INTERCONNECT STRATEGIES FOR JOINING INTEGRATED CIRCUITS TO HIGH-DENSITY POLYMER NEURAL INTERFACES

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Background: High density silicon neural probes for large scale recording achieve compact form factors using multiplexing and low-level processing via application-specific integrated circuitry (ASIC), employing both passive and active approaches. However, the chronic immune response to rigid probe implants poses a challenge for reliable long-term recording and motivates the use of compliant polymer substrates. This necessitates a new strategy for joining rigid ASIC chips. Taking into account the lower thermal budget and yield strength of polymers, four interconnect strategies to join Parylene probe arrays and ASICs were investigated: conductive epoxy, wedge wire bonding, anisotropic conductive film (ACF), and polymer ultrasonic bonding on bumped chips (PUB). The first three were adapted for use with Parylene, and the latter is a new method specifically developed for this purpose.

Materials and Methods: Test structures representing the interconnection region to the neural interface were fabricated from a Parylene C-Ti/Au-Parylene C sandwich, and in place of the ASIC, surrogate chips were made of glass with Ti/Au traces. Both Parylene and glass test structures contained 28 matching interconnect regions of varying bond pad size and pitch, with the smallest matching that of commercially available bare-die Intan chips. Alignment was performed with a custom-built polyether ether ketone (PEEK) jig and off-the-shelf rotation and translation stages. Conductive epoxy (Epo-Tek H20E) was manually applied using a polyurethane block. ACF (Dexerials CP13341-18AA) was applied manually and cured in an oven, using a custom jig to apply pressure via screws. Wedge wire and PUB bonding was performed using a Hybond Model 572A. Bonds were assessed by measuring electrical continuity and resistance. Yield was calculated as the fraction of successful bonds.

Results: Successful bonds were achieved with all techniques, but as the spacing between traces and bond area decreased, bonding yield decreased. For the smallest bonding area (100 μm pitch by 70 μm width), bonding via conductive epoxy produced an average yield of 66.7%; wedge wire 66.7%, ACF 87.5%, and PUB 87.5%. Failures with conductive epoxy were associated with insufficient clearance beyond the bonding area, since similar experiments on wider chips produced higher yield. Wedge bonding (25 μm wire diameter) becomes untenable for the tightest features because the resulting wedge extends into adjacent bonds with the tool used. ACF failures may be related to uneven pressure application; in one device, cracking was observed that disconnected bond pads. Failure modes associated with PUB bonding are under investigation; one possibility is a relationship between insulation thickness and ultrasonic transmission, as failures appear to be thickness dependent.

Conclusions: We achieved successful bonding between thin film Parylene and glass test structures towards producing a strategy to incorporate ASICs into polymer-based high density recording arrays. Initial results indicate that ACF and PUB bonding result in the highest yield at the finest pitch, making them likely candidates for high-density polymer ASIC integration.

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