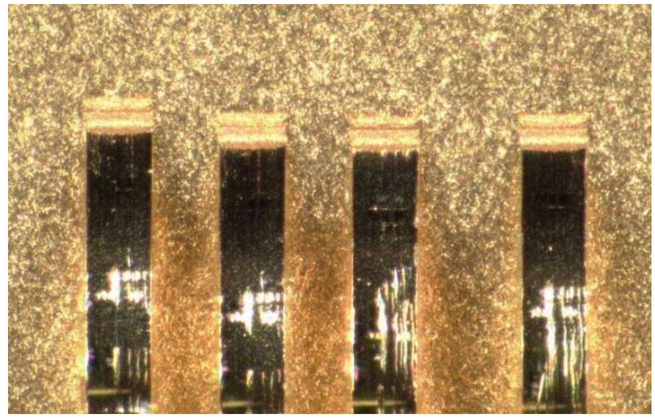

Figure 3 1x20 ribbon using cross-groove tool

We then changed the design to a waffle pattern face which resulted in a consistent bond. These first bonds were close to the maximum setting for force (1,500mN) and ultrasonic power. The TPT bonder however has a high force option which adds either 250mN, 1,200mN, or 2,000mN to the programmable force range. We used the 1,200mN weight which gave me a range of 1,200mN to 2,700mN as shown in Figure 4 below

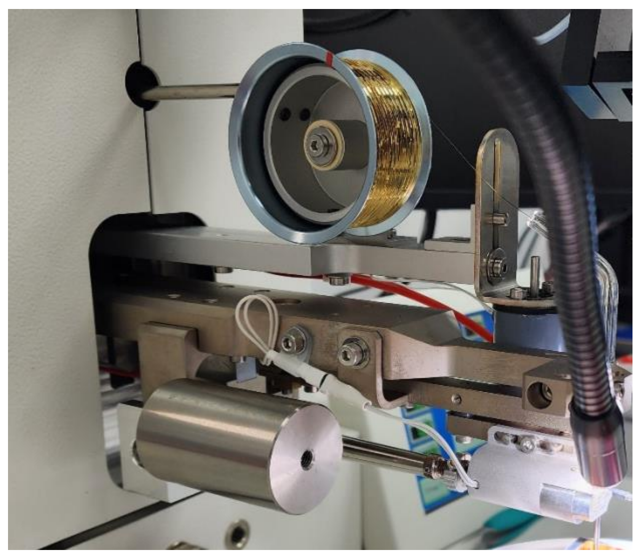

Figure 4 Bonder configure with the 1,200mN weight (cylinder in lower left of image)

This resulted in having a process window that wasn't limited by the machine capability.

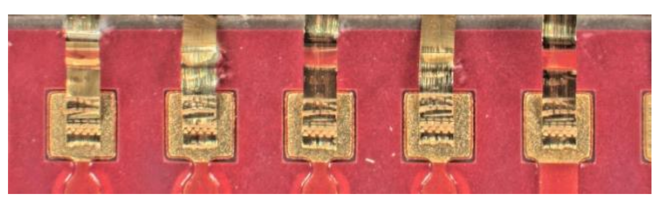

Figure 5 1x20 ribbons using the tool with a waffle face

The image below shows a 1x20 ribbon from the Rogers 6010 PWB to a hermetic D connector pin mounted to the package side wall. We were then able to make a few dozen successful ribbon interconnects.

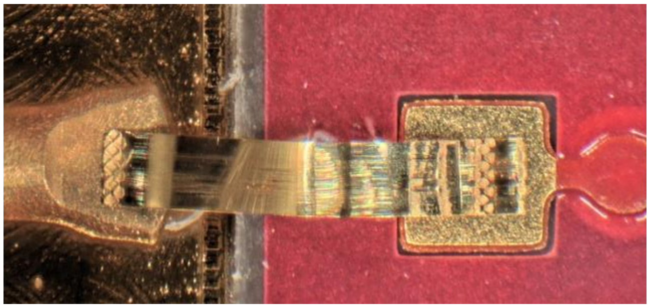

Figure 6 1x20 Ribbon from PWB to D connector pin

We encountered an issue as we explored the process window to improve the ribbon termination at the second bond. Because this ribbon is considerably stronger than 1x10 gold ribbon, the force required to break it is much higher. What occurred was the wedge tool breaking at the back of the ribbon guide slot. We believe the energy released when the ribbon broke “sprang” the ribbon rearward against the slot.

This wedge tool has physical size limitations which we are right against the edge of. The tool diameter is 1/16” with an inside hole diameter of 0.027” the tool foot is 0.004” long and 0.028” wide.

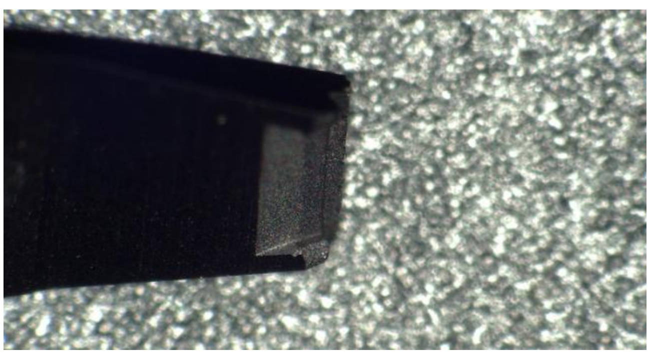

Figure 7 Wedge tool with broken back slot

We then tried various materials between Tungsten Carbide to Titanium tipped. We settled on the Tungsten Carbide with a maximum thickness of back mall for the ribbon slot.

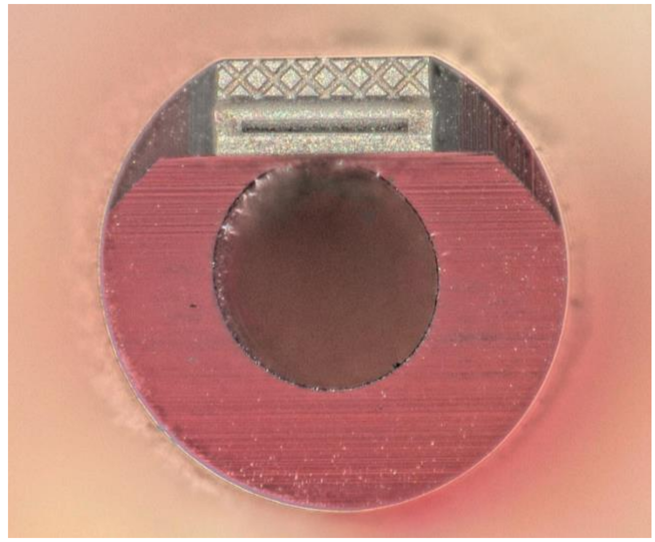

Figure 8 Final tool design

This final configuration has allowed bonding of a few hundred ribbons with good consistency of loop shape and second bond tear-off.

The measured signal functionality with these ribbons was only 0.2db better than 2 1x10 ribbons of equal length and loop shape. But this reduced bonding time and non-destruct pull test time by half with only having to place and test 1 ribbon for each interconnect.

Biography

David J Rasmussen – Hughes Circuits, Inc
546 S. Pacific St, San Marcos, CA 92078
Tel: 760-759-2806

David has over 40 years experience with wire bonding mostly from the equipment manufacturing side and is currently General Manager of Advanced Microelectronics at Hughes Circuits.

Development Support

David Pasfield – DeWeyl Tool Company
959 Transport Wy, Petaluma, CA 94954
Tel: 707-765-5779

TPT Bonders – CWI Technical Sales
704 Ginesi Drive, Suite 11A, Morganville, NJ 07751

References

B.K.Benton of Palomar Technologies Inc, May 2000 in the "Microwave Journal".

The "skin-effect" is discussed in detail in numerous publications. For a selected list of references see http://www.answers.com/topic/skin-effect

Roberto Gilardoni of Hesse & Knipps Semiconductor GmbH, "Ribbon Bonding for High Frequency Applications Advantages of Ribbon and the Impact on the Microwave Market", presented at International Microwave Symposium 2008