Hot Pin Pull Method – New Test Procedure for the Adhesion Measurement for 3D-MID

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HARTING Mitronics

- since 2003 we serve customer globally from our competence center in Switzerland with 50 employees
- whole MID process chain under one roof
- strengths: development and manufacturing services for individual 3D-MID components
- TS 16949 certified

Target markets

- automotive lighting (interior, rear)
- automotive sensor and actuator
- industrial
- medical
Our 3D-MID serial applications in HARTING Mitronics target markets

- Automotive
- Medical
- Sensors
- Industry
- Others
From idea to serial production – all manufacturing steps from one partner

- Development
- Tool shop
- Molding
- Laser structuring
- Inspection/Qualification
- Assembly
- Plating
- Cleaning
Influences to the adhesion force

Design
- geometry
- layout

Substrate material
- compound
- filler
- additive

Injection molding
- molding direction
- parameter
- gate

Metallization
- thickness
- deposition rate

Cleaning process
- ultrasonic
- water jet
- CO₂ snow jet

Laser structuring/activation
- frequency/velocity/power
- hatch

Handling
- damage
- contamination

Stress during lifetime
- thermal
- chemical
- mechanical

Packaging
- glueing/soldering
- wire bonding
- flip-chip

Adhesion measurement
- people
- method

Dr. Christian Goth | HARTING Mitronics
Conventional test methods

- Pull-off test
- Shear test – electronic components
- Shear test – conductor track
- Micro chisel
- Peel test
- Cross cut test/Tape test

Source: HSG-IMAT, H. Willeck, Dissertation
Conventional test methods

**Pull-off test**
- Tensile force $F_{\text{ten}}$
- Pull-off tool
- Adhesive/solder joint
- Pin/Rivet
- Metallization
- Surface A
- Substrate

**Shear test – electronic components**
- Shear chisel
- Component
- Solder joint
- Metallization
- Substrate

**Shear test – conductor track**
- Shear chisel
- Shear force $F_s$
- Metallization
- Substrate

**Micro chisel**
- Chisel
- Conductor material with flake surface A
- Metallization
- Substrate
- Direction of substrate movement

**Peel test**
- Tensile force $F_{\text{ten}}$
- Pull-off hook
- Eyelet
- Solder/adhesive
- Metallization with width $b$
- Substrate
- Direction of substrate movement

**Cross cut test/Tape test**
- GTO
- GT2
- GT4
New test method **Hot Pin Pull**

**Test equipment**
- micro-material testing system 4000Plus Nordson DAGE
- copper pins are available with a tip radius of 100 µm, 300 µm or 450 µm in tinned or untinned versions

**New measuring head**
- a special heatable cartridge
- can be programmed to apply a time-temperature reflow profile
Functional principal and test procedure

- **Preparation**
  - manual insertion of copper pins with a diameter of 900 μm
  - pin is held by a spring-loaded mechanism

- **Pin positioning with motorized axes (x,y,z)**
  - tinned pin: directly on the plain test structure
  - untinned pin: into dispensed solder paste

- **Soldering process**
  - pin temperature ramps up according to the defined temperature profile and is soldered to the metallized test structure
  - cooling is achieved by pulsing compressed air along the pin and onto the test sample

- **Measurement**
  - defined test temperature is reached: clamping mechanism to fix the pin
  - automatically pull-off process and recording of force
Size of test structures

- **Limited flexibility with standard tests**
  - shear test: limited by the pad dimensions / respectively component size
  - pull-off test: requires test circles with a minimum diameter of 3.0 mm

- **Investigations: test circles with a diameter from 0.6 to 1.1 mm / from 1.1 to 3.0 mm**
  - this means areas from 0.28 mm² to 7.07 mm²
  - material Vestamid HTplus TGP 3586
  - adaption of solder paste volume and temperature profile (1.3, 1.5, 1.9 and 3.0 mm)
  - constraint of the test: entirely removed metallization and completely wetted pads
Hot pin pull test can be performed with pad diameters up to 3.0 mm
- with increasing pad diameter the adhesion in N/mm² decreases
- standard deviation is relatively low compared to the conventionally used test methods
  - shear test: approx. 20 %, conventional pull-off test: > 20 %
- further optimization of temperature profile and solder paste volume is possible
- current recommendation for a test geometry: circle with a diameter of 1.0 mm

at least 10 measurements per specified value
Temperature profile

- **Further influencing factor: temperature profile to solder the pin to the test pad**
  - adherent connection without change in the composite

- **Necessary peak temperature and temperature profile?**

![Temperature Profile Graph]

- **Test conditions**
  - material Vectra E840i LDS
  - test circles with a diameter of 1.0 mm
  - temperature profile adapted to the reflow soldering profile recommendation
  - solder paste (SnBi), melting point 137°C
**Temperature profile influences the adhesion strength**

- Increase of peak temperature → decrease of the determined adhesion strength
- Pre-damage of the metal-plastic composite due to high temperatures
- Temperature profile should basically be defined as soft as possible
- Effect depends on the substrate material

*Graph showing the relationship between peak temperature and adhesion strength.*

**Note:** At least 8 measurements per specified value.
Wetting of test structures

- **Test structure is not completely wetted with solder**
  - a: metallization is usually just partly pulled off the substrate
  - b: even if the complete metallization is removed → not reproducible influences

- **Complete wetting of the test structure with solder**
  - c: metallization is pulled off completely from the substrate
  - required for reproducible testing with the hot pin pull method
Integration into series production

- **Important topic: integration of the test method into series production**
  - series product parts w/o any further modification of the layout and w/o additional test structures
  - ideally: there is an insulated pad → defined size of removed metallization
  - optional: the test pad/conductor track must be isolated (e.g. solder resist, cutting)

- **Investigations with 3D-MID position sensor for adaptive speed control**
  - size of the pad is 3.06 mm² (corresponding to a circle with a diameter of approx. 2 mm)
  - material Vectra E840i LDS
  - for this test series:
    - the whole metallization was removed in 100 % of the tested pads (20 values)
    - mean 4.86 N/mm², minimum of 3.90 N/mm², standard deviation below 10 %
    - material was released with the metallization – typical of LCP
Integration into series production

- **Variation of laser power**
  - material Stanyl ForTii NC1119B
  - laser power 7, 8, 9, 10 Watt
  - test structure: circles with diameter of 1 mm on serial 3D part

- **Resolution of test method is sensitive enough for detecting process changes**

![Graph showing adhesion in N/mm² vs. power in W for different laser powers (7, 8, 9, 10 W). The graph indicates at least 9 measurements per specified value.](image-url)
The investigations confirm that the hot pin pull method is an easy test procedure to determine the adhesion of metal coatings on thermoplastic materials:

- for all investigated test configurations the whole metallization was released
- test results show a low standard deviation below 10 %
- different pad sizes are possible
- current recommendation for a test geometry: circle with a diameter of 1.0 mm
- temperature profile should basically be defined as low as possible
- for reproducible test conditions: test should be proceeded with completely wetted structures
- the hot pin pull test allows the direct use of serial parts
- resolution of test method is sensitive enough for detecting process changes

To establish the hot pin pull method as a standard testing method for 3D-MID defined parameters are necessary, e.g.:

- machine parameters (e. g. take-off speed)
- test geometries (e.g. 1.0 mm circles)
- amount of solder paste (related to the test pad)
- temperature profile (related to the test pad and amount of solder paste)
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