FLAGSHIP

SYSTEM INTEGRATION

Interconnection technologies for integration of active devices with printed plastic electronics (ITAPPE)

INVESTIGATORS

GUANGBIN DOU

ANDREW HOLMES

INSTITUTION

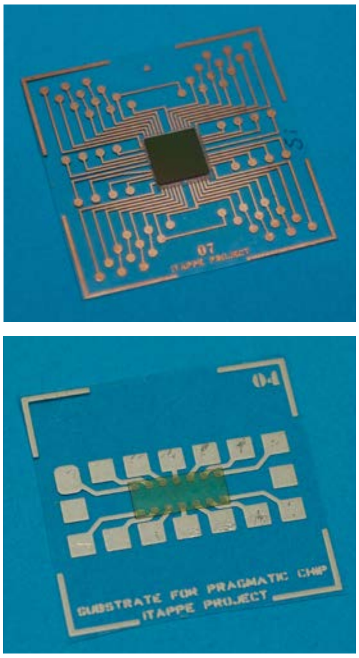
IMPERIAL COLLEGE LONDON

PARTNERS

CPI

PRAGMATIC

TRIBUS-D

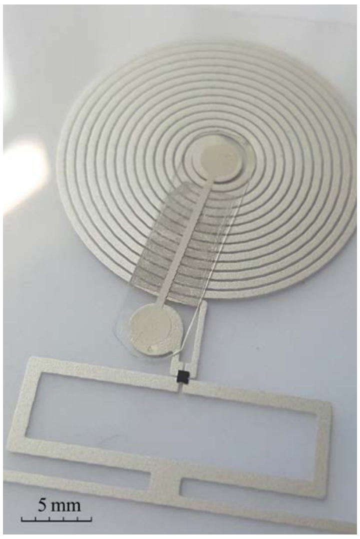


Silicon-to-flex (top) and flex-to-flex (bottom) assemblies produced by NCA packaging and TS bonding, respectively.

LAE systems invariably require active electronic devices which may be either conventional silicon chips or flexible ICs depending on the application. Fast and cost-effective methods are therefore needed for attaching active devices to low-temperature plastic electronic substrates. Currently the favoured approach is to use isotropic conductive adhesive (ICA) packaging, where islands of conductive adhesive, dispensed onto the substrate prior to chip placement, provide both mechanical and electrical connections between chip and substrate. In ITAPPE we have been exploring alternative approaches based on non-conductive adhesive (NCA) and thermosonic (TS) bonding which have the potential to reduce material costs while at the same time increasing throughput and reliability.

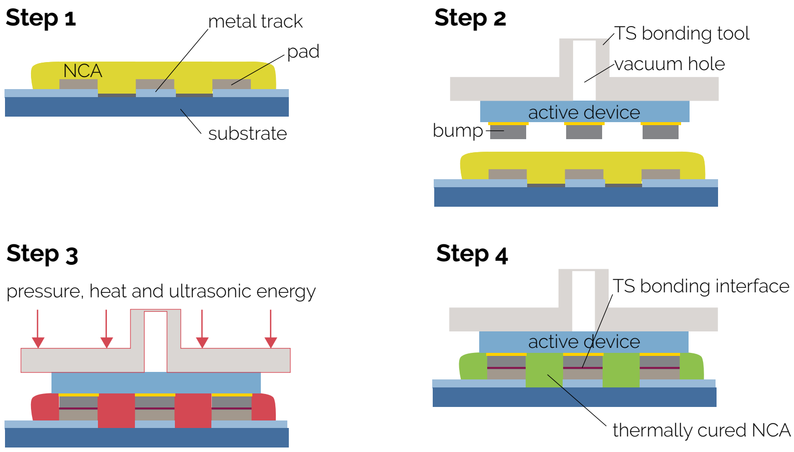
In NCA packaging, electrical connections between chip and substrate are mediated by conductive bumps on the chip, and the role of the adhesive is purely to pull these into contact with corresponding pads on the substrate. NCA packaging is more efficient than ICA at the point of assembly because it does not require selective deposition of the adhesive; instead the adhesive is applied over the entire device area. It also inherently provides an underfill between device and substrate which improves reliability, and is scalable to finer interconnect pitches which will be important for future applications. A disadvantage of NCA packaging is that it can be less reliable than other packaging methods because it relies on pressure contacts. However, as we have shown in earlier research, the reliability can be improved by including a thermosonic bonding step in the NCA process; this was the rationale for including a TS bonding element in the ITAPPE project. NCA packaging and TS bonding are both well established in traditional electronics manufacturing. The challenge in ITAPPE has been to establish processes suitable for low-temperature polymer substrates with printed conductors; appropriate methods for handling flexible ICs were also needed.

ITAPPE was funded as a Pathfinder project in the 2016 round. It was initially established as a 6-month project, but was subsequently extended to 12 months following promising early results. In ITAPPE Phase 1 we successfully demonstrated NCA processes for attaching both silicon chips and flexible ICs to PET substrates with printed copper or silver conductors. The silicon devices were commercial, copper-bumped test chips, while the flexible ICs were test chips fabricated and bumped by our project partners. We were also able to demonstrate TS attachment of flexible ICs to PET substrates with silver conductors. Electrical joint resistance measurements were used to assess the quality of the assemblies produced during process development, and once suitable process conditions had been identified samples were produced for long term temperature/humidity reliability testing. The silicon-to-flex assemblies showed excellent performance in these tests, exhibiting only a slight increase in average joint resistance after 3000 hours at 60°C/90%RH. Reliability testing of flex-to-flex assemblies is still ongoing at the time of writing.



RFID tag demonstrator, with silicon active device and strap attached using ITAPPE processes.

The most interesting results from ITAPPE Phase 1 were those relating to direct flex-to-flex bonding, as this could potentially provide a solution to active device integration for LAE that is faster, cheaper and more reliable than other approaches. Work in Phase 2 has been focused on developing this further towards a scalable process for flex-to-flex packaging that combines both TS bonding and NCA underfill. In addition to advancing the core bonding process, we are working with materials suppliers to identify the most appropriate adhesive formulation for a flex-to-flex thermosonic-adhesive process on low-temperature substrates. Desirable characteristics include low viscosity for easy displacement from the bonding sites during die placement, together with low curing temperature and short curing time. Also in Phase 2 we are working on functional demonstrators that showcase both the silicon-to-flex and flex-to-flex packaging processes we have developed in ITAPPE.



Thermosonic-adhesive packaging process combining NCA packaging with thermosonic bonding.

"The ITAPPE Pathfinder project has been an invaluable way to explore a potentially game-changing packaging technology for flexible electronics. Early results are very encouraging and PragmatIC is excited to continue this collaboration with Prof. Holmes."
Dr Richard Price, CTO, PragmatIC

Industry interaction

The ITAPPE project has benefited greatly from industrial collaboration. The three industry partners have remained strongly engaged throughout, providing a valuable mix of technical guidance, materials and practical assistance. All of the substrates used in the project were manufactured by CPI, while the silicon and flexible IC test chips were supplied by Tribus-D and PragmatIC respectively. Both CPI and PragmatIC have also assisted with reliability testing.

Looking to the future we are interested in establishing additional links with companies in other parts of the supply chain, in particular materials suppliers, manufacturers of bonding equipment, and end users of smart electronic systems.

Contact:
Dr Guangbin Dou: g.dou@imperial.ac.uk
Professor Andrew Holmes: a.holmes@imperial.ac.uk