“R2R component assembly with test and verification aspects”

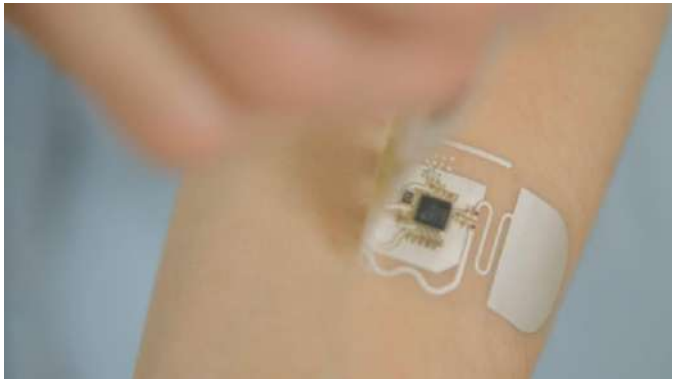
SmartEEs Workshop – Flexible and Wearable Electronics

Dr. Tuomas Happonen

Outline

- Introduction
- R2R component assembly
- R2R functional testing
- Pull test method
- Stretching and torsion test
- Q&A

Smart patch with ECG measurement and BLE radio interface functionalities



Affordable smart patches revolutionise patient monitoring | VTT News (vttresearch.com)

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244 M€
turnover and other operating income

2,129
employees

45%
of the net turnover from abroad

32.5%
a doctorate or a licentiate's degree

Established in
1942

Owned by Ministry of Economic Affairs and Employment

Cutting edge R2R pilot lines in Oulu for concept prototype manufacturing and verification

Printing

Assembly

Testing

Converting

Lasering

Injection molding

[VTT's Virtual Tour | Community | SmartEEs flexible and wearable electronics ecosystem (smartees2.eu)]

Introduction to assembly process

- Assembly process covers interconnecting surface mounted devices (SMDs) on a printed circuitry
- Hybrid integration combines and takes advantage of soft substrates with flexible, and even stretchable, circuitry and performance of SMD devices
- Conventional soldering process for component assembly is not a feasible solution due to the material and design choices

→ Conductive adhesives to bond SMDs on flexible and stretchable substrates both electrically and mechanically

01005” SMD resistor bonded on printed lines in fully automatic assembly process

Basics on electrically conductive adhesives

Isotropic conductive adhesives (ICA)

- Electrically conductive in all directions (x,y,z)
- High concentration of conductive particles
- Requires separated adhesive dots on individual interconnection pads
- Low adhesive consumption
- ”Global” curing at elevated temperature

Anisotropic conductive adhesives (ACA)

- Electrically conductive only in z-direction
- Low concentration of conductive particles
- Allows continuous adhesive area on individual interconnection pads
- High adhesive consumption
- ”Local” curing with pressure at elevated temperature (thermode)

Non-conductive adhesives (NCA)

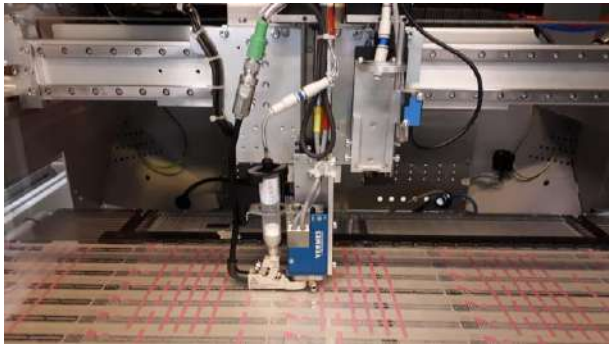
- No electrical conductivity
- Used for enhancing mechanical bonding or structural robustness
- Applied below component (underfill), around component edges (side-bonding) or fully covering the component (glob-top)

R2R assembly line for printed and flexible electronics

- All process steps (dispensing, assembly and curing) on the same run
- Stop and go type operation at individual process equipment
- S2S operation possible with manual handling
- Line total length about 18 meters
- Located at VTT Oulu printing hall C117a
- Line supplier: Scanditron Finland Oy
- Line integrator: db-matik AG (Germany)
- Acquired: December, 2018

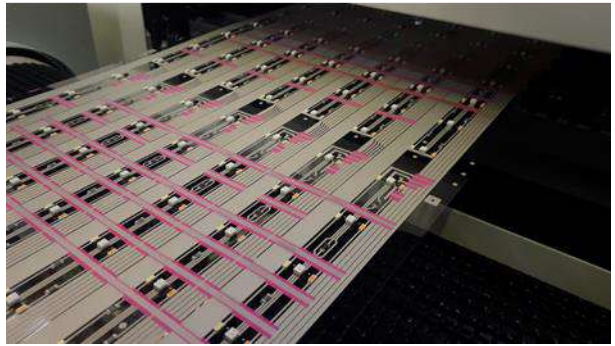
R2R assembly line / Conductive adhesive dispensing

- Elite Dispenser DR-61 (Nordson DIMA)
- Jet valve and rotary valve (Archimedes screw valve) in use
- Minimum repeatable dot size ~200 µm in diameter for a silver epoxy
- Process suitable for heat-curable ICA adhesives, ACA tools not available
- Working area about 400-500*300 mm (MD*TD)
- Customized vacuum table for dispensing base and web movement



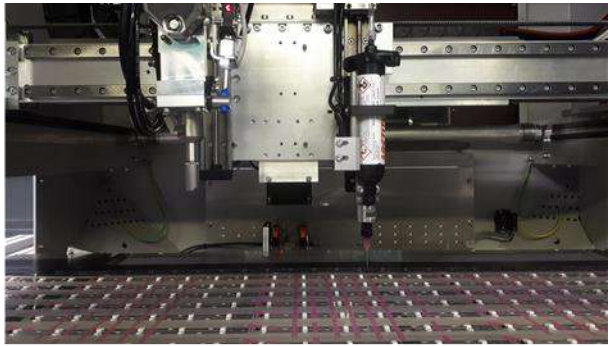
R2R assembly line / Component assembly

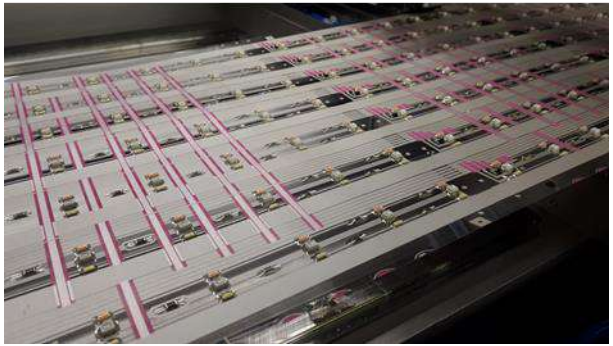
- Fuji NXT III
- DynaHead for multiple nozzles
- Minimum component size 01005’’ (0.4*0.2 mm) and maximum throughput 27000 CPH
- 8 / 12 / 16 / 24 / 32 / 56 mm feeders for SMD components provided on tapes / reels
- Working area about 400-500*300 mm (MD*TD)
- Customized vacuum table for assembly base and web movement



R2R assembly line / Non-conductive adhesive dispensing

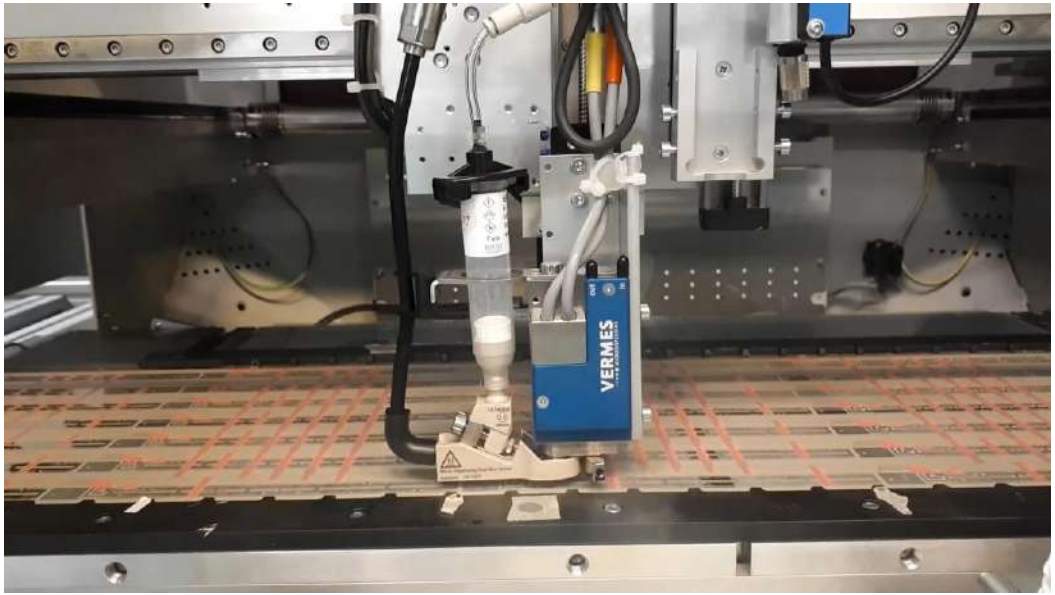
- Elite Dispenser DR-61 (Nordson DIMA)
- Stainless front closing needle valve and narrow round beam spray valve
- Utilizable for side-bonding, glob-top and covering layers
- Process suitable for UV-curable non-conductive adhesives (NCA)
- Working area about 400-500*300 mm (MD*TD)
- Customized vacuum table for dispensing base and web movement





R2R assembly line / Selected demonstrators

- LED foil in EU funded project InSCOPE (contents described in the video)



R2R assembly line / Selected demonstrators

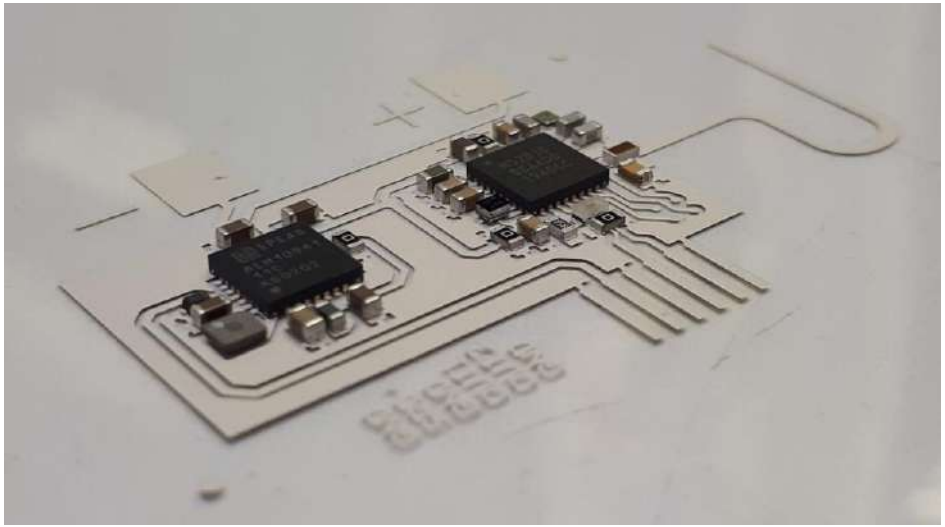
- “Reed” design in Business Finland funded project Flex-in-Glass
  - Close to 2 meter long decorative print and conductive lines on PET
  - Individually addressable RGB LEDs and capacitors bonded on the design
  - Two layouts in parallel including about 1000 components
  - Laminated inside glass

R2R assembly line / Selected demonstrators

- “Snowflake” design in EU funded project Delphi4LED
  - R2R printed circuitry on PET
  - Over 500 components at 250 * 250 mm area
  - Wide component spectrum: RGB LEDs, single color LEDs, resistors, capacitors and transistors
  - To be laser-cut into intended shape and injection moulded

R2R assembly line / Selected demonstrators

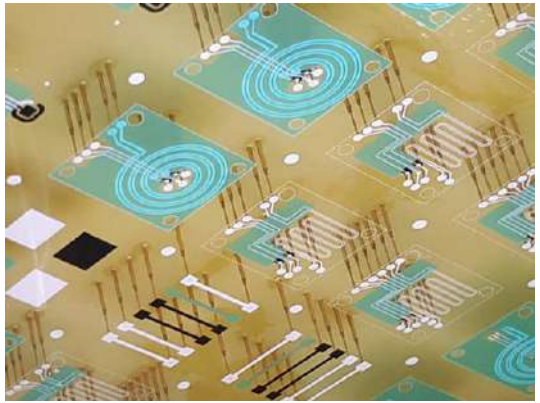
- Energy supply platform in EU funded project Smart2Go
  - R2R printed circuitry on PET
  - 30+ components at 20 * 40 mm area
  - Very broad component spectrum: ICs, accelerometer, crystal, LED, zener, resistors, capacitors and inductors
  - Flex battery, super cap, OPV etc. to be attached



R2R functional testing

- Stop-and-go operation mode
- Testing area 408 mm x 290 mm
- 400 arbitrarily configurable test pins
- Available test applications:
  - Open and short circuit testing
  - LCR measurements
  - Current and voltage measurements
  - OPV characterization (IV-curve)
  - LED and OLED functionality testing
- On-the-fly test result storage on a data base

→ Systematic quantification of quality, functionality and yield throughout a roll at industry-relevant volumes



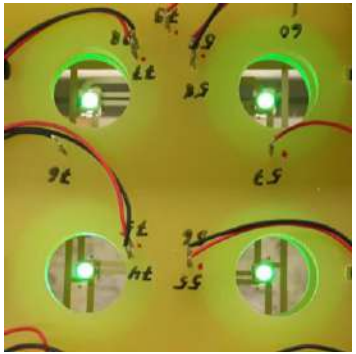
R2R functional testing process

Printed Intelligence: Roll-to-roll testing for printed electronics - YouTube

R2R functional testing: case LED foil

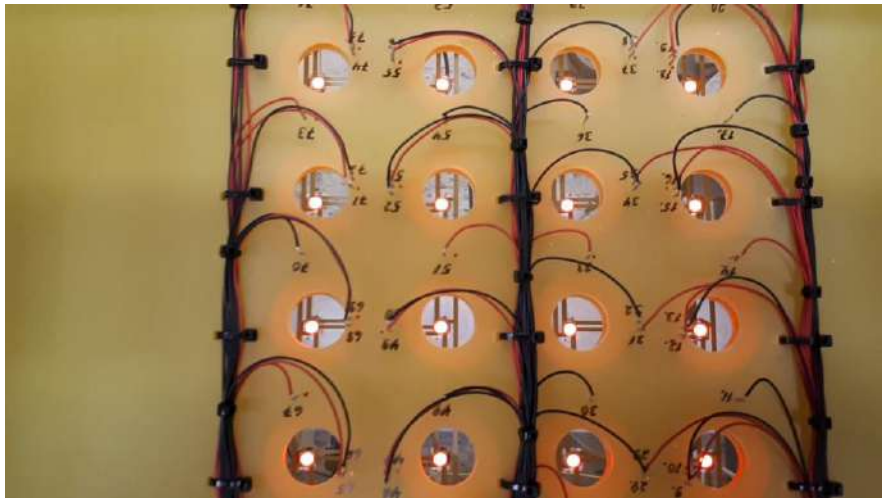
- Board-level testing: open and short circuit testing to verify continuity of printed wiring and to detect short circuits ~470 test cases per meter
- Component-level testing: component value measurements for chip resistors and capacitors, diode check ~130 test cases per meter
- Functional testing: power on test for a 4*6 RGB LED matrix, single colors at various intensities ~60 test cases per meter

→ Extensive test coverage for improved diagnostics



R2R functional testing: case LED foil

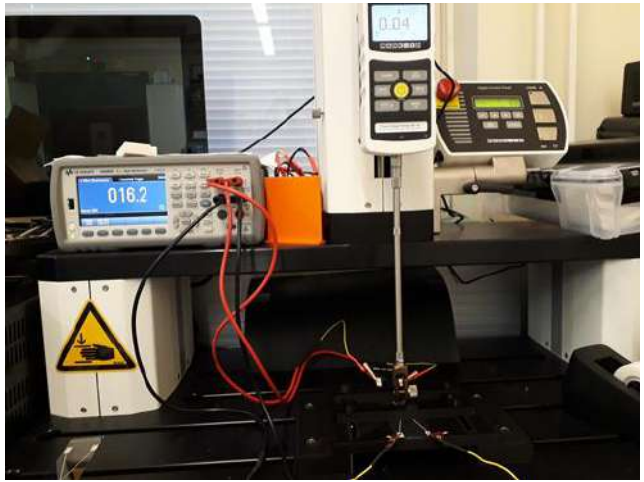
- Functional testing of addressable RGB LEDs: PWM signal generation and DC power supply from the automated test equipment → detection of correct color and intensity via camera (AOI)



Pull test method for characterizing bonding strength

- Conductive adhesive interconnection technology is an alternative for traditional soldering process for bonding SMD components at low processing temperatures
- From mechanical durability and reliability perspectives, adequate bonding strength of rigid SMDs on flexible substrates is a necessity

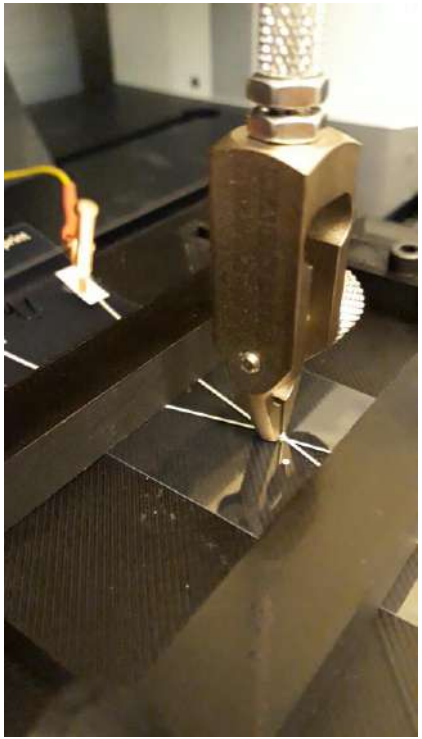
→ Pull-test setup for quantification of adhesive bonding strength and to optimize process parameters in printed and hybrid assemblies



Pull test method for characterizing bonding strength

- Test procedure: upwards-going motion at constant speed to induce a pulling force perpendicular to substrate
- Failure criterion is the force at time of electrical failure

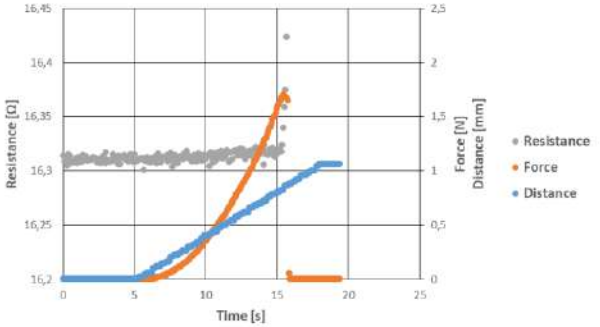
→ Accordant to MIL-STD-883E METHOD 2011.7 BOND STRENGTH (DESTRUCTIVE BOND PULL TEST), Test condition A – Bond peel

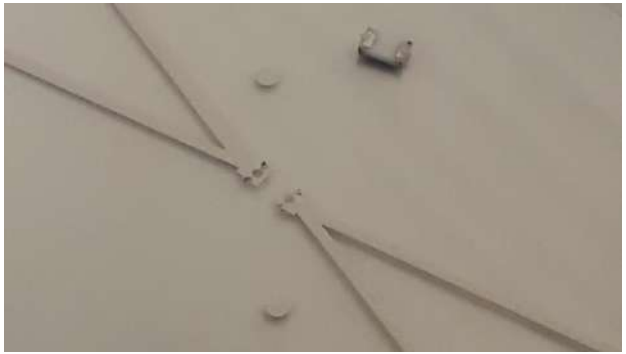


Pull test method for characterizing bonding strength

- Motorized test stand ESM303 from Mark-10 equipped with a force gauge
- Digital multimeter for online electrical characterization
- Miniaturized component grips and wedge grips to packages from 0402” upwards
- LabView SW for controlling the automated setup
- Failure analysis with failure mode classification

- More results to be published in EMPC2021: T.Happonen et al. “Adhesive bonding strength for printed and hybrid electronics”

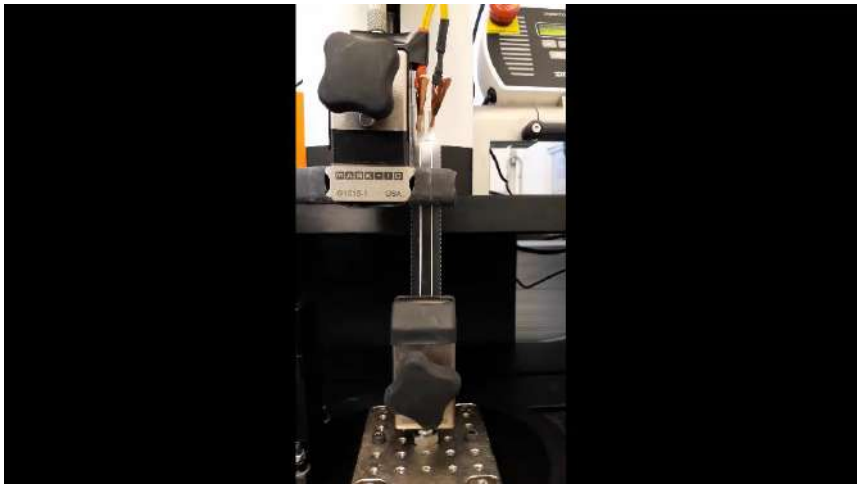




Stretching and torsion test

- Stretchable substrates enable free-form and multi-dimensional use conditions for printed and hybrid electronics
- One-dimensional linear elongation is not necessarily enough to depict the durability of stretchable systems or stretch-rigid interface under mechanical stresses

→ Combined stretching and torsion test to mimic realistic operational environment of systems on elastic substrates



Developed in EU funded project iRel 4.0

Printed and hybrid electronics verification offering

Materials and manufacturing process verification

- Substrates, inks, adhesives, encapsulates, SMD, etc. and their combinations
- Tolerance analysis of printed circuitry and functionalities
- Assembly process yield
- Performance test of functionalities e.g. PV, LEDs…

Product concept verification

- System performance
- System reliability
  - Temperature cycling
  - Temperature – humidity
  - High T aging
  - Bending
  - Stretching + torsion
  - SMD pull test
  - Washability

Way forward

If you are interested in joint or bilateral R&D efforts to

- learn and discover the possibilities provided by flexible / stretchable / large-area / hybrid / structural electronics in comparison to traditional electronics (rigid PCBs, soldering process etc),

describe your case to us for establishing product concept, manufacturing process and reliability verification

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