Wire Bonding Quality Assurance and Testing Methods

Visual and mechanical testing methods of wire bonds

- Light- and scanning electron microscopical examinations
- Pull test
- Shear test

\[ F = F_1 = F_2 \quad \text{bei } \beta_1 = \beta_2 = 30^\circ \]

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Wire Bonding Quality Assurance and Testing Methods

Wire bonding and quality assurance: General requirements

Global formulation:
• low cost technology
• easy to realize and flexible during application
• strong mechanical stability
• thermal stability (in regard to further processing steps) and
• good long term stability
• low contact resistance
• as much as possible great welding area between wire and metallization
• no physical and chemical interactions with other materials

Test methods:
• visual inspektion MIL-STD 883 method 2010, 2017
• pull test MIL-STD 883 methode 2011 (destructive), methode 2023 (non destructive)
• shear test ASTM F 1269-89
Wire Bonding Quality Assurance and Testing Methods

Bond pads on chip:
- Multiple imprints of test probes or deep very imprints
- Strong adverse effects of surface quality
- Influence on bondability
Remark: Visual inspection of bondpads **before** wire bonding!
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Ball and wedge bond lift offs of wafer metallizations while TS-Au-B/W-Bonding

Wafer metallization lift offs while TS-Au-W/W-Bonding
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SEM-View (BSE): PCB metallization lift off and undersurface of a lift off bond (wedge)
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Quality Tests (Visual Methods)

**Ball Bond**
- Loop high
- Loop length
- Loop size and sweeping
- Influence to neck and heel

**Wedge Bond**
- Loop high
- Loop length
- Horizontal and vertical deformation
- Position of bonds on the pad

Geometrical Parameters during Wire Bond

SEM – Figure of a typical Ball Bond

SEM – Figure of a typical Wedge Bond
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Ball bond failures
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Visual inspection of wire bonds
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Visual inspection of wire bonds
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Wedges on chip

- strong squeezing out of chip metallization while bonding
- possible evidence of a too soften surface metallization
### Wire Bonding Quality Assurance and Testing Methods

<table>
<thead>
<tr>
<th>Wire Diameter</th>
<th>Standard</th>
<th>Cutting Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>A pad width</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>B pad length</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>D wire diameter</td>
<td>P</td>
<td>W</td>
</tr>
<tr>
<td>W bond width</td>
<td>P</td>
<td>W</td>
</tr>
</tbody>
</table>

#### Wire Bonding Measurements

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mil</td>
<td>100µm</td>
<td>125µm</td>
<td>125µm</td>
<td>45µm</td>
<td>.004in</td>
<td>.005in</td>
<td>.005in</td>
<td>.0018in</td>
</tr>
<tr>
<td>2 Mil</td>
<td>125µm</td>
<td>150µm</td>
<td>200µm</td>
<td>75µm</td>
<td>.005in</td>
<td>.006in</td>
<td>.008in</td>
<td>.003in</td>
</tr>
<tr>
<td>3 Mil</td>
<td>180µm</td>
<td>200µm</td>
<td>250µm</td>
<td>125µm</td>
<td>.0072in</td>
<td>.008in</td>
<td>.01in</td>
<td>.005in</td>
</tr>
<tr>
<td>4 Mil</td>
<td>200µm</td>
<td>280µm</td>
<td>280µm</td>
<td>130µm</td>
<td>.008in</td>
<td>.0112in</td>
<td>.0112in</td>
<td>.0052in</td>
</tr>
</tbody>
</table>

#### Heavy Wire

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Mil</td>
<td>250µm</td>
<td>300µm</td>
<td>350µm</td>
<td>150µm</td>
<td>.01in</td>
<td>.012</td>
<td>.014in</td>
<td>.006in</td>
</tr>
<tr>
<td>6 Mil</td>
<td>250µm</td>
<td>500µm</td>
<td>400µm</td>
<td>200µm</td>
<td>.01in</td>
<td>.02in</td>
<td>.016in</td>
<td>.008in</td>
</tr>
<tr>
<td>10 Mil</td>
<td>400µm</td>
<td>800µm</td>
<td>600µm</td>
<td>320µm</td>
<td>.016in</td>
<td>.032in</td>
<td>.024in</td>
<td>.0128in</td>
</tr>
<tr>
<td>20 Mil</td>
<td>800µm</td>
<td>1300µm 150µm</td>
<td>650µm</td>
<td>650µm</td>
<td>.032in</td>
<td>.052in</td>
<td>.046in</td>
<td>.026in</td>
</tr>
</tbody>
</table>
Overbonded wedges (too much deformation), right: Detail
Wire Bonding Quality Assurance and Testing Methods

Results of a tilted glued or soldered chip on bonding process:

- Surfaces of chip pads aren’t horizontal
- Bonding tool is touched down tilted, too
- Wedge is deformed non-uniform
- Pad metallization or chip could be damaged
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Optical inspection of die tilting

IZM: Hillmann, Großer, Ghaharemani

sheet 16
Wire Bonding Quality Assurance and Testing Methods

Wire Sweep Definition

\[ \text{Sweep \%} = \frac{\alpha}{L} \times 100\% \]
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Mechanical bond contact inspection (tests)

<table>
<thead>
<tr>
<th>to proof:</th>
<th>selected tests:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- mechanical stiffness of loops</td>
<td>- pull test</td>
</tr>
<tr>
<td>- ball bond strength</td>
<td>- shear test</td>
</tr>
<tr>
<td>- heavy wire wedge bond strength</td>
<td>- shear test</td>
</tr>
<tr>
<td>- simultaneous proofing of many bond contacts</td>
<td>- centrifugal test</td>
</tr>
<tr>
<td>- fatigue behaviour of loops</td>
<td>- vibration test</td>
</tr>
<tr>
<td>- crack initiation and growth</td>
<td>- mechanical shock test</td>
</tr>
<tr>
<td>- sweep off behaviour</td>
<td>- air jet test</td>
</tr>
</tbody>
</table>
Wire Bonding Quality Assurance and Testing Methods

Principle of pull test

\[ F = F_1 = F_2 \quad \text{bei} \quad \beta_1 = \beta_2 = 30^\circ \]

Quelle: Dage Firmenschrift
Failure modes:
1, 5 Bond lift off from pad metallization (lift off)
2, 4 Wire break at bond (heelcrack or neck break when ball/wedge bonding)
3 wire break
Load/Force distribution while bond pull test

\[ F_1 = F_2 = \frac{F}{2 \sin \Theta} = \frac{F}{2} \left[ 1 + \left( \frac{d}{2h} \right)^2 \right]^{1/2} \]

true for \( \Phi = 0 \), both bond contacts at one level and \( \Theta_1 = \Theta_2 = \Theta \)

load at chip:

\[ F_1 = F \frac{\cos(\Theta_2 - \Phi)}{\sin(\Theta_1 + \Theta_2)} \]

load at substrate:

\[ F_2 = F \frac{\cos(\Theta_1 + \Phi)}{\sin(\Theta_1 + \Theta_2)} \]
Wire Bonding Quality Assurance and Testing Methods

Quality criteria for pull testing

\[ F = F_1 = F_2 \quad \text{if} \quad \beta_1 = \beta_2 = 30^\circ \]

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>laboratory</td>
</tr>
<tr>
<td>pull force</td>
<td>&gt;50 %</td>
</tr>
<tr>
<td>- average value (based on nondeformed wire)</td>
<td>&lt;15 %</td>
</tr>
<tr>
<td>- standard deviation (based on average value)</td>
<td>0 %</td>
</tr>
<tr>
<td>- proportion of values &lt; (based on standards) cN</td>
<td>0 %</td>
</tr>
<tr>
<td>lift offs</td>
<td>0 %</td>
</tr>
<tr>
<td>- pull lift off</td>
<td></td>
</tr>
<tr>
<td>- bond lift off</td>
<td></td>
</tr>
</tbody>
</table>
Wire Bonding Quality Assurance and Testing Methods

Minimum pull forces for destructive pull test (MIL STD 883, Methode 2011):

Wires:
1 Au (preseal)
2 Al (preseal)
   Au (postseal)
3 Al (postseal)
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Pull Force

- increasing quantity of pull lift offs
- increasing quantity of heel cracks

optimum

increasing parameters
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Principle of shear test

1. Substrate/Pad
2. Interface Ball/Substrate
3. Au-Ball
4. Shear Tool
5. Shear Level

$ F_s $ Shear Force
$ S $ Shear Height

Source: Dage and „DVS-Merkblatt Drahtbonden“
# Wire Bonding Quality Assurance and Testing Methods

## Standard report of pull test: Standard AlSi1 wire (30 µm)

<table>
<thead>
<tr>
<th>US power 1./2. bond [scale]</th>
<th>average value pull force [cN]</th>
<th>pull force &lt; 6 cN [%]</th>
<th>pull lift offs [%]</th>
<th>bond lift offs [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>104/110</td>
<td>10,5</td>
<td>1,6</td>
<td>16,7</td>
<td>10,0</td>
</tr>
<tr>
<td>109/115</td>
<td>12,0</td>
<td>1,4</td>
<td>6,7</td>
<td>5,0</td>
</tr>
<tr>
<td>114/120</td>
<td>14,5</td>
<td>0,9</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>124/130</td>
<td>15,0</td>
<td>0,8</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>134/140</td>
<td>14,5</td>
<td>0,9</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>144/150</td>
<td>11,5</td>
<td>1,0</td>
<td>11,5</td>
<td>0,0</td>
</tr>
<tr>
<td>154/160</td>
<td>8,5</td>
<td>1,2</td>
<td>20,0</td>
<td>0,0</td>
</tr>
</tbody>
</table>

- **number of tests:** $n = 30$
- **US time:** 30 ms
- **bond force:** 32 cN
- **tensile wire strength:** 19 cN

**US power 1./2. bond [scale]**

### Error rate

- **average pull force [cN]**
- **standard deviation [cN]**
- **pull force < 6 cN [%]**
- **pull lift offs [%]**
- **bond lift offs [%]**

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Failure modes while shear test

- Ball lift off
- Metallization lift off
- Ball shear
- Metallization cracking
- Chip cratering
### Wire Bonding Quality Assurance and Testing Methods

#### Quality criteria for ball shear testing (TS bonding)

<table>
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<th>Characteristics</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>laboratory</td>
</tr>
<tr>
<td>shear force</td>
<td></td>
</tr>
<tr>
<td>- average value (based on minimum shear force value)</td>
<td></td>
</tr>
<tr>
<td>- standard deviation (based on average value)</td>
<td></td>
</tr>
<tr>
<td>- minimum shear force (based on ball diameter after bonding)</td>
<td></td>
</tr>
</tbody>
</table>
| lift offs                        |            | see beneath, no value < ...
| - bond lift off                  | 0 %        | 0 %       |
| - shear lift off                 | 0 %        | 0 %       |
| - percentage off Au on pad       | > 80 %     | > 50 %    |

- no metallization lift off, no cratering

<table>
<thead>
<tr>
<th>Minimum shear value</th>
<th>ballbond diameter (µm)</th>
<th>shear force (cN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>125</td>
<td>75</td>
</tr>
</tbody>
</table>
Wire Bonding Quality Assurance and Testing Methods

Heavy wire wedge shear testing

Heavy wire: 400 µm
Pitch: 750 µm

Pitch = W + S

Principle of shear test
Wire Bonding Quality Assurance and Testing Methods

Problems while evaluation of heavy wire shear test results

Partial shear lift off

Questions: Where is the limit between shear lift off and shear through the bond? What shear height should be chosen while shear testing?

Source: IZM Berlin
## Wire Bonding Quality Assurance and Testing Methods

Load Cartridge Options:

1. **Wire Pull**
   - Maximum Pull Force
   - Cartridge 1: 100 g
   - Cartridge 2: 1 kg
   - Cartridge 3: 10 kg

2. **Tweezer Pull/Peel**
   - Maximum Pull Force
   - Cartridge 1: 100 g
   - Cartridge 2: 5 kg

3. **Ball Shear**
   - Maximum Shear Force
   - Cartridge 1: 250 g
   - Cartridge 2: 5 kg
   - Cartridge 3: 100 kg

4. **Shear**
   - Maximum Shear Force
   - Cartridge 2: 5 kg
   - Cartridge 3: 100 kg

**Special Load Cartridges:**
- High Force Tweezer Pull up to 10 kg
- Heated Bump Pull up to 10 kg
- Stud Pull
- Cold Bump Pull up to 5 kg

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