QUALITY LABORATORY FOR INVESTIGATION OF LEAD-FREE MATERIALS AND PROCESSES

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Key words: quality laboratory, testing quality and reliability, solderability testing, lead-free coating, lead-free soldered joints

Abstract: The main technological objective of the GreenRoSE project is to provide European SMEs of the electronics sector with the knowledge and tools to produce electronic equipment free of hazardous substances, with defined quality and reliability. For the realization of the objectives the Advanced Interconnections Technology Laboratory for substitution technology assessment and quality tests has been set up in ITR, ISSP and Cynel. The main testing equipment of the Quality Laboratory in ITR is as follows: solderability testers, rotary dip tester, ionograph , sirometer, digital Viscometer, AOI, resistivity 4 point resistance meter, climatic chamber, stereoscopic and metallurgical microscopes, system for microstructures metallographic preparation of the samples, UV laser system, convection oven and double-wave soldering machine.

The range of investigations that can be carried out in ITR Quality Laboratory concerns: quality investigation of materials and components for assembly processes, quality evaluation of soldering technologies parameters, quality investigation of solder joints as well as climatic tests performance of soldering materials, PCBs and solder joints.

ITR has designed test boards for solderability measurements of PCBs with lead-free coating, characterisation of the immersion tin coating and estimation of solder joints quality produced in reflow and wave soldering processes.

Laboratorij za raziskavo in študij materialov in procesov brez svinca

Ključne besede: laboratorij, testiranje kakovosti in zanesljivosti, testiranje spajkljivosti, prevleke brez svinca, spajkani stiki brez svinca

Izvleček: Glavni tehnološki cilj projekta GreenRoSE je zagotoviti Evropskim proizvajalcem elektronike znanje in orodje za proizvodnjo naprav brez škodljivih snovi, s predpisano kakovostjo in zanesljivostjo. Za uresničitev tega cilja smo ustanovili ustrezne tehnološke laboratorije na Poljskem (ITR, Cynel) in v Latviji (ISSP). V laboratoriju ITR imamo na razpolago sledečo testno opremo : merilnik spajkljivosti, merilnik omakanja, ionograf, sirometer, digitalni viskozimeter, AOI, štiri-točkovni merilnik upornosti, klimatsko komoro, stereoskopske in metalurške mikroskope, sisteme za mikrostrukturno in metalurško pripravo vzorcev, UV laserski sistem, temperaturno komoro in napravo za valno spajkanje.

V tem laboratoriju lahko opravimo naslednje raziskave : preiskave kakovosti materialov in komponent za montažo, preiskave kakovosti tehnologij spajkanja, preiskave kakovosti zaspajkanih stikov, kakor tudi obnašanje materialov, tiskanin in spajkanih stikov v klimatski komori.

ITR je razvil testne plošče za meritve spajkljivosti tiskanin s prevlekami brez svinca, za vrednotenje spajkanja s potapljanjem ter za oceno kakovosti spajkanih stikov pri različnih načinih spajkanja.

1. Introduction

The main technological objective of the GreenRoSE project is to provide European SMEs of the electronics sector with the knowledge and tools to produce electronic equipment free of hazardous substances (in particular lead and halogen compounds).

For technology assessment and quality tests the Advanced Interconnections Technology Laboratory has been set up. The laboratory has contributed to research identified in WorkPackages and specifically to develop techniques and standards for quality and reliability testing. This laboratory will also support the needs of SME Core Group partners throughout the project and provide a support platform for wider exploitation of the new technologies both during and after the project.

The Quality Laboratory has been set up at ITR and Cynel, Poland as well as at ISSP, Latvia.

2. Description of the quality laboratory

The Quality Laboratory in ITR is equipped with the following equipment:

- Solderability testers MK-6A, General Electic Co. and Menisco ST 60/LT 6000, Metronelec
- Rotary dip tester, ITR
- Ionograph Omega Meter 600R, Alpha Metals

- Sirometer Model 300, Alpha Metals
- Brookfield Digital Viscometer DV-II ,
- AOI CAMTEC 2V50 system, PCB-MB Material Anlagen Service
- Resistivity 4 point resistance meter model 34420A, Agilent Technology
- Climatic chamber C-70/200, CTS
- Stereoscopic Zoom Microscope Nikon SMZ1500 (Zoom range 7X - 112,5X)
- Metallurgical Microscope Nikon Eclipse L150 (Zoom:100X,200X,500X,1000X)
- System for microstructures metallographic preparation of the samples
- UV Laser system.
- Convection oven VIP70A, BTU
- Double-Wave soldering machine ERSA ETZ 250

Solderability testers

Two types of computerized wetting balance machines for solderability measurements are available in the Laboratory at ITR. First one Menisco ST60 is a fully automatic (Fig.1). The Menisco ST60 can be used for incoming quality control of materials, preassembly testing after extended component storage, soldering process parameter selection and optimization, flux efficiency determination, solder alloy, and solder paste quality checking and monitoring. The second solderability tester Mk6A makes possible to measure surface tension or interfacial tension of alloys and solderability of components by Wetting Globule Method.

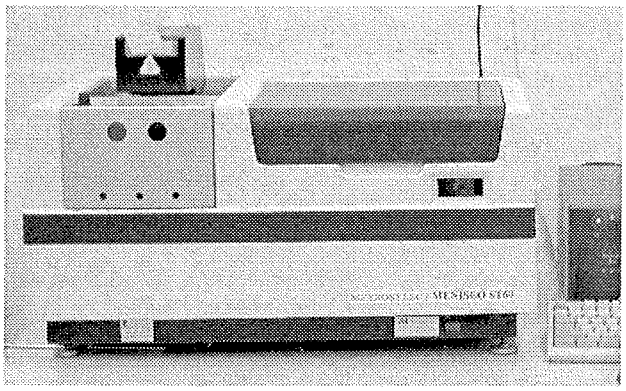


Figure 1. Solderability tester Menisco ST60

Rotary dip tester TL-14

Rotary dip tester TL-14 is recommended for solderability testing of plated through holes, surface conductors and attachment lands. It simulates wave soldering process.

Ionograph Omega Meter 600R

Omega Meter Systems allows quantitative measurements of ionic contamination on printed circuit boards and printed wiring assemblies resulting from varied technological processes.

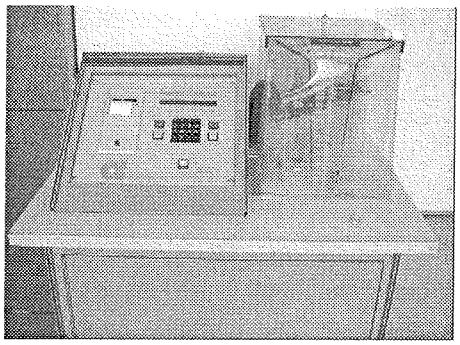


Figure 2. Ionograph Omega Meter 600R

Resistivity 4 point resistance meter

Agilent 34401A Multimiter can be used to measure resistance in the ranges: 100Ω, 1KΩ, 100 KΩ, 1MΩ, 10 MΩ and 100MΩ with maximum resolution of 100 μΩ.

Sirometer Model 300 and Climatic chamber CTS - 70/200

Sirometer allows measuring the insulating material's resistance and electro-migration to the flow of current between conductors (Fig.3a). Surface insulation resistance (SIR) and electro-migration (EM) testing are used in a number way to characterize residues or determine the effect of residues on the performance of printed circuit boards. Sirometer co-operates with the climatic chamber CTS -70/200 in our laboratory. Characteristics of the climatic chamber are presented below:

- Temperature range + 10°C to +95°C
- Humidity range 10% to 98% rel. humidity
- At dew. point range I +7°C to +89.5°C
- Dew. point range II -5°C to +7°C
- Temperature fluctuation: ± 0.1 to ± 0.3 K temporary

Brookfield Digital Viscometer DV-II

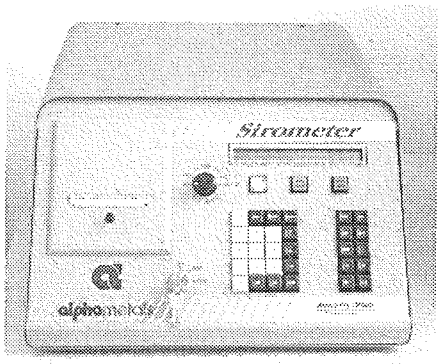
The Brookfield digital viscometer, Model DV-II is a laboratory Viscometer which can be utilized with all Brookfield accessories (Fig.3b). It allows to measure rheological properties of solder pastes, conductive adhesives and other materials.

Microscopes

The Stereoscopic Zoom Microscope Nikon SMZ1500 with zoom range 7X - 112,5X and provides very good optical performance (Fig.4a).

The Metallurgical Microscope Nikon Eclipse L150 (Zoom: 100X, 200X, 500X, 1000X) can be used for inspection and measurements. CF160 infinity enables the microscope images to be crisp and clear with high contrast and minimal flare (also under dark field microscopy) (Fig.4b).

a



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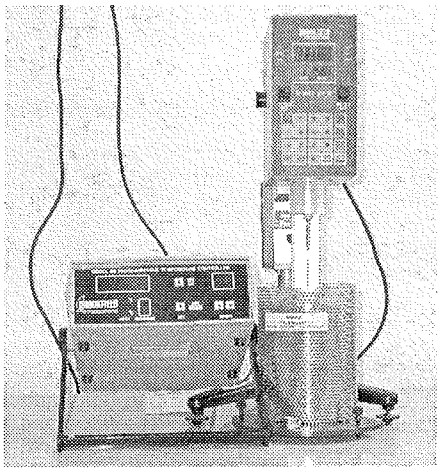
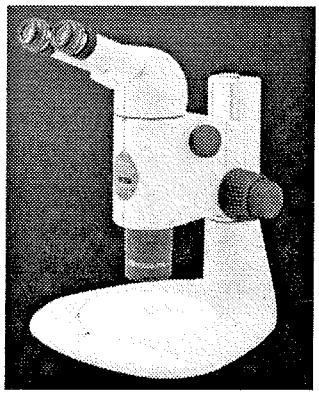


Figure 3. Sirometer Model 300 (a), Brookfield digital viscometer DV-II (b).

a)



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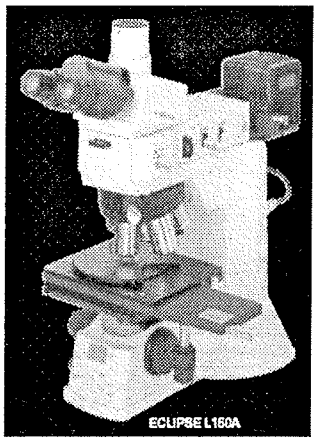


Figure 4. Stereoscopic Zoom Microscope (a). Metallurgical Microscope (b).

System for preparation of the metallographic specimens

System for preparation of metallographic specimens consists of a cut-off machine Mecatome 255/300, a polishing machine Mecapol P262 and an automatic and manual cut-off machine Mecatome 255/300.

The specimens are used for quality evaluation of the laminate system, plated-through holes (PTHs), copper foils, plating, and/or coatings in PWB production and also for quality of solder joints.

Automatic Optical Inspection CAMTEC 2V50 (AOI)

Camtec 2V50 provides an optimal tool for use in the visual inspection of printed circuit through the entire manufacturing process as well as after paste print, component placement and reflow process.

UV Laser system

High power diode-pumped, repetitively q-switched UV:YAG laser system. The machine is used for drilling micro-via and structuring conductors, channels as well as cutting various shapes in many different organic and metallic materials. UV laser system is also used for very precision measurements of distance in the aim to control the quality of manufactured PCBs.

Convection oven VIP70A

VIP 70A is a convection oven with 5-Zone independent control air configuration. Windows-based operating software provides user-friendly control, advanced profiling, data collection, programmable event sequencing and host communication. It has edge rail conveyor and fixed and retractable center board supports eliminate sagging associated with thin boards.

Double wave soldering machine ERSA ETZ 250

Double wave soldering machine ERSA ETZ 250 enables analyzing and controlling soldering processes of mixed assemblies with SMD and Through-Hole components. It is completely adopted for lead-free soldering. The machine has got two flux systems (spray and foam) what makes possible to investigate the whole spectrum of fluxes.

3. Test boards for quality assessment of materials and solder joints

ITR has also offered test boards for quality assessment of materials and solder joints (Fig.5a-e, Fig.6 and Fig.7). All test boards can be manufactured in ITR and SMEs (GreenRoSE partners). Assembly processes can be done at pilot line in Semicon and ITR.

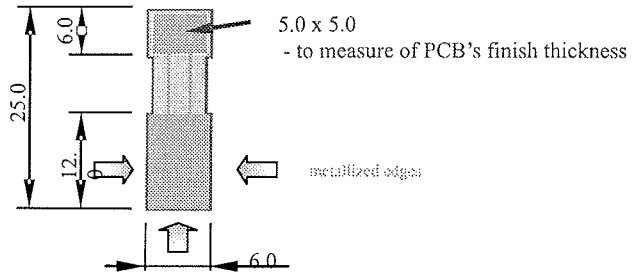
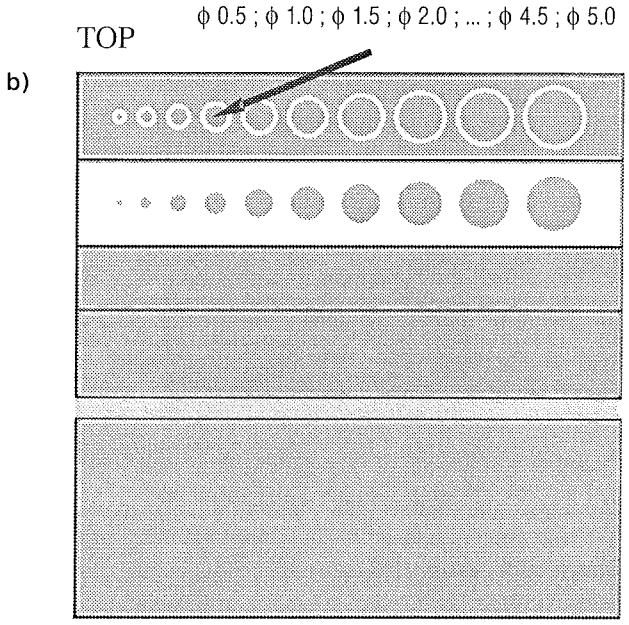


Figure 5a. Test board for wettability test using the meniscograph method, tin thickness measurement and assessment of tin porosity.

b)



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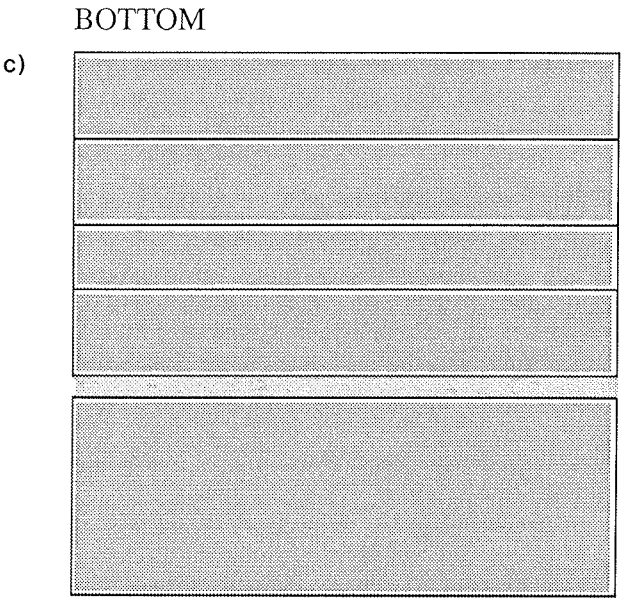
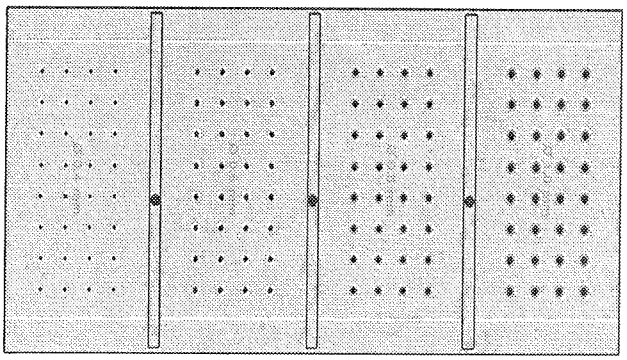


Figure 5b and 5c. Test board: for spread tests in reflow soldering process (b) and for PTH wettability test carried out by rotary-dip test (c).



d)

e)

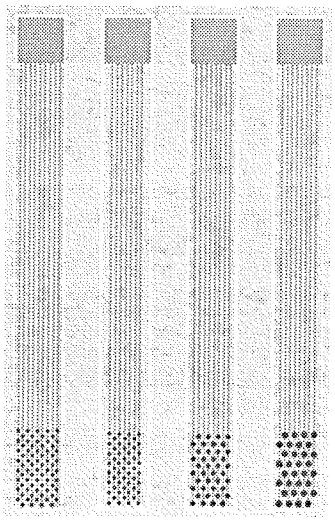


Figure 5d and 5e. Test board for: tin thickness measurement in PTH - diameters: ϕ 0.4; ϕ 0.6; ϕ 0.8 and ϕ 1.0 mm (d) estimation of solder mask compatibility with the tin immersion process and soldering processes (e).

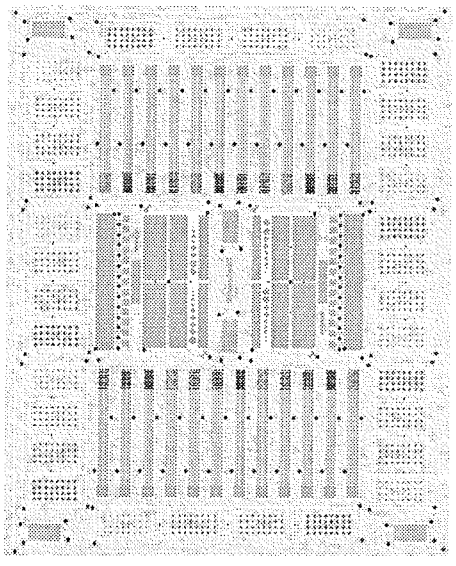
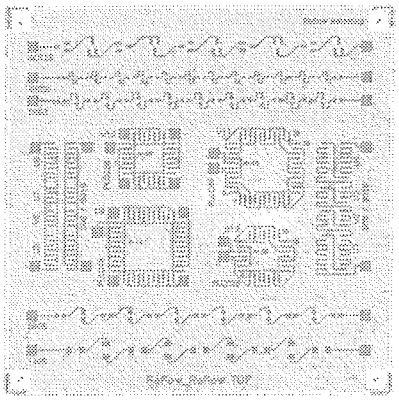


Figure 6. The set of test boards

Reflow soldering

TOP



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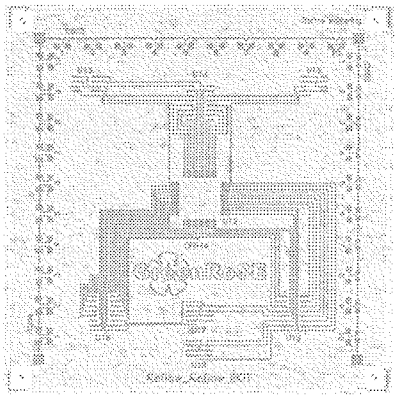
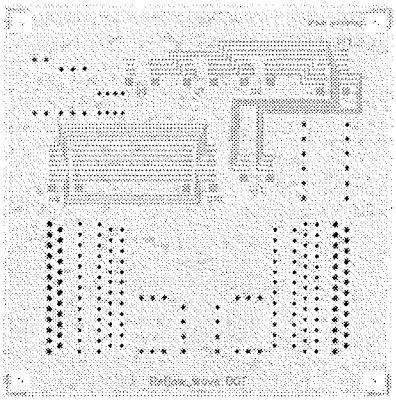


Wave soldering

TOP



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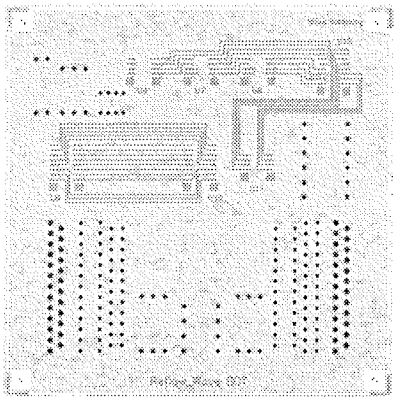


Figure 7.Test boards for soldering processes.

4. ITR Quality Lab investigation range

The range of investigations that can be carried out in ITR Quality Laboratory concerns the following issues:

1. Quality investigation of materials for assembly processes, included:
   - Solder alloys for wave soldering process: surface tension and surface interfacial tension of alloys, solderability
   - Solder wires for hand soldering process: dimensional tolerance, flux content, flux efficacy test, copper corrosion test, surface insulation resistance comb test and electrical migration test of flux residues, ionisable surface contaminants
   - Solder pastes: viscosity, wetting, slump, solder ball, tack, metal content by weight, solder shapes- granularity, copper corrosion, ionic residue, surface insulation resistance comb test and electrical migration test of flux residues.
   - Fluxes: activity, acid value, non-volatile matter, halogen determination, tack test, spread test, copper corrosion, ionic flux residues, ionic residue, surface insulation resistance comb test and electrical migration test of flux residues.
2. Quality investigation of components for assembly processes, included:
   - Printed circuit boards: Visual and dimensional examination, plating thickness /microsection/ and immersion tin thickness, solderability of pads and through holes, solder mask compatibility of soldering process, tin whiskers, ionic contamination, surface insulation resistance, electrical tests, changes in resistance and delamination after thermal shock.
   - Electronic components: solderability of electronic components.
3. Quality evaluation of soldering technology parameters, included:
   - Wave soldering process: time-temperature profile selection, flux selection, checking of fluxing process.
   - Reflow soldering process: solder paste selection, stencils laser made, solder paste inspection, time-temperature profile choice.
4. Quality investigation of solder joints, included:
   - Evaluation of solder joints quality: Visual inspection of solder joints, solder joint failures qualification, electrical and mechanical measurements of solder joints,
   - Solder joint cross sections evaluation for: explanation of solder joint failures, investigation of intermetallic compounds.
5. Climatic tests performance of soldering materials, PCBs and solder joints.

4.1. Catalogue of available services for quality testing

In the Quality Laboratory four groups of tests are available:

- test group for lead-free materials applied in printed-circuit board assemblies,
- test group for printed circuit boards with lead-free finish,
- test group for lead-free components for surface mount technology and through- hole technology,
- test group for lead-free printed-circuit board assemblies.

The tests are performed according to the required international standards.

5. Examples of the performed tests

5.1. The Wetting Balance measurement

For solderability measurement of PCBs with different finishes the wetting balance method was used. The maximal wetting force Pmax, wetting time τ_z, time to obtain 2/3 maximal theoretical force $P_{maxTeor.}$ and wetting angle θ after 2 and 3 s were measured using Meniscograph Solderability Tester MENISCO ST 60 (Fig.1).

Table 1. Solderability requirements

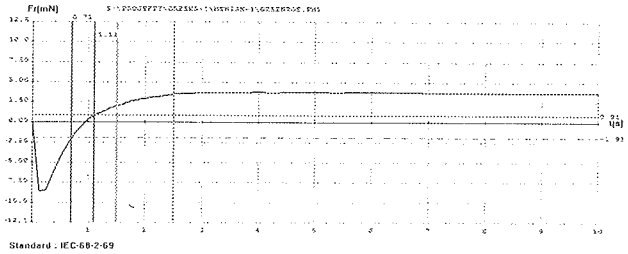
Standard	Criteria	Requirement
J - STD 003 [2]	Wetting time τ_z [s]	≤ 2 s
	Max wetting force P_{max} [mN/m]	≥ 120 mN/m
	Contact angle θ [°] after 3 s	≤ 55°

The following experimental procedure was established:

- Atmosphere: air,
- Test coupon: 18μm Cu double-clad FR-4 with Sn, OSP and Ag coatings, thickness = 1.5 mm (Fig.5a),
- Alloy SAC407,
- Flux: VOC- LP11/AC, TN/4A and MPWC, ITR and VOC -free - 330 Alpha, 1075-EXR46 Indium and Koki,
- Immersion depth: was 3 mm,
- Immersion time: 10 s,
- Immersion speed: 21 mm/s,
- Test temperatures: 250°C.

The test boards have been tested in the state "as delivered", after aging: dry heat - 4h at 155°C, after humidity (24h at 125°C + 96h at 30°C 70% RH) and 1 x reflow process.

Examples of boards with very good solderability and bad solderability are presented in figures 8 and 9, respectively.



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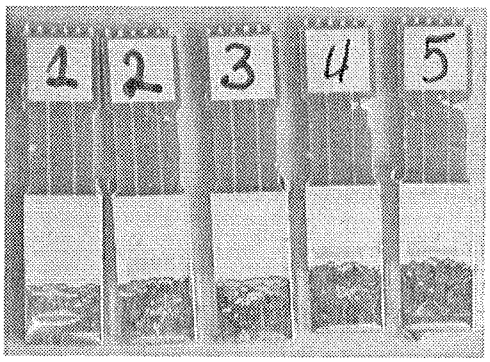

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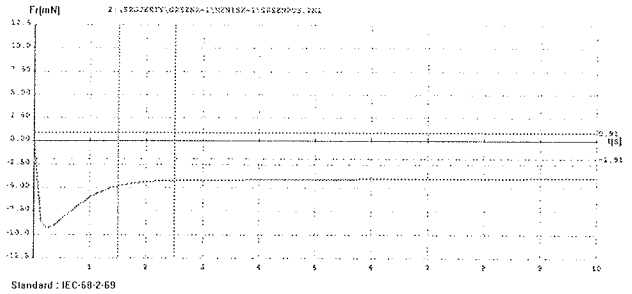
Figure 8. An average wetting curves for test board with Sn that passed the requirements (a) and example of the test board (b).



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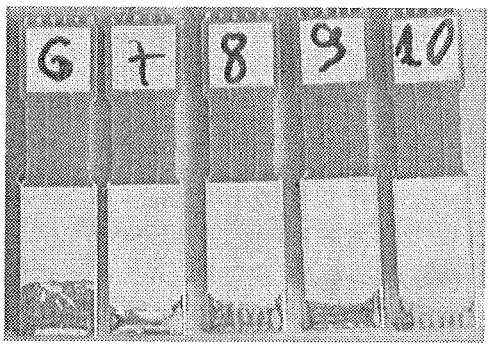


b)

Figure 9. An average wetting curves for test board with Sn that did not pass the requirements (a) and example of the test board (b).

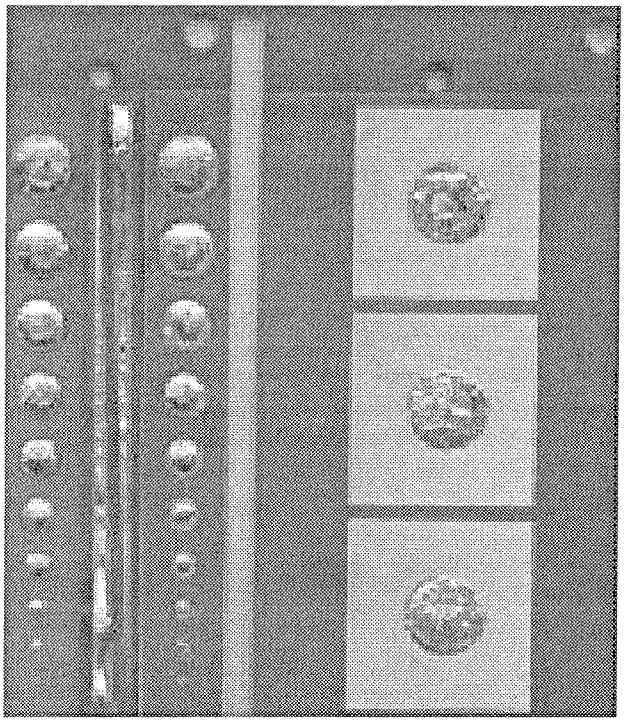
5.2. The reflow wettability test

Wettability tests of lead-free solder pastes on PCBs with led-free coatings have been carried out on the base of the Standard ANSI/J-STD-005 /3/. After applying solder paste

by stencil the specimen is placed on the surface of the soldering bath at the temperature 250°C for 20 s.

Requirement: class "A" – When examined visually at 10X, the solder shall uniformly wet surface and there should be no evidence of dewetting or non-wetting of the copper and there shall be no solder spatter around the printed dots. (Defects: B- non-wetting, C- dewetting, D- spattering).

An example of the testing equipment is shown in Fig.10. Examples of good and bed wettability of lead-free solder pastes on PCBs with led-free coatings are presented in Fig.11.



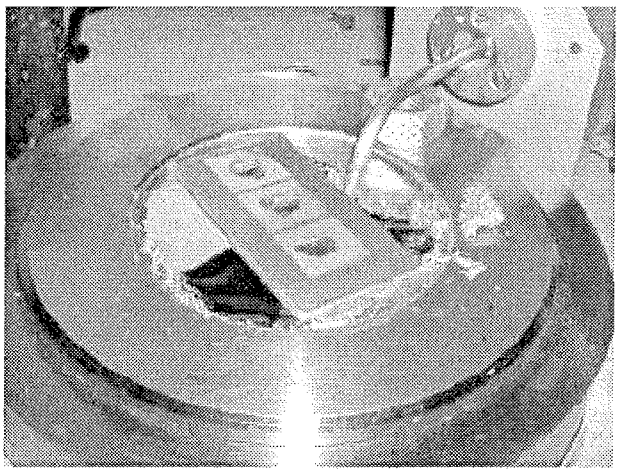
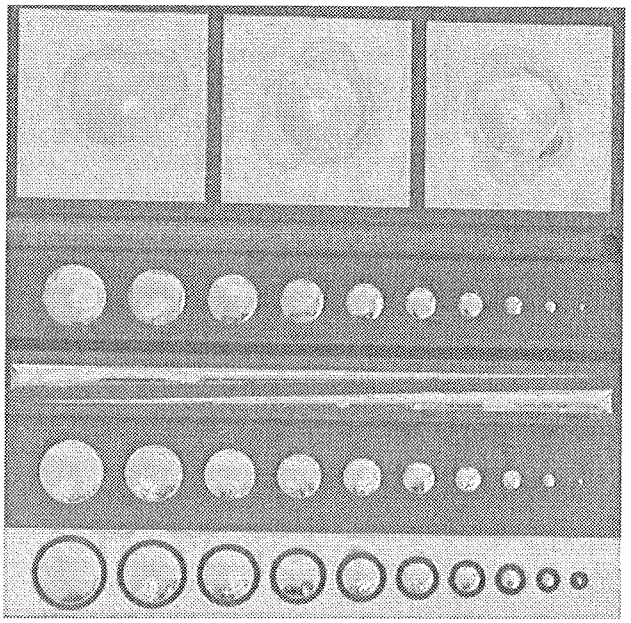


Figure 10. Example of the testing equipment.

6. Conclusion

The Quality Laboratory in ITR is equipped with modern measuring and controlling devices and technology equipment which allow performing quality investigation of materials and components, quality evaluation of soldering processes and solder joints as well as climatic tests.



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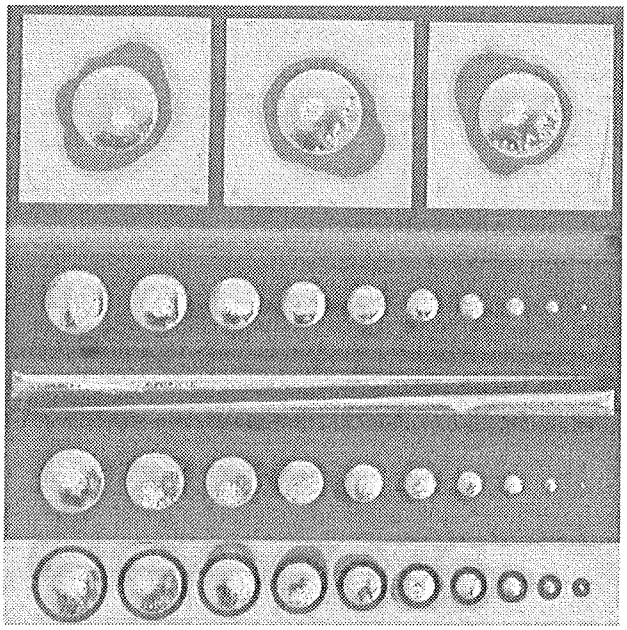

b)

Figure 11. Example of good (a) and (b) bad wettability of solder paste on tin coating.

The necessary materials and services for the quality test can be supplied by the following Partners: Eldos, SEMICON and RWT. Eldos can manufacture test boards; Cynel can deliver some lead-free alloys. The assembly processes can be done in Semicon, RWT and ITR. Other quality investigation can be carried out in the laboratory of other GreenRoSE's research Partners: ISSE, Cynel Unipress, ITRI, TUB, IVF, IJS and HIPOT R&D.

7. References

/1/ ANSI/J-STD-003. Solderability Test for Printed Boards. April 1992, update February 2003

/2/ EN 600682-2. "Basic environmental testing procedures. Part 2. Test B: Dry heat". 1993

3/ ANSI/J-STD-005. Requirements for Soldering Pastes. January 1995 (IPC-TM-650 2.4.45 Solder Paste-Wetting Test)

8. Acknowledgment

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