Wire Bonding: Thermocompression Bonding [1]

Semiconductor chips must be linked electrically to the outside world in order to function. This electrical linking is achieved by means of tiny metal wires that are physically bonded to the semiconductor chip on one end and to an electrical connector on the other. The bonding of the wire to the surface of a semiconductor chip is a difficult task. The wire must make a good electrical connection that will not degrade with time.

The earliest means of bonding wires to commercially produced silicon semiconductor devices involved tiny balls of solder that in essence soldered the wire to the chip. These solder bonds proved difficult to produce reliably. Sometimes the joint was mechanically weak; at others the solder joints would form a diode junction with the semiconductor materials and thus degrade the performance of the semiconductor.

Thermocompression bonding, the innovation under consideration, involves heating the semiconductor surface to about 200°C to 300°C and then simply pressing the wire to be bonded against the semiconductor chip surface at the appropriate place with a pressure from 5,000 to 10,000 lb/sq in. In a few seconds a bond with excellent physical and electrical properties is formed. The machine that performs this task is called a thermocompression bonder.

Development History
Thermocompression bonding was developed by three scientists of Bell Laboratories: O. L. Anderson, H. Christensen, and P. Andreatch. Most of the work of this team was performed in the 1955–58 time period. The team published its findings,[2] and the need was so great that many semiconductor manufacturers built their own thermocompression bonders in-house in the 1957–59 period.

Commercialization
The first commercial thermocompression bonder was offered by Kulicke and Soffa in late 1959. Demand for the product was so strong that within a year of introduction, net sales exceeded $l million.

K&S observed thermocompression bonding in production equipment that was operating at a Western Electric semiconductor plant in 1958. K&S engineers made only minor mechanical modifications to the Western Electric thermocompression bonder before commercializing it.

Wire Bonding: Ultrasonic Bonding
The ultrasonic bonding of metals involves rubbing together the two pieces of metal to be bonded with such high energy that surface impurities on the two metal surfaces to be bonded are scrubbed away and the underlying atoms of metal brought into close enough contact to form a good bond. In ultrasonic bonding, the energy for mechanically rubbing the two pieces of metal together is provided by a tool that vibrates mechanically at an ultrasonic frequency.

Development History
Ultrasonic bonding as a general welding technique was discovered in the 1950s. Its first application to the attachment of wires to semiconductor chips apparently occurred in the mid-l960s, according to interviewees at Sonobond Corporation, Westchester, Pennsylvania, a supplier of ultrasonic welding equipment. Who was actually first to develop an ultrasonic bonder for semiconductor manufacturing use is not clear. It appears that Sonobond initially supplied ultrasonic transducers — the generators of ultrasonic energy needed for welding — to Fairchild and Motorola who then designed the first ultrasonic bonding equipment-in-house.

Commercialization
Ultrasonic bonding equipment for the bonding of wires to semiconductor chips was commercialized by Sonobond in the 1960s. The corporation initially provided only the source of ultrasonic energy to semiconductor manufacturers but later commercialized a complete machine for the ultrasonic bonding of wires to semiconductor chips.

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[1] This material is from the Appendix of *The Sources of Innovation* by Eric von Hippel, Oxford University Press, 1988. This appendix is available at `web.mit.edu/evhippel/www`.

[2] O. L. Anderson, H. Christensen, and P. Andreatch, *Technique for Connecting Electrical Leads to Semiconductors*, **Journal of Applied Physics 28**, No. 8 (August 1957): 923.