Subprotocol: PUB Bonding of Parylene MEAs

Description: This subprotocol is for bonding thin-film metal on Parylene to a rigid printed circuit board (PCB) substrate using polymer ultrasonic on bump (PUB) bonding [1]. In this method, ultrasonic welding is performed using a standard bonder tool sized to match your pad size. Flat metal contact/bond pads are joined via a coined bump through the Parylene polymer multielectrode array (pMEA) via the tool. This forms permanent bonds and is typically destructive to the pads on the Parylene device.

Note: Standard equipment and materials (e.g. tweezers, microscopes, DI water, cleanroom wipes, N_2 gun, scale, etc.) are not listed in materials lists.

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1 INTRODUCTION

PUB bonding is accomplished in four main steps: ball bonding, gold bumping, polymer bonding and underfill (Figure 1.1).

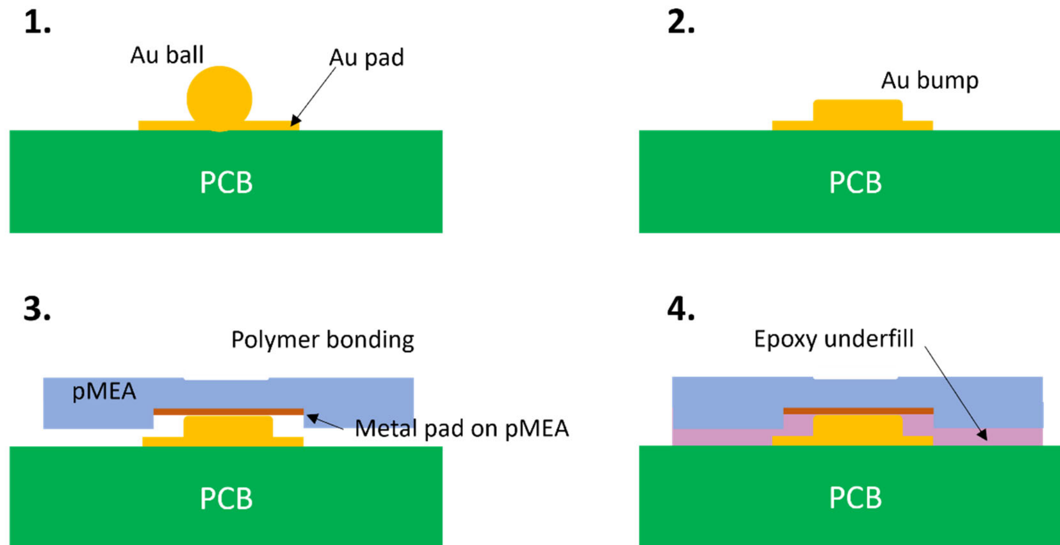

Figure 1.1. Schematic of the major steps of PUB bonding: ball bonding (1), gold bumping (2), polymer bonding (3), underfill (4).

2 PCB AND pMEA PREPARATION

2.1 PCB REQUIREMENTS

1. FR-4 board base material.
2. Surface finish of pads of 20-30 microinches of ENIG.

2.2 DEVICE DESIGN

Materials: *Dowel pins*
Low-friction tape

To facilitate PUB bonding, features for alignment (i.e., holes) and for underfill (i.e., ports) are recommended in the PCB and/or pMEA layout. Figure 2.1 shows a 2D CAD model for a pMEA with alignment holes and underfill ports.

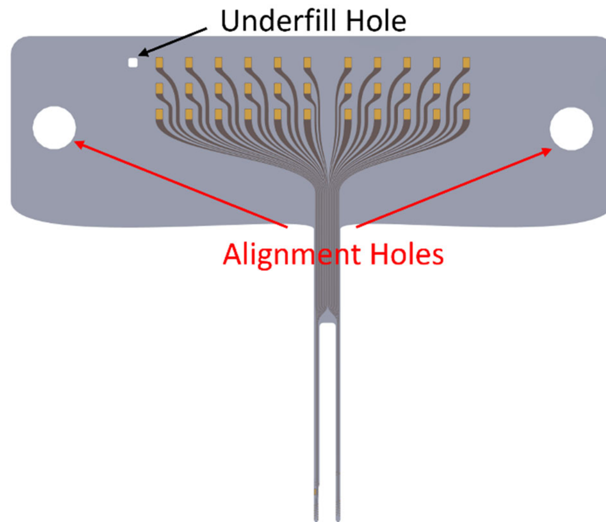

Figure 2.1. CAD model of PUB bonded probe with alignment holes and underfill ports.

1. The alignment holes (Figure 2.1) are designed to have a diameter of 1.26 mm, which comprises a clearance fit for a dowel pin of 3/64" (1.19 mm) diameter.
    a. For simpler devices, manual alignment with temporary low-friction tape may also be used.
2. Placement of alignment holes or tape around the bonding area ensures that the entire pad region remains flat during bonding.
3. The underfilling ports (Figure 2) are 250 µm squares, but the size here is only critical insofar as the operator can contact the chip surface with underfill epoxy.

3 PUB Bonding Steps

3.1 Ball Bonding

Materials: *Au wire*
Equipment: *Ball Bonder*

The purpose of this step is to place gold (Au) balls on the PCB pads.

1. Turn on wire bonder and microscope.
2. Choose "Uniform Bond" and "Adaptive Height" (can choose other options if desired)
3. Place and securely clamp PCB on the ball bonder workstage.
4. Set adaptive height by lowering and tapping capillary to PCB bond pad (if "Adaptive Height" was selected)
5. Adjust bonding parameters according to Table 1.

	Bond 1
Ultrasonic	120 mW
Time	180 ms
Force	14 g
EFO	20 (pwr)

Temperature	60 °C
Tail length	30
Pull length	02
Loop height	010

Table 1. Parameters for Au ball bonding on PCB with 20-30 microinch soft bondable gold surface finish

6. Place two ball bonds per pad to increase yield, with the second directly behind the first (Figure 3.1).

3.2 Gold Bumping

Equipment: *Wedge Bonder*
'Waffle' tool

The purpose of this step is to make all initial Au balls the same height and achieve a flat contact surface.

1. Install 'waffle' tool in the ultrasonic bonder if not already installed. This tool is commonly used for Tape-Automatic Bonding (TAB).
2. Place and secure PCB on the wedge bonder workstage using the clamp.
    a. Check and ensure the height of workstage is correct for 'waffle' tool
3. Adjust bumping parameters according to table 2.

	Bond 1	Bond 2
Ultrasonic	3	3.4
Time	4.4	3.4
Force	5.0	7.0
Temperature	RT	RT

Table 2. Parameters for ball bumping on PCB.

4. Bump each ball twice (Bond 1 and Bond 2) to ensure same height across balls.

Figure 3.1 shows two pads on a PCB substrate with 30 microinches of soft bondable Au surface finish with four bonded Au balls. The top two were bumped with a visible waffle imprint whereas the bottom two were left uncoined (Step 3.1) for illustration.

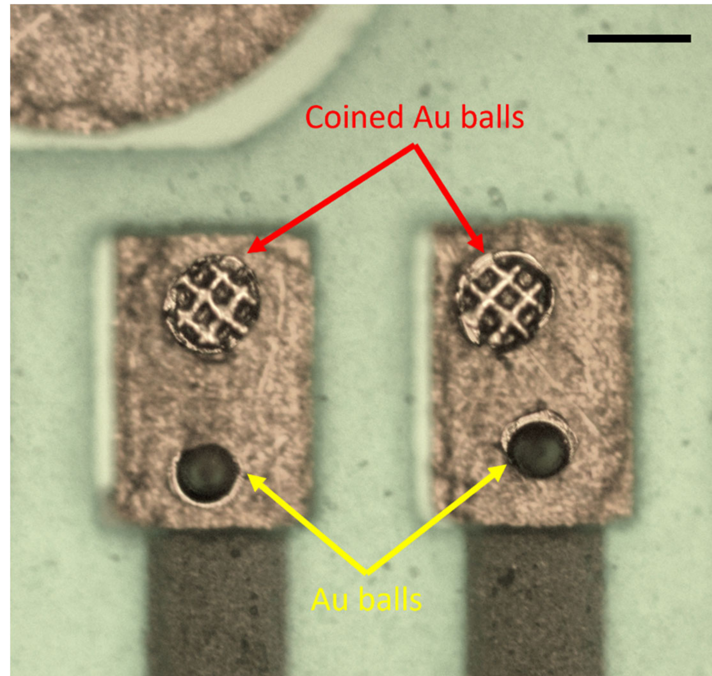

Figure 3.1. Au balls bonded to metal pads on PCB substrate. The bottom two balls were left uncoined, whereas the top two balls were bumped with 'waffle' tool. Scale bar is 100 µm.

3.3 Polymer Bonding

Materials: *Temporary tape or dowel pins*
Equipment: *Wedge bonder*
'Waffle' tool

The purpose of this step is to create a secure bond between the pMEA and the PCB.

1. Ensure pMEA is clean prior to this step.
2. Place pMEA electrode face (electrode openings) down on top of PCB and align bond pads to PCB pads.
    a. pMEA may be undersized following thermal annealing and should be designed accordingly.
    b. Alignment of pads may be done using dowel pins in alignment holes – designed for both PCB and pMEA (Figure 2.1) – or manual alignment using temporary tape (Figure 4.1).
3. Ensure Parylene pMEA lies flat on PCB. This step is critical for overall bonding success.
4. Install 'waffle' tool and set parameters from Table 3.
5. Place and secure PCB and pMEA on the wedge bonder workstage using the clamp and adjust bumping parameters according to Table 4.

	Bond 1	Bond 2
Ultrasonic	8.0	9.0
Time	3	4.5
Force	7.0	6.0
Temperature	60 °C	60 °C

Table 2. Parameters for Au ball bumping on PCB

6. Ultrasonically bond each pad twice (Bond 1 and Bond 2). Bond pads should be visible through Parylene, as shown in Figure 4.1.

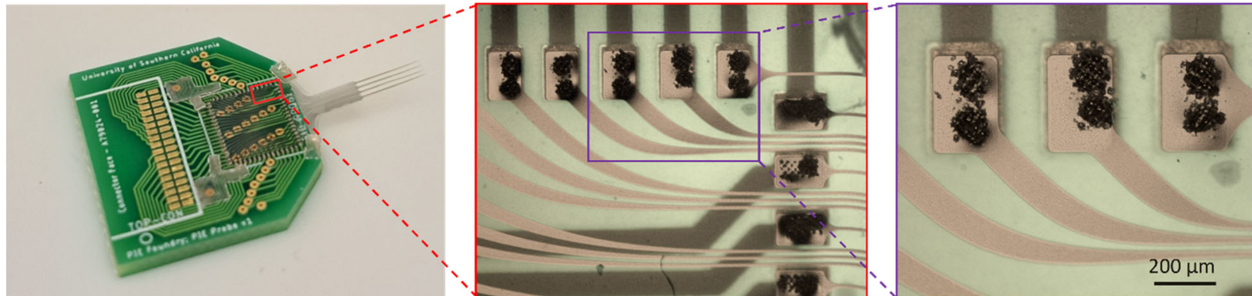

Figure 4.1. pMEA bonded to PCB through PUB using manual alignment.

3.4 UNDERFILL

Materials: *EpoTek MED 301*
Equipment: *Toothpick/fine gauge syringe tip*

The purpose of this step is to glue together the pMEA to the PCB after a secure bond has been created at the pads location via PUB bonding to provide additional safety to the overall assembly (Figure 1.3).

1. Prepare EpoTek MED 301 using a scale for accuracy:
    a. Two-part epoxy (Part A, Part B).
    b. Mix ratio by weight – 4 (Part A) : 1 (Part B)
2. Degas for 1 hour in a desiccator.
3. Using a toothpick or fine gauge syringe tip, apply a droplet of epoxy at the underfill port or edge of the pMEA between the substrate and Parylene MEA, allowing epoxy to fill the gap via capillary action.
    a. To avoid creating bubbles, place epoxy on only one entry point and let epoxy flow.
4. Once epoxy has underfilled the bonding area, cure overnight at room temperature.

APPENDICES

A. MATERIAL SOURCES

Note: Standard materials (e.g. acetone, DI water, cleanroom wipes, etc.) are not listed

Material	**Supplier**
EPO-TEK MED-301	Epoxy Technology, Billerica, MA
3/64”dowel pins (Catalog #98381A981)	McMaster-CARR, Elmhurst, IL
Low-friction tape (Catalog #76025A713)	McMaster-CARR, Elmhurst, IL
Au wire	California Fine Wire Company, Grover Beach, CA

B. EQUIPMENT MODELS

Note: Standard equipment (e.g. tweezers, microscopes, N2 gun, scale, etc.) are not listed

Equipment	**Model #**	**Supplier**
Sonicating bath	1510	Branson, Brookfield, CT

Ball bonder	626	Hybond, Escondido, CA
Wedge bonder	527A	Hybond, Escondido, CA
‘Waffle’ tool	7045W-TI-10050-3/4-M	Small Precision Tools, Lyss, Switzerland

REFERENCES

[1] J.J. Yoo and E. Meng, “c,” *J. Micromechanics and Microengineering*, Feb. 2021, doi: 10.1088/1361-6439/abe246.