E-Beam Substrate Testing

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Overview

- Background
- What is an E-Beam Tester?
- Measurements
- Interpreting Results
- Comparison With other Test Methods
- Conclusion

Background

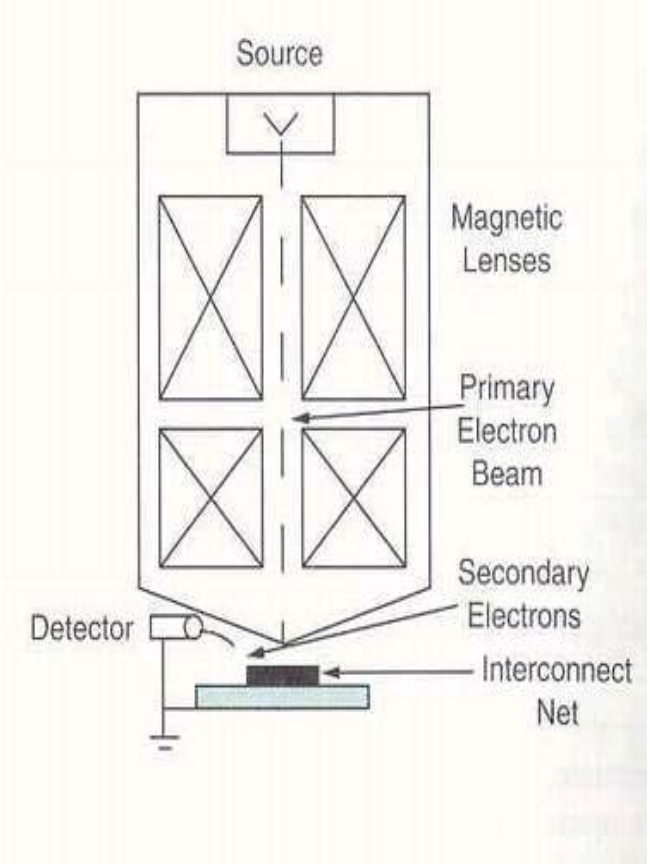
- What is substrate testing?
  - The testing of package interconnections prior to die attachment
- What types of interconnect faults exist?
  - Opens, shorts, latent opens, latent shorts
- Methods of testing?
  - Resistance testing, Capacitance Testing, E-beam Testing, Latent Open Testing

What is an E-Beam Tester?

- Noncontact substrate testing method
- Steps for test:
  - Terminal of net is charged
  - Other terminals of that net are examined to ensure charge transfer (test for opens)
  - Terminals of neighboring net are checked for transfer of charge (test for shorts)
  - Electron flood gun is used to erase substrate charge
  - Repeat process for the next net to be examined

Measurements

- High energy primary electrons fired from source
- Secondary electrons emitted from target pad
- Secondary electron current is measured by detector mounted below the beam emitter



E-Beam Substrate Tester [1]

Interpreting the Results

- The secondary electron current is dependent upon voltage at pad (voltage barrier
  - High pad voltage => small current
  - Low pad voltage => large current
- Pad voltages are determined and displayed in a voltage contrast
  - Opens = areas that should have been charged but were not
  - Shorts = areas that were charged that shouldn't have been
    - Shorts to power or ground result in fast dissipation of charge
    - If a short is detected, a secondary test is conducted to determine which adjacent nets are affected

Comparison of Methods [2]

Details	Capacitance	Resistance	Electron Beam	Latent Open
Frequency	1 - 10 MHz	DC	----	1 kHz - 1MHz
Probe Head	1	2	----	2
Probe Movement	Simple	Complex	Complex	Complex
Probe Time / Test (T_n)	200 ms	200 ms	15 ms Charge / Net (Tn) +10ms Test	200 ms
Total Test Time	nNTn medium	N(N-1)Tn/2+ (n-1)NTn large	2nNTn+NTn small	(n-1)NTn large
Opens Resolution	1 MΩ	10 MΩ	10 - 100 MΩ	3 - 10 mΩ
Shorts Resolution	1 MΩ	300 MΩ	1 Ω - 100 MΩ	----
Equipment Cost	Small	Small	Large	Large

N = # nets; n = # terminals/net; Tn = time/test

Problems

- Resolution is affected by the capacitance of the target net

$$t_{measurement} < \tau_{net} = R_{net} \times C_{net}$$

- Low resistance opens are difficult to detect
- Integrated passive devices (i.e. resistors and capacitors) lower the voltages at the terminals
- The exact location and cause of faults are not easily determined

References

- [1] Tummala, Rao ed., *Fundamentals of Microsystems Packaging*, New York: McGraw-Hill, pp. 760-764.
- [2] Tummala, Rao, et al., *Microelectronics Packaging Handbook*, New York: Chapman and Hall, pp. 821-838.
- [3] M. Brunner and R. Schmid, "Electron-Beam MCM Substrate Tester," *IEEE Trans. Components Packaging Manuf. Technol. B*, CPMT-24 (1), 2000.