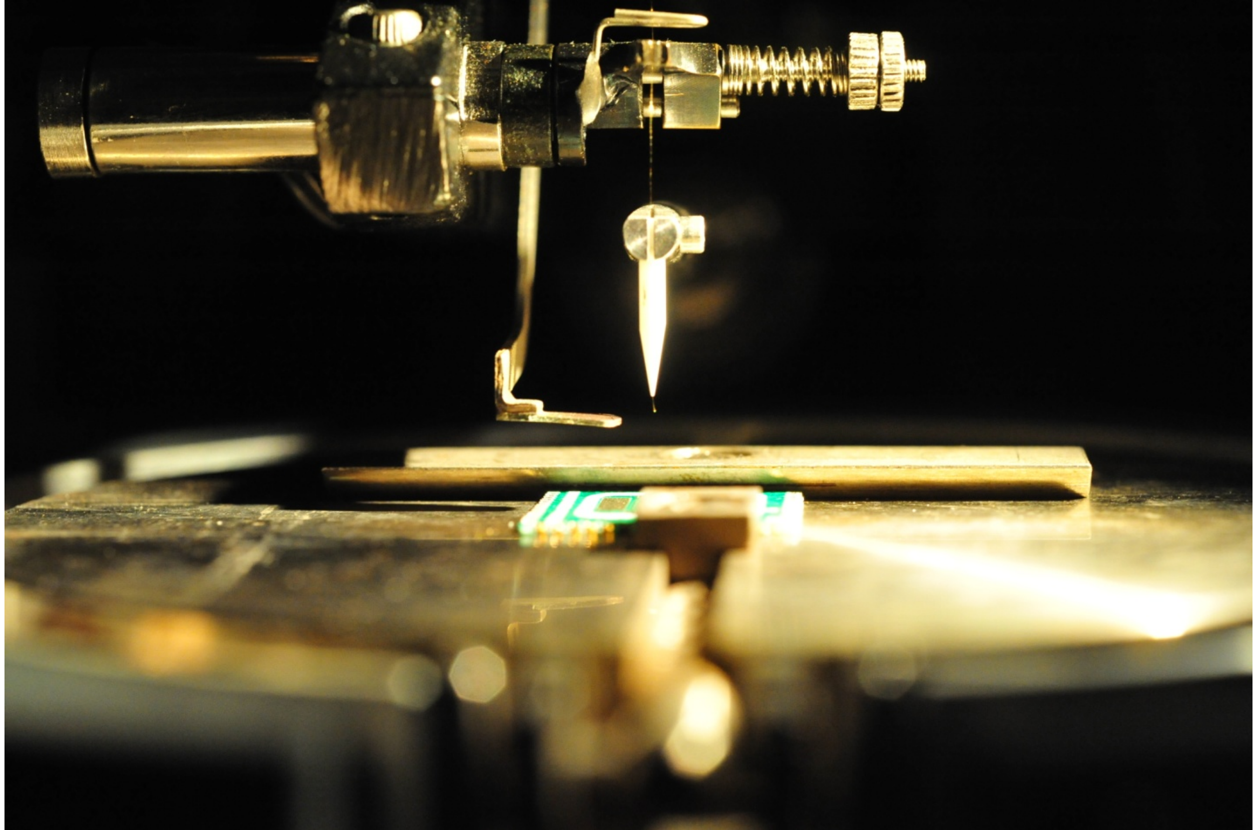


S tandard O perating P rocedure

For

Kulicke & Soffa

Model 4124

Ball Wire Bonder

Introduction

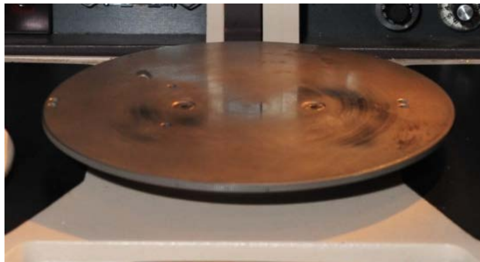
The purpose of the gold ball wire bonder is to provide conductive leads from an integrated circuit chip or any other device needing connectivity so that power can be applied to and signals can be received from the finished devices. Typically the device is mounted on or in a standard PACKAGE but in some cases directly to a printed circuit board or other substrate. Ball bonding requires that the first bond be a ball type bond and the secondary bond be a capillary wedge bond. The bonding process requires the precise application of heat, ultrasonic energy, physical force and time to produce a durable connection between the device and the substrate.

Safety considerations

During the bonding process a high voltage electrical pulse is generated to form the bonding ball on the tip of the wire; contact with the wire during this time will result in personal injury and or severe damage to the device. As part of the process is significant heating of the device and substrate, care should be given not to touch the sample holder and that all materials used should be able to withstand temperatures in the 150C to 200C range. Lower temperatures can be used at the sacrifice of bond strength and longevity. The unit has many moving parts and fragile structures and care must be taken to design your process so as to not block or damage them.

Machine "Anatomy"

Starting from lowest center moving counter clockwise around the machine;



Base plate; the flat broad metal plate that is interconnected with the chessman to hold the chuck assembly and precisely move it under the bonding head.

Chessman; the mouse looking apparatus that moves the base plate. located on the chessman are the bond cycling button (corresponding the left index finger position) and the wedge stitching button (corresponding to the left thumb position).

Bond cycle button; pressing this cycles the bonder through the bonding cycle in a semiautomatic fashion. Pressing and holding the button will take the bonder to the search phase of whatever portion of the cycle you are in (ball or wedge).

Wedge stitching button; pressing and holding this button while operating the bonding button will cause the bonder to make a wedge bond and return to search so that multiple "stitches" can be made (this button will work only for the wedge portion of the cycle but will work whether using semiautomatic or manual).

Power switch; Guess what this does

Chuck or work holder temperature control; used to adjust the temperature of the chuck and the work piece. Press and hold the $°C$ button and adjust the set point (normally 150 - 200) using the knob to the left.

Set-up / reset switch; this is a three position switch where the down-most position is momentary. Normal position is center and pressing down-ward will reset the bonder to the beginning of the cycle.

Clamp Switch: in the down position the clamp is in automatic mode and held open for a period of time in the up position. it is used for threading and feeding wire and will disable normal cyclic functions while open. If held open for too long it will time out to protect the solenoid and the machine will have to be reset.

Test switch: it is a momentary switch that will activate and apply ultrasonic energy to the bonding tool.

Motor switch; there is no reason to use this switch DO NOT TOUCH.

work holder or chuck connector: applies power to and receives temp data from the chuck .

Capillary safety lever; prevents the bonding tool from moving in its full range during testing and set up.

Ball size knob; adjust the voltage of the EFO (electronic flame off) thus is a factor in the size of the ball at the end of the gold wire.

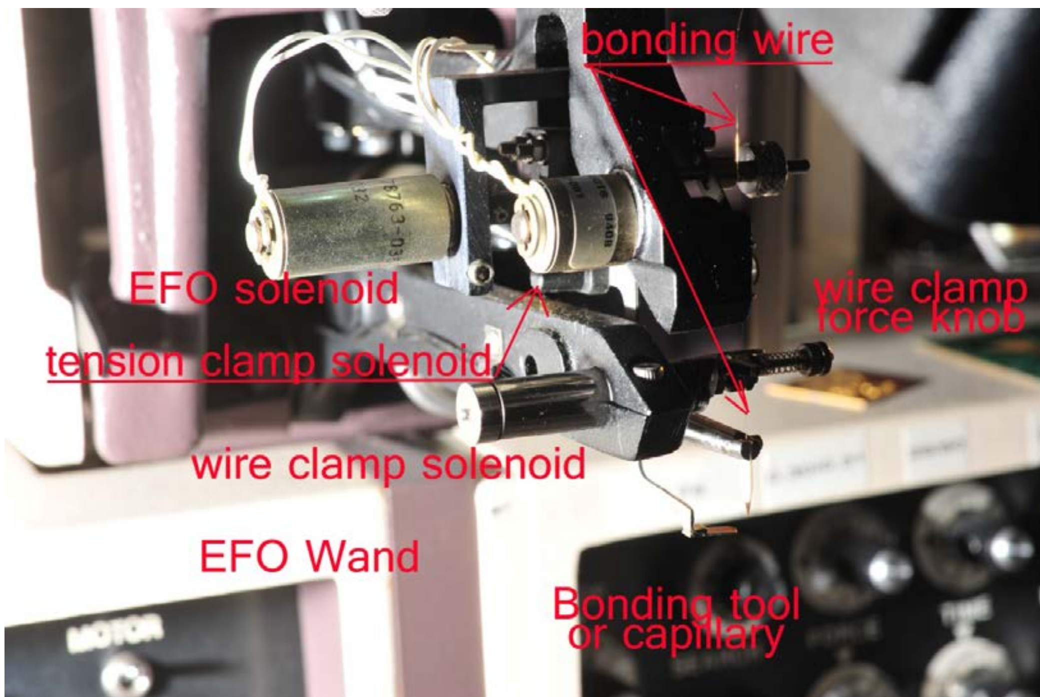
EFO on / off switch and indicator; directs high voltage current to the EFO wand.

EFO button; used to apply a HV spark to the wire manually. Caution: activating this button while touching the EFO wand will knock you out of your chair. if wires or high parts of the work piece contact the wand while HV is applied the device will likely be destroyed.

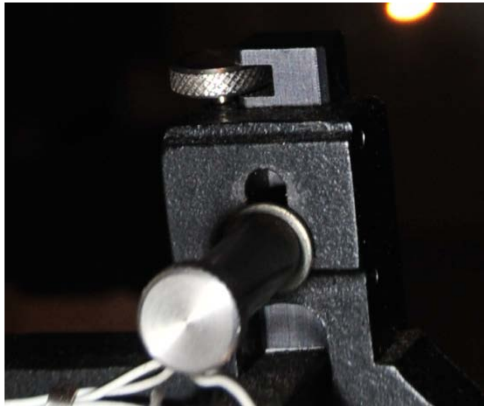
Fiber lamp: provides work piece lighting and is a source of light for the spotlight as well.

wire spool holder; protective dust cover for the wire spool. Protruding from the bottom of this assembly is a long thin leg with a loop at the end called the kicker.

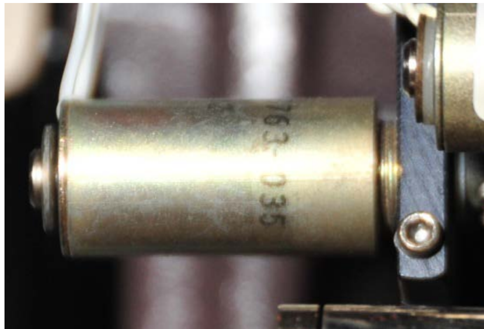
Spot light housing; used to adjust the position of the spot light as well as the focus on the work piece bonding point.



Bonding head: The bonding head is the module that has the moving parts that feeds the wire and makes the bonds. It consists of the following parts.



EFO wand height adjustment and locking knobs, for setting the proper distance between the wire tail and the wand

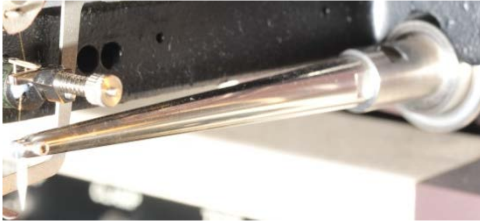


The EFO wand solenoid, which moves the wand under the wire during the ball making process; this solenoid can be actuated by hand

The wire tension clamp and solenoid, the clamp loosens to freely feed wire between bond phases with a set tension that straightens the wire as it is fed.

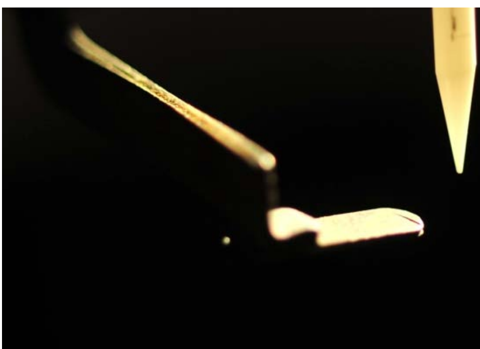
The main wire clamp, firmly holds the wire when needed and releases when feeding wire. It can be manually actuated

(with care). both of these clamps have force adjustment knobs that must be precisely adjusted for proper function. This clamp also clamps the wire with the proper timing to produce the proper tail length for making a new ball at the end of the bonding cycle.



The ultrasonic transducer, produces and focuses the ultrasonic energy to the tip of the bonding capillary.

the Capillary, a hollow high density ceramic tube through which the wire is fed and is the tool part that conveys the wire and bonds it to the work piece.



EFO wand; moves to a position under the tail of the wire in the capillary and produces a high voltage spark to produce the ball on the wire.

Loop Knob; sets the amount of wire that is fed between bond 1 (ball) and bond 2 (wedge).

The next four pairs of knobs have the same function for their respective bond phases although their settings will be different.

Search knob; sets the height to which the capillary travels over the work piece when the chessman bond button is pressed and held.

Force knob; adjust the amount of downward force that is applied to the wire and work piece when the bonding button pressed and released.

Time knob; sets the duration of the ultrasonic energy pulse.

Power knob; sets the amplitude of the ultrasonic energy pulse that is applied to the wire -work piece interface.

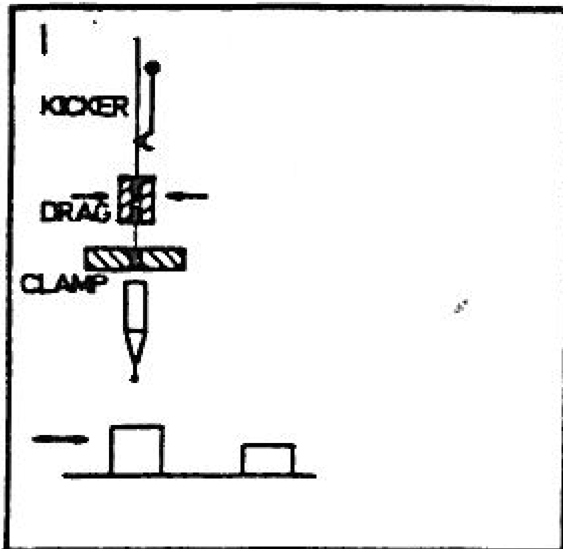
LED indicators; indicate which phase of the bond cycle the machine is in and when ultra sonic energy is applied.

Manual Z lever; manually lowers the capillary to the work piece and activates the bonding process when in the lowest position then returns to home position. if a cycle is initiated using this lever the chessman buttons are disabled until the cycle is complete. One can be very creative and careful with this lever.

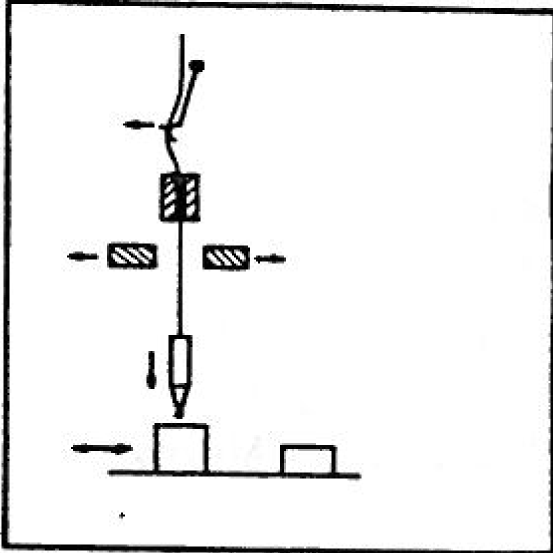
Stereo Zoom Microscope. can be manually tilted up and down to aid in threading, manually making balls, inspecting capillary damage, of course the main use is viewing the bonding process.

The Bonding Process Cycle:

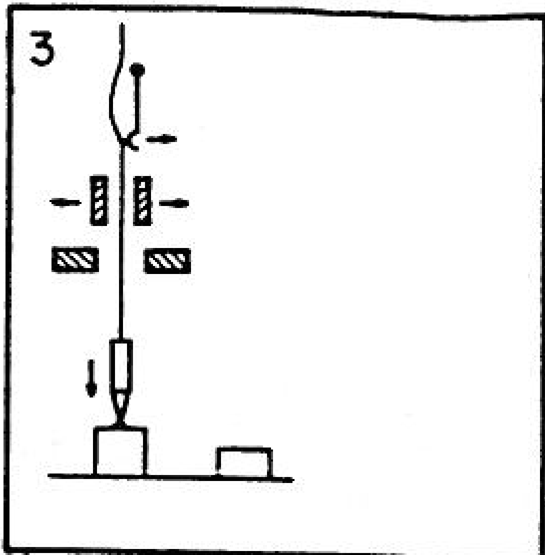
There are nine steps to the bonding process when using the chessman (semi-automatic mode) using the bonding and stitching buttons.



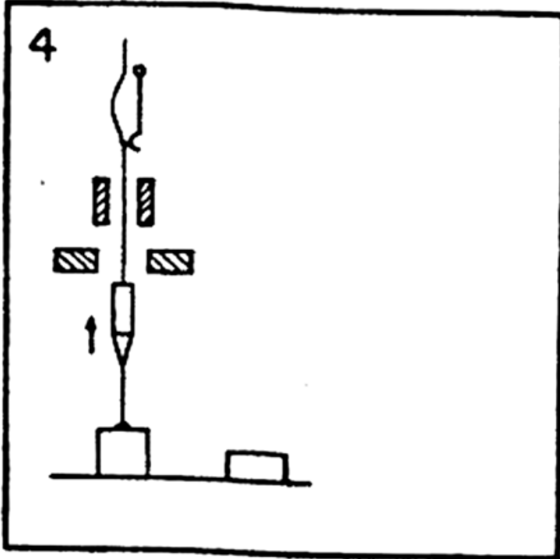
Step 1: Start of the cycle. the bonding head is in the reset position. the operator positions the work piece so that the site of the first bond is under the spot light. The ball is ready. Notice that the tension and wire clamps are closed.



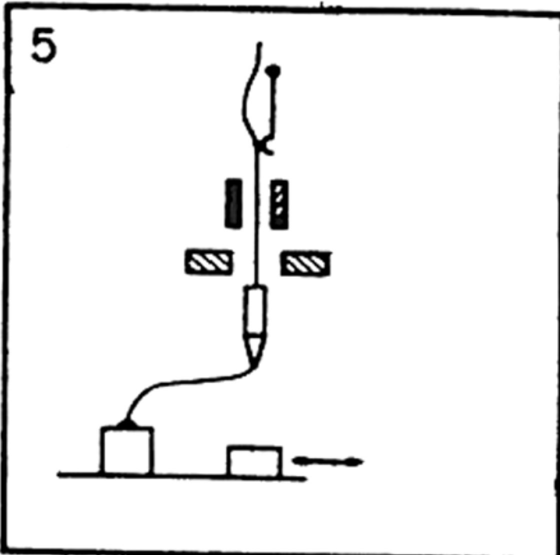
Step 2: Press and hold the bond button on the chessman (this should only be done if you are sure that all of you height settings are correct). The wire clamp opens and the kicker pulls out slack in the wire, The capillary descends to the first search position and stops hovering over the work piece. The tension clamp gently pulls the wire so that the ball is seated in the capillary tip. Move the chessman in x and y to precisely place the tip and ball over the bonding pad (TRICK!!! You can adjust the search knob on the fly, with care, to aid you in precise placement).



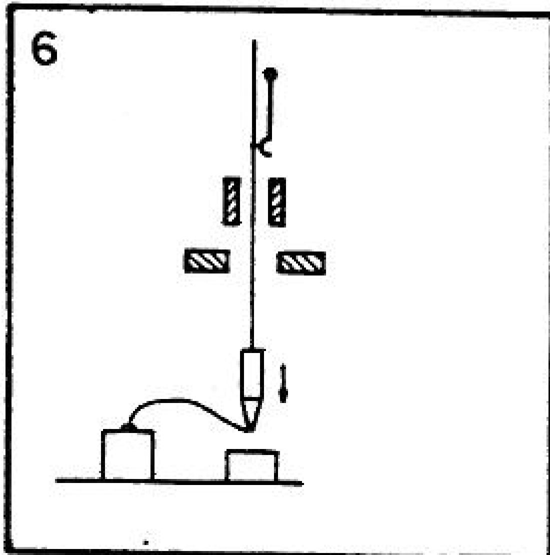
Step 3: Release the bonding button. The capillary drops to the bond pad and the bond is made as follows. The force actuator applies downward force, the ultrasonic generator fires for the set time and power. the tension clamp opens and the kicker returns home.



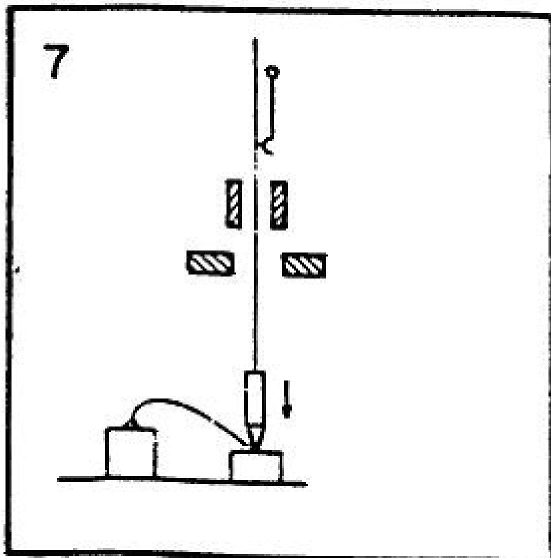
Step 4: the bonding head moves up to the set loop position feeding wire below it.



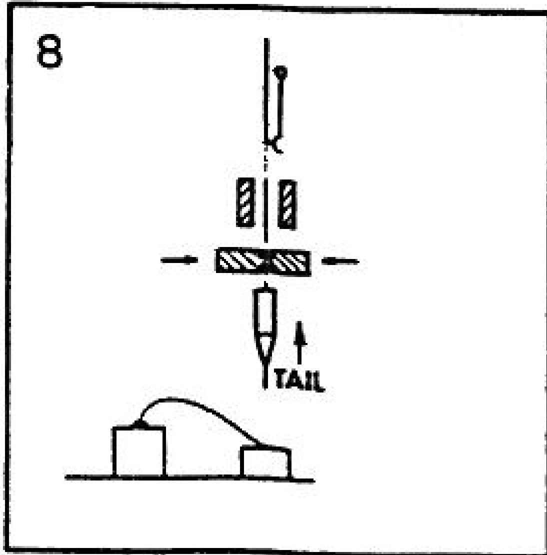
Step 5: Move the work piece so that the spotlight is at the position of the second bond (the wedge bond)



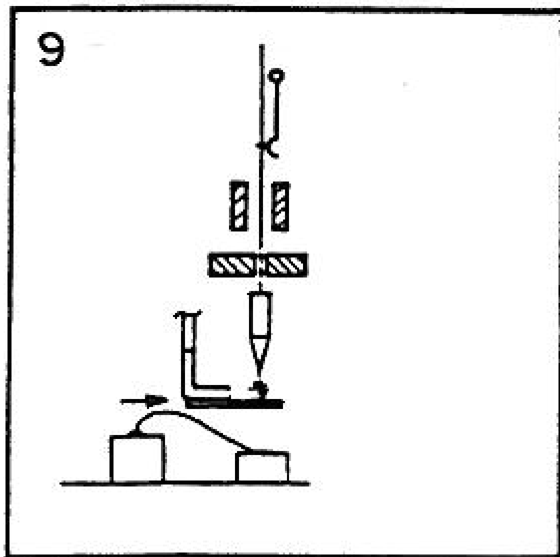
Step 6: Once again press and hold the bonding button on the chessman. The capillary drops to the 2nd search position and hovers allowing precise placement of the bond (be careful not to move too far). instances where the second bond is fragile the stitching button can be held here to repeat steps 6 and 7 as many times as needed.



Step 7: Release the bonding button, the capillary will lower to bond site and the bond will be made just as with the first bond but with the 2nd bond parameters.



Step 8: after the bond is made the head will start to move to the reset position. after the capillary lifts and feeds a preset length of wire the wire clamp will close, tearing the supply wire end from the 2nd bond site and creating a tail underneath the capillary of a specific length.



Step 9: When in the reset position the EFO wand will move under the tail and fire creating a spark the melts the end of the tail creating a ball.

The bonding cycle is modified when the Manual Z lever is used. The operator has full control of the movement of the capillary by varying the position of the lever, when the lever is moved from the fully up position the clamps open as in Step 2 and the operator can maneuver and search with the lever for precise positioning. Once found the lever can be pressed all the way down to activate the ball bond. lifting the lever slowly to what looks like a good loop position (or all the way and back down to a good loop position) and repositioning for the second bond. pressing the lever all the way down again activates

the 2nd bond then the head returns to reset position and a new ball is automatically made. learning the manual process aids in making difficult bonds.

Process and sample preparation

IT IS HIGHLY RECOMMENDED THAT YOU PREPARE SEVERAL TEST DEVICES WITH SIMILAR CHARACTERISTICS TO BE USED AS TEST AND SETUP DEVICES; TO ATTEMPT TO BOND A SINGLE ONE OF A KIND DEVICE WITH NO STARTING POINT IS DOOMED TO FAILURE AND DESTRUCTION!!!

Extensive pre-preparation of the sample and process is required before you attempt to use the machine. You are required to have a complete properly scaled schematic diagram of the device, substrate and lines indicating the paths of the wire from the device to the package. Die bonding adhesives must be strong, fully cured and able to withstand the process conditions. Device pads must be of materials that are compatible and durable to the bonding process. If they are not then there will once again be sacrifices in strength and durability. Excess adhesives and other materials that may interfere with the bonding process must be removed. The device and substrate must be pristinely clean and free from residue and particulate debris. The materials that the device bonding pads are made from are critical and highly variable results can be had if the wrong materials are used; consult staff for advice on this matter. Devices, substrates, packages and PCBs should be designed from the beginning so that they can be wired without crossing wires. Wire runs should be kept as short as possible and runs, longer than one Cm, are impractical because the tire tends to sag with time and can cause shorts. Operators who plug capillaries because they are not following these rules will be charged for the capillary replacement.

The die and substrate bonding areas must be in contact with a heat source so if there are bottom side features and irregularities then some method must be devised to conduct the heat; ask staff for readymade adapters. Some MEMS devices cannot be bonded as the ultrasonic energy can destroy them. Devices with fragile parts like membranes, floating mirrors and cantilevers must be designed so that the contact pads have the appropriate separation so the US pulse leaves them intact. The maximum work-piece size is about 3 inches square. If all these criteria make it unworkable then there are other methods of making interconnects that, although labor intensive, are viable possibilities.

Initial Bonder Setup

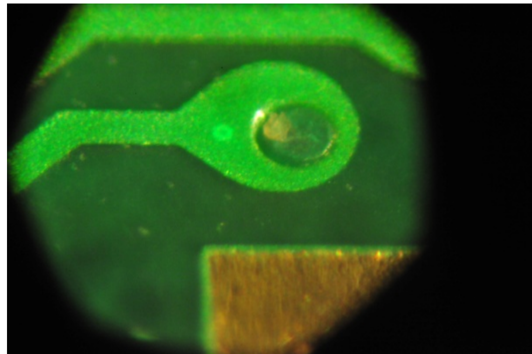
It is critical that the parametric values of the machine be proper for the device that is currently placed on the chuck. It is highly recommended that a detailed notebook be maintained of all the setting

for each specific job. One of the worst things that you can do to a machine like this is to start adjusting parameters randomly without a complete understanding of the consequences. For example; too much ultrasonic power applied to a mal-adjusted capillary will cause the wire to melt in the capillary causing a permanent blockage.

The parametric labels on the machine are a good starting point for dies of less than a mm in size epoxy bonded to ceramic packages about a cm square. Yes , in this case, size matters. THESE VALUES SHOULD BE RESET AT THE END OF YOUR BONDING OPERATION.

Loading the work piece and chuck height adjustment:

It is critical that the work piece height be adjusted to the machines virtual "zero" plane. The chuck is height adjustable or should be if you are providing your own. Turn the base of the chuck counter-clock wise to lower the height, start with the chuck in the lowest position (the base screwed all the way in). Clamp the work piece to the surface of the chuck and set the base on the edge of the bonder plate and carefully slide it to the center under the bonding tool and capillary taking care that no contact with the tool is made if there are tall parts to the device. Slowly adjust the height until the pointer light (a small green spot of light) appears, move the chuck so that the spot falls on the lowest part of the work piece and continue to adjust height until it is a small ring of light and then continue until the center just fills in providing a spot about 50 um across. If this spot is in correct adjustment then the height should be at bonder zero.



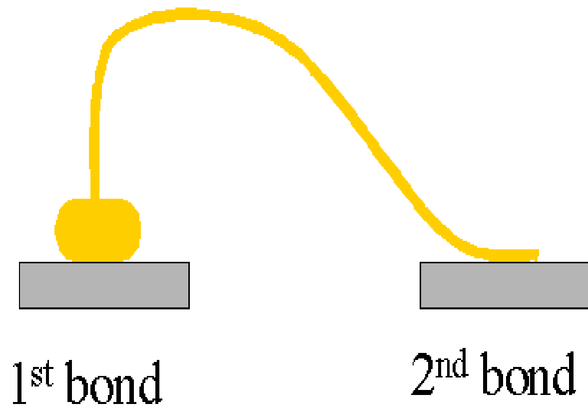
Confirm proper positioning as follows;

Move the capillary safety lever to the up position; this will keep the capillary from impacting any unwanted surfaces. Turn the loop control knob to 10. Press the bonding button on the chessman; this will safely cycle the machine through the through the first bond and into the loop control phase of the cycle. Slowly, while watching in the scope, lower the capillary safety lever to its lower stop. If it looks like the capillary is going to impact the surface of the work piece then return the safety lever to the up position and lower the chuck height and try again. When you can lower the safety lever all the way then move to the loop control knob and adjust it from 10 towards 0 while watching in the scope. Once again, if impact looks probable, raise the safety lever and adjust the chuck. The goal is to have the gold ball just touch the lowest part of the work piece when the loop is set to zero. CAUTION never adjust or move the chuck when the capillary is close to or in contact with the work piece, the capillary, wire and ball are all

very fragile; always raise the bonding head with the safety lever before making any adjustments. When you are satisfied that these conditions are met then adjust the loop knob so that the capillary tip is well above the work piece and will not hit any of the higher components. It is advisable to do a test bond on the ground plane of the work piece (usually the lowest) to see if the other positional parameters are met as follows.

Find a bonding surface with sufficient space to do a few test bonds. Turn the first search dials up several rotations (both searches and the loop zero and nearly identical but not exactly). Press and hold the bond button on the chessman; this will bring the capillary down to the first search position. Continuing to hold the button maneuver so that the spotlight is on a bond pad on the die then adjust the 1st search so that the capillary tip hovers a comfortable distance from the surface of the die (usually about one ball width). After satisfied with the positioning maneuver to a safe area (usually somewhere on the ground plane) and release the bonding button. The capillary will lower and make a ball bond on the surface and then move up to the preset loop position stringing wire below it. Move the chessman so that the spot light is 8 to 10 ball diameters away from the ball then press and hold the bond button. The capillary will move down to the height of the second search as set allowing farther adjustment with the search dial so that it hovers just above the bond point. Watch this closely in the scope because it happens fast. taking care not to move the chessman release the button; the capillary will lower and make the wedge bond, start to rise leaving wire trailing behind briefly then tearing the trailing wire from the surface and returning to the reset position where the EFO wand will make a new ball on the trail. Check to see that all of this was done correctly. If the chessman was not moved look to see if the spotlight falls precisely where the capillary dented the work piece during the wedge bond; if not adjust the spot using the x and y adjustment knobs on the spotlight column.

Assess the overall quality and characteristics of the bond. Of course both bonds should stick. If they did then ideally the ball should remain relatively round with a slight dent on top caused by the capillary circling the wire. The wire-ball interface should be straight and smooth. The wire should start a gentle curve toward the wedge bond about two ball diameters above the ball and terminate at the wedge without touching the substrate beforehand. The wedge should look like a fish tail, crescent shaped and symmetrical to the wire. Inside the wedge crescent there should be a shallow round indentation caused by the capillary that is perfectly round and even in depth.



If the bond does not look like this then consult staff for adjustment recommendations. Should the wire loose the ball, or come out of the capillary consult staff for special procedures for fixing the problem. Under no circumstances are non-staff operators allowed to make adjustments to the machine beyond basic bonding parameters. After initial training on the machine, it is recommended that operators make appointments with staff to assist with fine tuning techniques for their particular devices.

Finally, welcome to the fine art of wire bonding.