Subprotocol: Ball Bonding of Parylene MEAs through Vias/Rivets

Description: This subprotocol is for bonding Parylene polymer microelectrode arrays (pMEAs) to a rigid PCB substrate where the electrode face is not in direct contact with the pads on the PCB substrate. At the pad sites, Au balls are ultrasonically bonded through vias in the pMEA to interconnect different metal layers. This is expected to form permanent bonds at low temperature (60 ℃) while reducing bonding area [2].

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

Ball bonding through vias is accomplished in three main steps: aligning, ball bonding, and underfill (Figure 1).

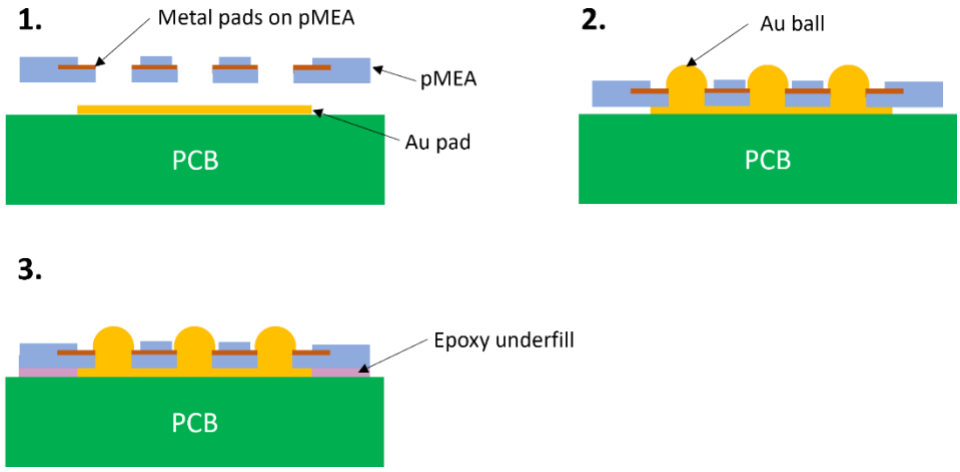

Figure 1. Schematic of the major steps of ball bonding: align pMEA pads to PCB pads (1), ball bond through MEA vias (2), underfill (3).

2 PCB AND MEA 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 bonding, features on the PCB and/or MEA for alignment (i.e., holes) and for underfill (i.e., ports) are suggested. Figure 2a shows a 2D CAD model for a MEA with alignment holes and underfill ports. Figure 2b zooms into a metal contact pad of the MEA with three vias per pad.

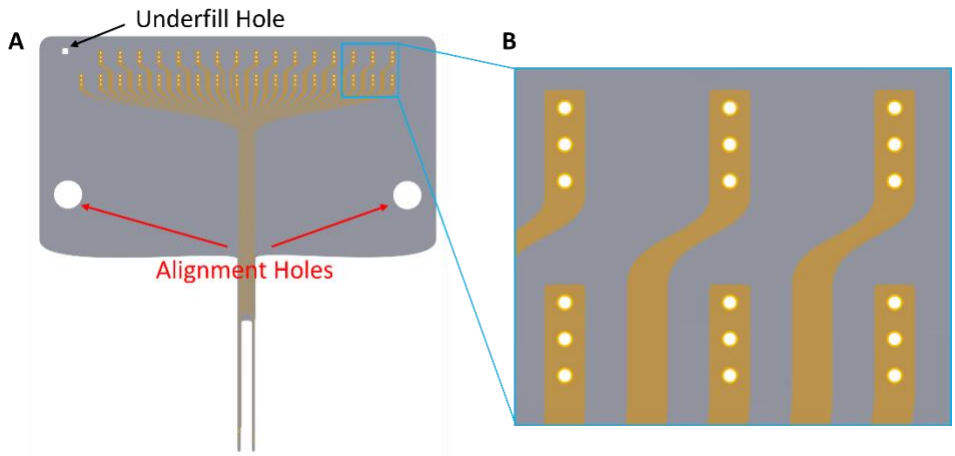

Figure 2. (A) CAD model of ball bonded probe with alignment holes and underfill ports. (B) Zoomed-in view of pads with three 60 µm *vias/pad.*

1. The size of the via/rivet should be 10-15 µm smaller than the diameter of the bonded ball.
    a. The recipes described below result in Au balls of 75-80 µm in diameter. The diameter of the vias in the MEA is designed to be 60 µm.
2. The alignment holes (Figure 2) 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.
3. Placement of alignment holes or tape around the bonding area ensures that the entire pad region remains flat during the bonding process.
4. The underfill 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 Ball 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 through the vias (Figure 1.2).

1. Place and clamp PCB on the ball bonder workstage.
2. Adjust bonding parameters according to Table 1.

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

Temperature	60 ℃
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

3. Place one ball per via (3 vias per pad to increase yield):
    a. Figure 3 shows preliminary successful results of Au balls bonded to a PCB pad with 30 microinches of soft bondable Au (ENIG) pads through rectangular rivets 50 µm wide, manually aligned to a PCB substrate.
        i. The lifted edges around the rivets in the pad sites of the MEA may be related to the squareness of the design. For the next iteration, square/rectangular shapes will be substituted by circular configurations.

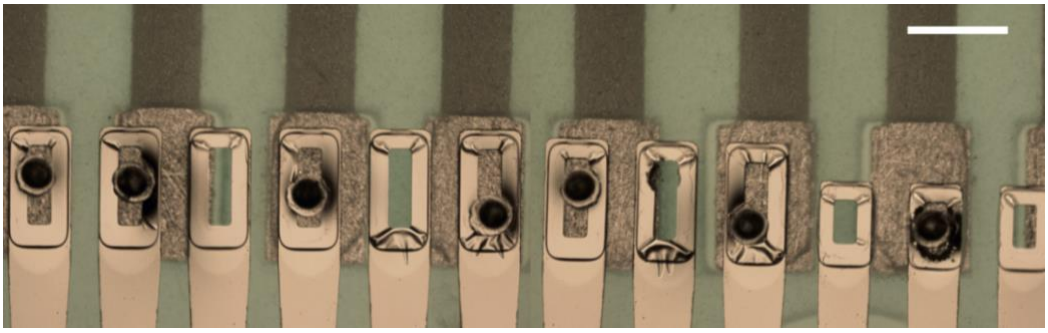

Figure 3. Ball bonding through 50 µm wide rivets in a Parylene MEA*. Scale bar is 200* µm.

3.2 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 – 100 (Part A) : 35 (Part B)
2. Using a toothpick or fine gauge syringe tip, apply a droplet of epoxy at the underfill port (Figure 2) between the substrate and Parylene MEA, alloing epoxy to fill the gap via capillary action.
    a. To avoid creating bubbles, place epoxy on only one underfill port and let epoxy flow.
    b. Avoid degassing the entire device while curing as this can cause damage as trapped gasses can damage bond sites looking for a path to escape.
3. Once epoxy has underfilled the bonding area, cure in oven at 60-65 ℃ for 75 minutes. Check if epoxy has solidified. If epoxy is not cured yet, return to oven for an additional 20 minutes.

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	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

REFERENCES

[1] Y. Wang, et al., “Flexible multichannel electrodes for acute recording in nonhuman primates,” *Microsyst. Nanoeng.*, July 2023, doi: 10.1038/s41378-023-00550-y.