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Optimisation of industrial production of low-force sensors – adhesive bonding of force-centring ball

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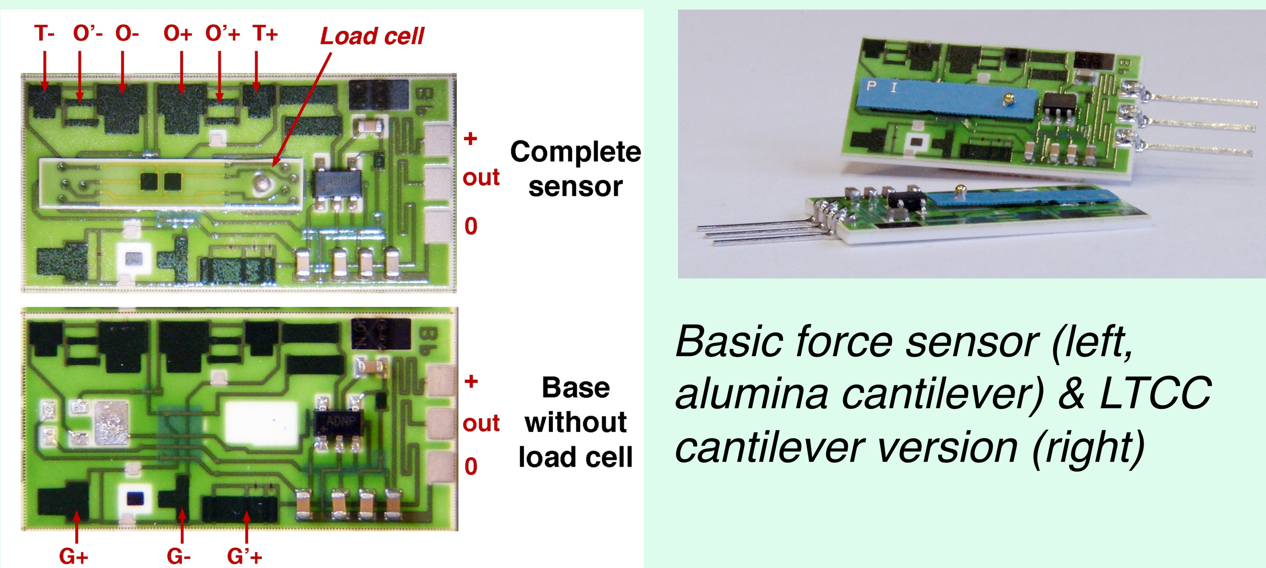
Sensor & sensing principle



Basic force sensor (left, alumina cantilever) & LTCC cantilever version (right)

Cantilever load cell (alumina or LTCC)
Solder :
- Mechanical attachment
- Electrical connection
Force centring ball, soldered or glued (this study)
Sensor cantilever (load cell)
Base (alumina)
Sacrificial layer as separator (standoff)

Sensor assembly principle, showing force-centring ball and solder pads

Goal: replace soldering of ball by adhesive bonding

Advantages

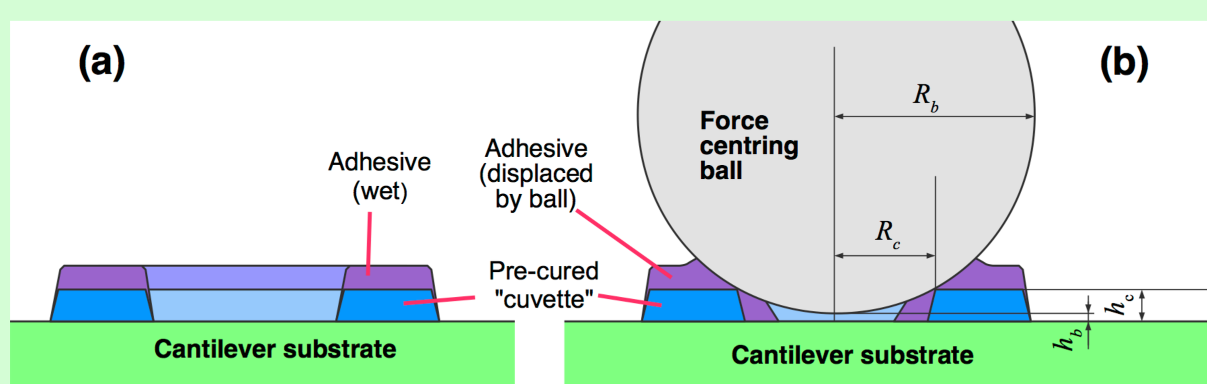
- No need for expensive special metallisation of cantilever and ball
- Allows use of glass balls: better thermal & electrical decoupling; low-cost
- One less solder reflow cycle: reduced leaching of metallisations (more critical issue with modern lead-free solder)

Issues

- Ensure positioning without the strong capillary forces present with soldering
- Ensure sufficient bonding strength

Approach

- Print "cuvette" for mechanical centring of ball

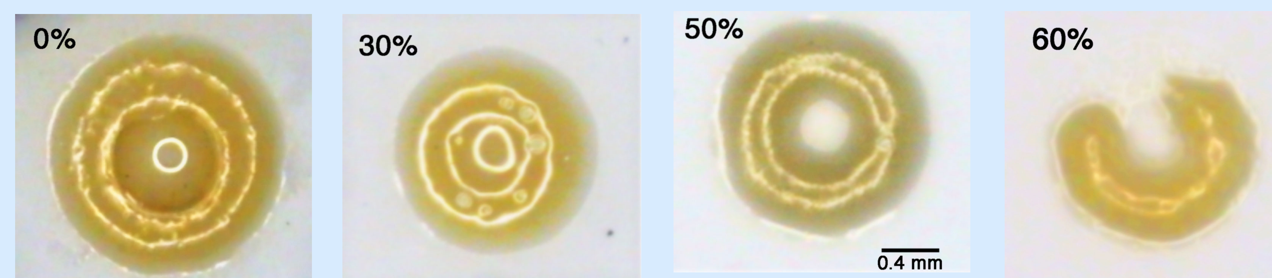


Adhesive bonding principle with two functional layers:
1) "Cuvette" layer for mechanical centring
2) Actual "glue" layer for actual attachment

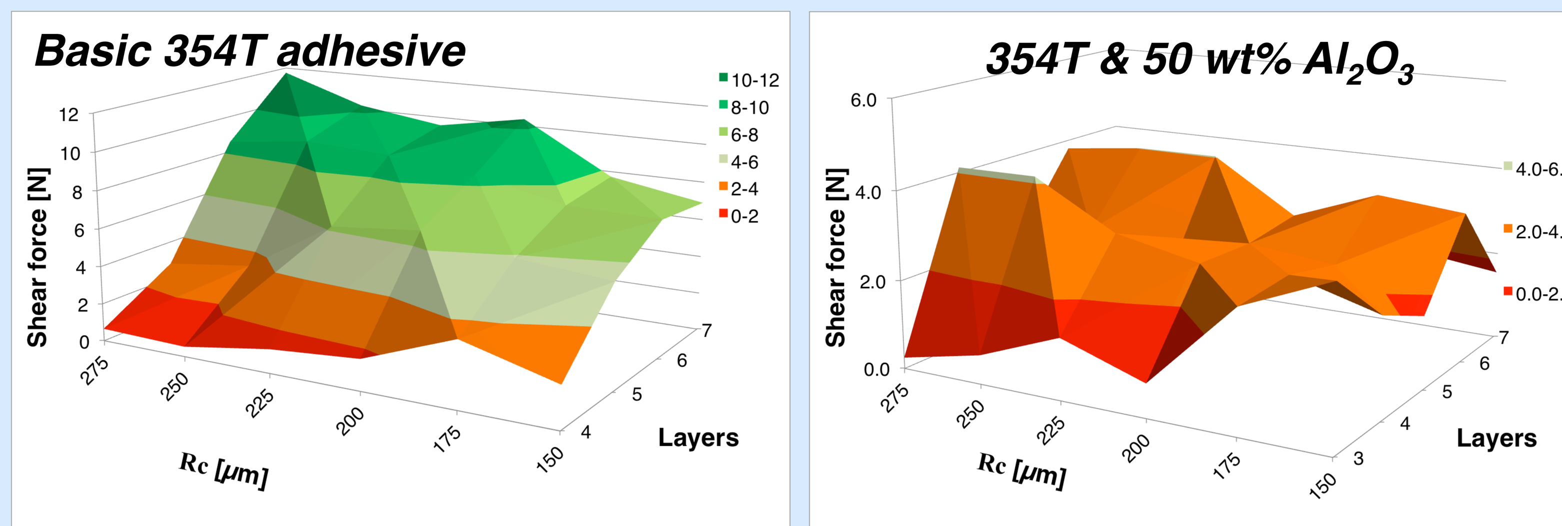
Manufacturing steps

1. Circuit on base: standard thick-film (TF) deposition
2. Piezoresistive cantilever load cell: TF or LTCC process
3. Load cell coarse trimming: laser
4. Pre-tinning of load cell pads: solder
5. **Assembly of force-centring ball onto load cell: solder or adhesive – object of this study**
6. Individualisation of cantilevers
7. Mounting of components, including cantilever: SMT process / soldering
8. Active sensor trimming: laser
9. Cleaning
10. Individualisation of sensors
11. Final steps: lead attachment / inspection

First optimisation of compositions



Cuvette screen printing tests, with Epo-Tek 354T epoxy adhesive loaded with variable amounts of alumina powder (%mass)



Shear strength of ball attachment, build-up with thin layers of basic Epo-Tek 354T adhesive (left) vs same loaded with alumina powder

Cuvette formation (Epo-Tek + alumina):

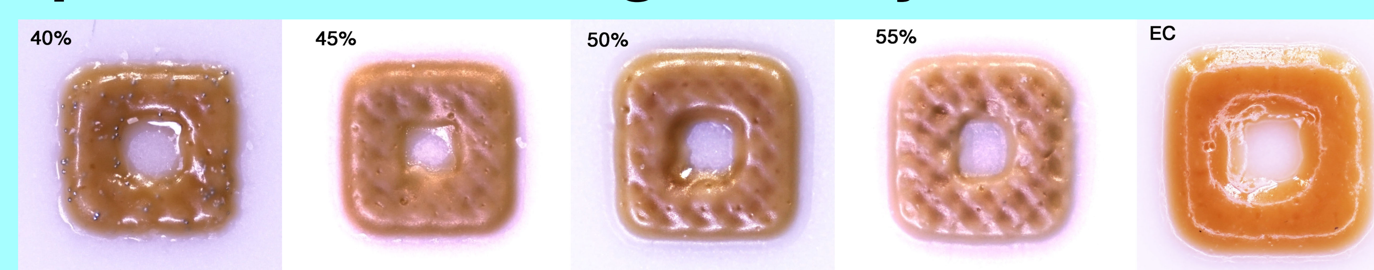
- Too little alumina (0% & 30%): slumping, excessive flow
- Too much (60%): too viscous, misprints
- Optimal value ~50%

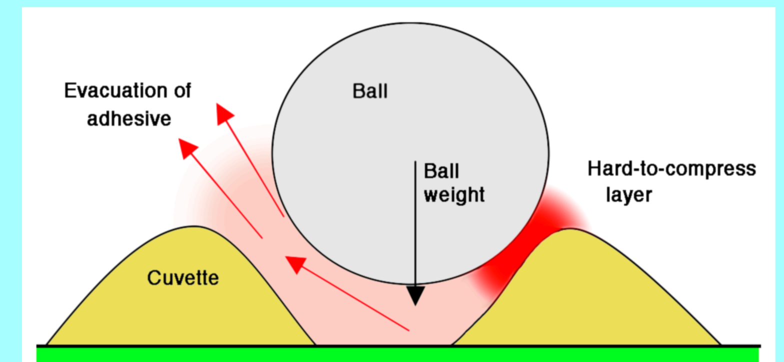
However:

- Adhesive bonding poor with 50% Al_2O_3
- Good bonding with basic Epo-Tek 354T

Use different compositions for "cuvette" and "glue" layers

Optimised cuvette geometry & formulation

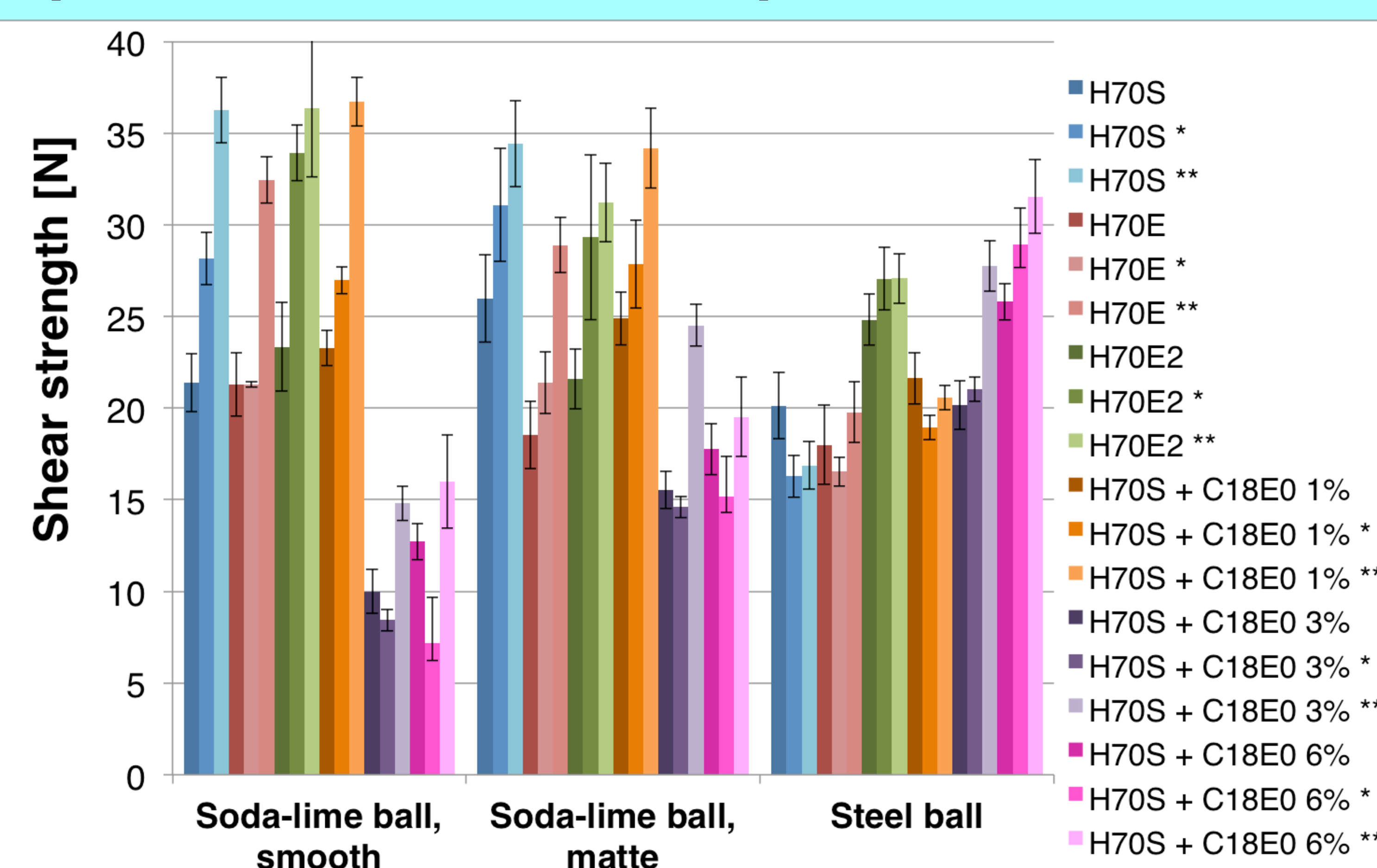




Optimised cuvette with square geometry to allow easy evacuation of excess adhesive in the corners & new formulation with 41% Al2O3 + 1.7% ethylcellulose EC-300-48 ("EC") showing much better printing characteristics

New geometry, 'cuvette' & 'glue' formulations selected for optimised printing & bonding

Optimised adhesive composition & resistance to solder reflow



Comparison of different adhesive formulations (/** = simulated soldering cycles, 5/15 min at 260°C)*

- Epo-Tek H70E2 selected: good strength & right rheology
- Resistance to solder reflow not problematic
- Sufficient strength for all tested ball materials

Conclusions

- Adhesive ball mounting process successfully developed to replace solder attachment:
  1) Depositing a 'cuvette' layer for mechanical centring
  2) Placing & bonding the ball with a second 'glue' layer
- Simpler processing than soldering; fewer solder reflow cycles
- Proper positioning of ball achieved
- Obtained strength levels acceptable by a large margin