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Flip Chip Hybridization Using Indium Bump Technology at ARL

by Kimberley A. Olver

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Flip chip hybridization bonding is a microelectronics packaging technique which directly connects an active device to a substrate facedown, eliminating the need for peripheral wirebonds. Solder material is used as the conductive link between the two parts. Soldier bumps are directly deposited onto the active regions of the device and substrate. The main type of solder bump used at the Army Research Laboratory is the indium solder bump. Indium bump technology has been a part of the electronic interconnect process field for many years. This report discusses the techniques of flip chip hybrid bonding using indium bumps.

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1. Introduction

Flip chip hybridization is a microelectronics packaging and assembly process which directly connects an individual chip (device) to a substrate (readout) facedown, eliminating the need for peripheral wirebonding. Conductive connections are made between the two parts using interconnect bumps consisting of a solder material. Both parts are placed into a Flip Chip Hybrid Bonder and, using thermo-compression as the bonding technique, "flipped" together. Flip chip assembly is also known as Direct Chip Attach (DCA), because the chip is directly attached to the substrate via conductive bumps (see figure 1).

Flip chip hybridization allows for lower lead resistance due to very short conductive bonds, and is a very reliable and robust technique due to the solder joint connections. It is capable of high density connections with a very low profile.

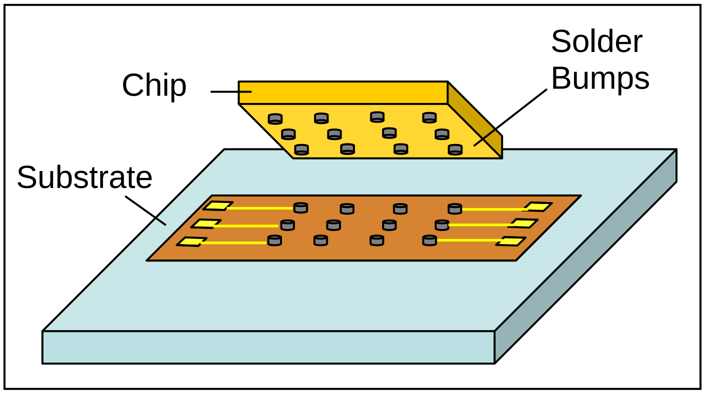

Figure 1. Orientation of chip and substrate for hybrid bump bonding.

The main type of conductive interconnect solder bump used by the Army Research Laboratory (ARL) for direct connection of active devices to substrates is the indium bump. Indium bump technology is a unique process used mainly for flip-chip hybridization of semiconductor components, and has been part of the electronic interconnect process for about 40 years as part of a low cost assembly process. Because of its cryogenic stability, thermal and electrical conductivity, self-adhesive (ductile) nature and relative ease of application, indium is a good material for these applications.

2. Process Overview

2.1 Indium Bump Placement

In the indium bump process, indium is deposited as the last step in the photolithography/ metallization processing of a device wafer. Indium bump masks are designed for both top and bottom parts. If commercial readouts are a preference, they should be purchased with indium bumps already in place. For a 5 to 6 micron high indium bump, an 8 to 9 micron thick photoresist layer is used. A vacuum-thermal evaporation of 300Å chromium for adhesion followed by several microns of indium is completed, a metal lift-off is done, and indium bumps are the result. The height and shape of the bumps are determined by the photoresist used and the mask design.

A lift-off of the extra material produces indium bumps several microns in height. Both top and bottom components are processed with indium bumps, and using a flip chip bonder as illustrated in figure 2, the parts are either compression or thermo-compression bonded together. Bump area and the total number of bumps determine the amount of pressure needed for successful bonding. If a substantial amount of indium is being used (e.g., for thermal conductivity) thermo-compression bonding will be necessary.

In designing indium bump masks for the device and submount system, the indium bump masks for top and bottom parts have to be mirror images of each other for flip chip bonding purposes. The mask design of the actual indium bump is variable. Indium is a soft metal, and because it is evaporated onto the wafer, the shape of the bump can be chosen to best suit the application. Round pillars, square pads, and ovals are some of the shapes of bumps used. The height of the indium is also variable simply by using a thinner or thicker photoresist and evaporating less or more material.

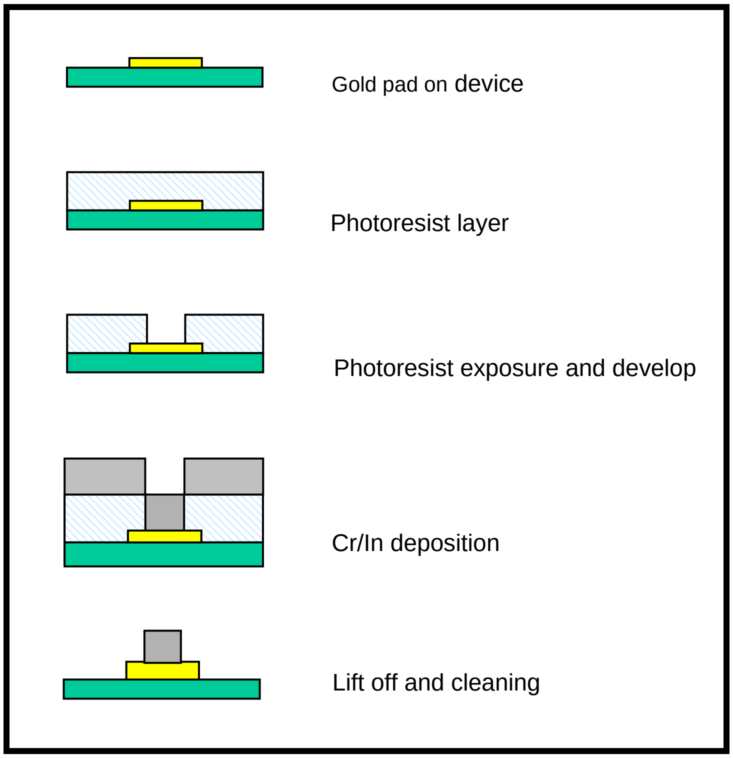

Figure 2. Processing steps for evaporating indium bumps onto Au pads.

2.2 Flip Chip Hybridization

Connections are made between two parts using solder bumps made of Cr/In. The two parts are mounted onto the upper and lower chucks of the bonder with bumps facing each other. (See figure 3). An optical borescope system connected to a camera is moved into place between the two parts, and the bumps are aligned in the x and y direction. A second separate optical collimation system is then brought into place, and using a reflected beam of visible light, the rotation angle (theta) and planarity are corrected on the lower vacuum chuck. The borescope is removed, and the bottom part moves up to the top part while keeping all alignments constant. The bumps make contact, and through pressure (and sometimes heat), the parts are connected. The amount of pressure and (if used) the heat needed to melt the indium vary with the materials being used in the system, as well as with the size and distribution of the indium bumps. After some experimentation, it was found that for 20 micron square bumps, a compression force of 0.5 grams per bump works well. For example, the total compression force required to hybridize a chip containing an 8 x 8 array of 20 micron square indium bumps would be 32 grams (0.5 grams per bump times 64 bumps), and a large format array (1000 x 1000 array) would require a total bonding force of 500 kilograms.

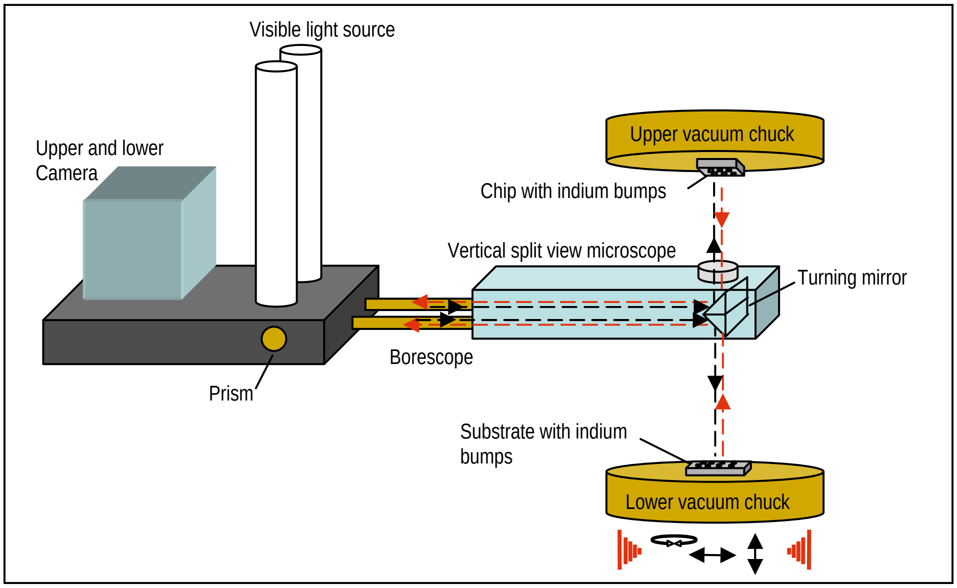

Figure 3. Alignment of the chip and substrate in the bonder with a split view microscope and camera system.

3. Conclusion

Flip chip hybridization, also known as DCA, is a well proven packaging technique used for the direct connection of processed device chips to readout devices and submounts. A grid of solder bumps on the surface of the active area on the device chip is joined directly to a corresponding set of solder bumps on the substrate. The main advantage of flip chip hybridization, compared with other packaging techniques, is that peripheral wire bonding is avoided and the very short electrical connections allows for lower lead resistances. It is a robust, reliable technique due to the solder joint connections.

The main solder material used by ARL for flip chip hybridization is indium. Indium bump technology is a process used to place indium bumps on to the active sites of the device chip and corresponding submount when bonding the two parts together facedown. There are advantages of using indium as the solder material. It is relatively inexpensive, it has good thermal and electrical conductivity, it is ductile, and it is cryogenically stable. A disadvantage, however, is that indium bumps are not easily reworked.

References

1. Micro and Nanotechnology Commercialization Education Foundation (MANCEF) www.mancef.com.
2. Research Devices, Inc. Flip Chip Aligner Bonder Model M8-A User's Manual, Piscataway, NJ 08854,(now part of Laurier Inc), Londonderry, New Hampshire, 03053.
3. Course Material written for 2002 class titled "Flip Chip Assembly Initiative, The National Training Center for Microelectronics, Northampton Community College, Bethlehem, PA. 18020 www.northampton.edu.
4. Olver, Kimberley A. "Evaporated Indium Bumps for Flip Chip Assembly", Tutorial #38 www.flipchips.com, February 2004.
5. Paterson, Deborah S.; Elenius, Peter; Leal, James A. Wafer Bumping Technologies: A Comparative Analysis of Solder Deposition Processes and Assembly Considerations. *SUSS Technical Bulletin*, Karl Suss America, 1999.
6. Riley, George A. "Introduction to Flip Chip; What, Why, How", tutorial #1, www.flipchips.com, October 2000.

Glossary

Flip Chip Hybridization – A packaging technique introduced by IBM, where the chip is attached to the plastic or ceramic substrate facedown without using cumbersome peripheral wire bonding. A grid of solder balls (bumps) on the surface of the active area of the die is joined directly to a corresponding set of solder pads on the substrate. An integrated circuit designed for facedown mounting is attached by controlled-collapsed solder pillars on input/output pads of the device.

DCA – Direct Chip Attach – a chip directly attached to a substrate, board or carrier by conductive solder bumps.

Borescope – an optical device (as in a prism or optical fiber) used to inspect an inaccessible space (i.e., an engine cylinder).

Hybridization – the act of producing something that initially has two different types of components, and bringing them together in order to perform a function.

Readout device – any microelectronic device that presents data output for immediate use.

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