New Requirements for Sir- Measurement

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Abstract
During the last period of newly assembled electrical devices (pcbs), new component types like LGA and QFN were also qualified as well as smaller passive components with reliability requirements based on the automotive and industrial industry. In the narrow gaps under components, residues can accumulate more by the capillary forces. This is not that much a surface resistance than an interface issue. Also that the flux residues under such types of components creates interaction with the solder resists from the pcb, as well as the component body was not completely described in the standard SIR measurement. On the other hand also, electrical influence with higher voltage creates new terms and conditions, in particular the combination of power and logic in such devices. The standard SIR measurement cannot analyze those combinations. The paper will discuss the requirements for a measurement process, and will give results. The influences of the pcb and component quality will also be discussed. Furthermore it will describe requirements for nc solder paste to increase the chemical/thermical/electrical reliability for whole devices.

Introduction
Since the beginning of the Surface Mount Technology there had been created a lot of measurement methods to qualify the quality/stability of flux residues by using solder paste. That means there are international, national and company standards for the qualification of that auxiliary material [STD-01]. That qualification gives an initial idea of the quality but unfortunately it doesn't give all information for the whole assembly. As an example, in some cases there will be used, on the residues of no clean flux residues, conformal coating. Each single material passed the qualification according the standards but in combination with both, it is possible to create failure [Sch-06]. Other points are new types of components (miniaturization) that the physics changed or the final application e.g. power devices in combination with surface mount on pcbs, Figure 1. This type of components is classical SMD with voltage from 250V till 500V as QFN. Therefore the physics could change due to new of component as well as new voltage, which creates a new quality/quantity of electrical field strength.

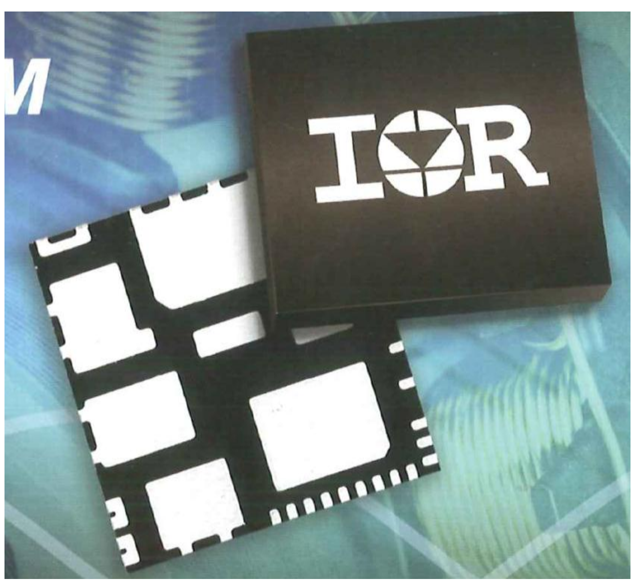

Figure 1 Example for a power-QFN component

Another point is the combination of high humidity and voltage. Especially the automotive industry requires that also for simply devices.

FLUX PENETRATION UNDER COMPONENTS

The standard test methods for measuring effects of fluxes are determining the insulation resistance only on free surfaces. The actual situation of electronic assemblies is considerably more complex. Among and between components, both the flux, but also the dewing moisture is concentrated. Depending on the gap height and areas of the components, capillary forces can effect very different. Because of component designs such as QFN or LGA, these effects are becoming more and more relevant. Even the cleaning of assemblies is complicated by these small gaps. Perhaps this problem will be intensified even by cleaning.

For a theoretical analysis of these phenomena, at first the conditions on the resulting capillary gaps should be considered. For this purpose some similarities to the application of the known underfilling in Flip-Chip technology can be pointed out. This is a horizontal gap between parallel plates, which will be filled by a fluid, as it has been simulated in the work of Haeussermann [HAE-09].

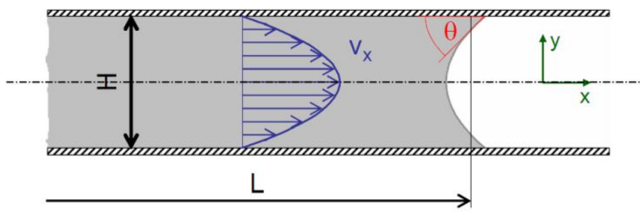

Figure 2 Two plate model (horizontal plates) [HAE-09]

Starting from these geometrical conditions, the following equations (1) to (4) can be used for calculating the wetting by a liquid medium:

$$\gamma_{SL} = \gamma_S - \gamma_L \cos\theta \qquad (1)$$

$$\Delta p = \frac{2\,\gamma_{SL} \cos\theta}{H} \qquad (2)$$

$$v = \frac{\gamma_{SL}\, H \cos\theta}{6\, L\, \eta} \qquad (3)$$

$$L = \sqrt{\frac{\gamma_{SL}\, H\, t \cos\theta}{3\,\eta}} \qquad (4)$$

Δp – pressure difference; v – penetration speed;
L – penetration length; H – assembling height;
η – viscosity; γ_S – surface energy (solid);
γ_L – surface tension (liquid);
γ_{SL} – interfacial tension (solid-liquid); θ – contact angle

Instead of the underfillers, used in the original calculation, corresponding data for fluxes and PCB substrates were looking for. Table 1 shows the material properties used for the further calculation, which intended only as typical examples for illustration. As a substrate, a solder resist was assumed, whose surface energy is mainly disperse [BEL-94], as it is also the case for the most organic solvents of the fluxes.

Table 1 Material properties from references (typical examples)

Material	Properties		Ref.
substrate	surface energy	39 mN/m	WAN-06
	contact angle (flux/mask)	26,2°	
alcohol based flux	surface tension	22.6 mN/m	WES-08
	viscosity	2.97 mPa*s	
flux cleaner	surface tension	23 mN/m	CRC-04
	viscosity	1.2 mPa*s	

With the sample data, some estimation for wetting of the capillary gaps can be made. First of all, it can be calculated that the capillary filling pressure increases enormously with decreasing gap. While at gap heights of 100 microns and more the pressure hardly changes with <5 mbar, for gaps smaller than 50 microns it increases drastically, e.g. up to 67 mbar for 5 microns (Figure 4). However, very low pressures are sufficient to fill the gap completely with flux (in theory), because there is no opposed weight force in the horizontal position. The calculated depth of flux penetration in Figure 3 is calculated for a propagation time of one second.

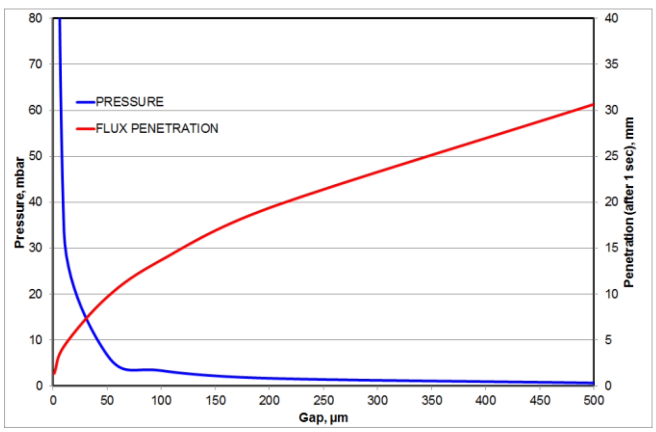

Figure 3 Capillary pressure and penetration depth of the flux

As it can be seen, the penetration depth increases with larger gap sizes, despite of the smaller capillary pressure, which is mainly determined by the viscosity and the resulting flow speed. Figure 45 shows the calculated penetration speeds in a 100 micron gap for a flux and a cleaning agent, while the cleaning agent is wetting little faster. The wetting rate is particularly high in the first 5 seconds and then approaching to a lower limit of about 1 mm/s.

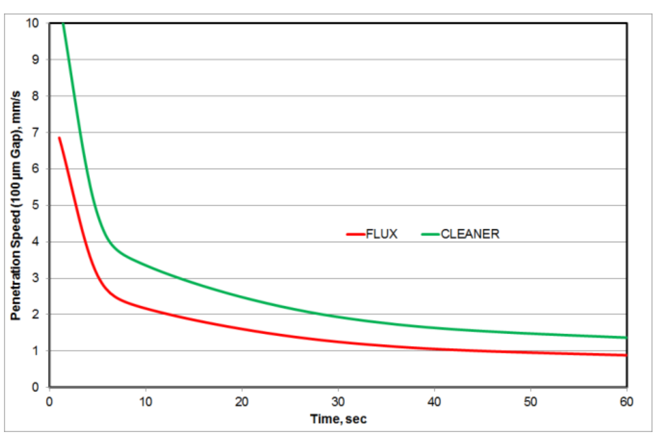

Figure 4 Dynamic of penetration for fluxes and cleaner

Accordingly, the penetration of the flux slows down; however, the flux already has spread out nearly 50 mm (theoretically) after 10 seconds (Figure 5). For real components a complete filling of the gap may be achieved, in most cases, after the first second.

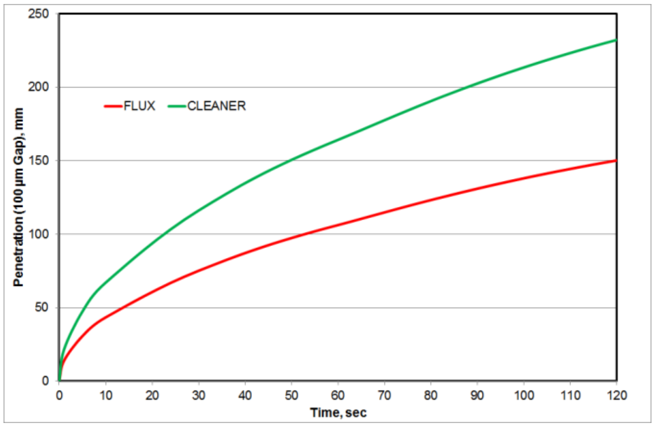

Figure 5 Penetration length depending on time

The temperature was not taken into consideration in the shown calculations, which is obviously also influencing the wetting. After measurements in [WAN 06], the viscosity of fluxes decreases with increasing temperature from 25°C to 80°C for 3 to 4 orders of magnitude. The wetting or filling of the capillaries would be so much faster. However, at these temperatures the solvents of fluxes are starting to evaporate, so that the flux is drying, and the wetting process could be terminated. Since these are two competing mechanisms, the influence of temperature must be further investigated experimentally at selected fluxes and structures.

PRACTICAL INVESTIGATION WITH QFN COMPONENTS

That has been developed a short test to see the interaction of different combinations:

- Comparison of two no clean (ww) vs. water washable (WW) solder pastes (Type 5 paste)
- Cleaning with solvent cleaner vs. DI water
- Two stencil thicknesses 20µm and 100µm

A special layout was created for a QFN with 16 leads, Figure 6.

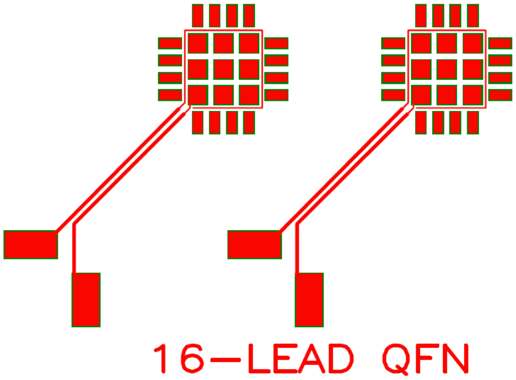

Figure 6 QFN test structure

This potential difference came via the heat sink structure as minus (the component finish had 100% metal) and an additional wire which is located the pcb under the QFN body. A voltage of 50 V was applied for a distance of 200 µm (178…213 µm measured) between wire and pad. This generates high field strength of 250 kV/m. The diagram in figure 7 shows the measured results after 7 days (168 h) for high humidity and temperature 85°C/85% r.H., accordingly automotive requirements.

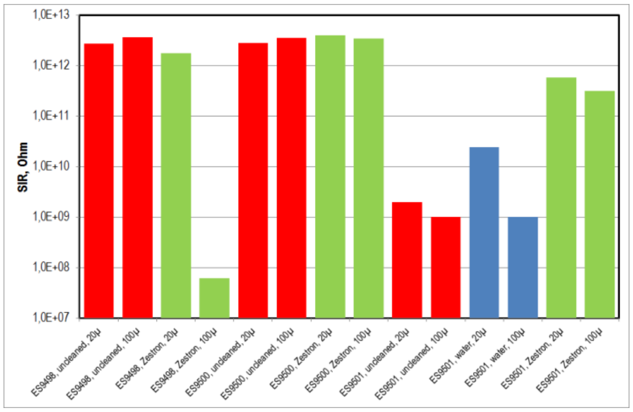

Figure 7 SIR results with different combination

Generally the ww paste gave just good results by using the solvent cleaner and generally worse results with the higher printing deposit. The same happens with one of the no clean fluxes. An explanation could be, that based on a cleaning process, the flux residues will just apply a little solved but not completely removed. Due to the fact that this are just first results, it has to be verified with more samples and combinations.

HIGH VOLTAGE INVESTIGATION WITH A SIR COMB

As it mentioned in the introduction new components with high voltage are applied on pcbs and there are not really information about the interactions with the residues of solder paste fluxes. A short practical test has been done by using the standard SIR comb with test voltage of 1000V, which works well for dry conditions. After a storage for 7 days with high humidity and temperature 85°C/85% r.H. the test was repeated and shows only single small variances of one magnitude, despite of solder paste.

Table 2SIR results of three different pastes with 1000V

PCB	***A***	***B***	***C***	***D***
Paste 1	376 E9	603 E9	186 E9	639 E9
Paste 2	837 E9	608 E9	245 E9	48,5 E9
Paste 3	447 E9	723 E9	471 E9	608 E9
initial PCB	677 E9	496 E9	665 E9	692 E9

For future investigations a combination of actual component layouts and high voltage measurements of assembled test pcb's is planned.

INVESTIGATION OF BEDEWING EFFECTS

Electronic components which are exposed to large temperature differences can be particularly stressed by bedewing. If the environment cools quickly and a free exchange of air is also not possible, the water absorption capacity of the air decreases rapidly, therefore the excess water is condensing. This phenomenon occurs for example in electronic appliances for automobiles, which must be specifically inspected and protected therefore. Figure 8 shows the climatic conditions for such bedewing test with 5 cycles between 10°C and 80°C and a humidity of up to 90% (r.H.). Good to see are the soaking temperatures at about 22°C, where the dewing starts.

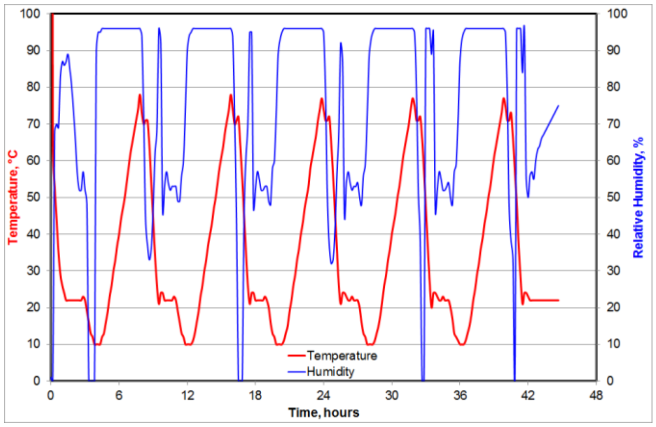

Figure 8 Humidity and temperature during bedewing test

The electrical insulation resistance of conventional SIR comb structures can be measured by such a bedewing test. Figure 9 shows, that even for a reference board without any ionic impurities, the insulation resistance may decrease by bedewing up to three orders of magnitude from 10^{13} to 10^{10} Ω. However, the insulation resistance is recovered after each drying phase.

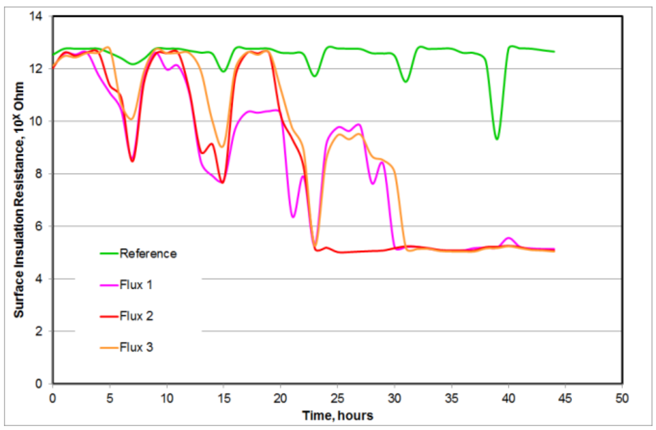

Figure 9 Surface insulation (SIR) during bedewing test

Completely different is it for flux contaminated printed circuit boards, especially if they are in operation under electrical voltage. The resistance drops here down on some hundreds of Kiloohms and finally left on this extremely low level. This is obviously a continuous short circuit caused by migration of ions. It can be also seen that the condition worsens stepwise for each bedewing cycle, indicating a gradual propagation of conductive structures.

The used comb boards have the opportunity to dry at every heating cycle again relatively quickly. Actual assemblies can be even more critical, as among and between components, the air circulation is not ensured and flux residues are concentrated especially in these areas. This issue is the subject of the following considerations.

CONCLUSION AND FURTHER WORK

Different single tests were already addressed for understanding the new requirements by electrical and environmental properties for new requirements on electrical devices. To make it easier and practical for future qualifications it should start a multifunctional project which includes experts and user for all single influences.

REFERENCES

STD-01 ISO 9454-1 (DIN EN 29454-1), Bellcore GR-78-CORE, Siemens Standard (SN 59650:1998), DIN 32513 – Soft soldering pastes, IEC 61190 – Electronic Assembly Materials, JIS Z 3197 – Testing methods for soldering fluxes and

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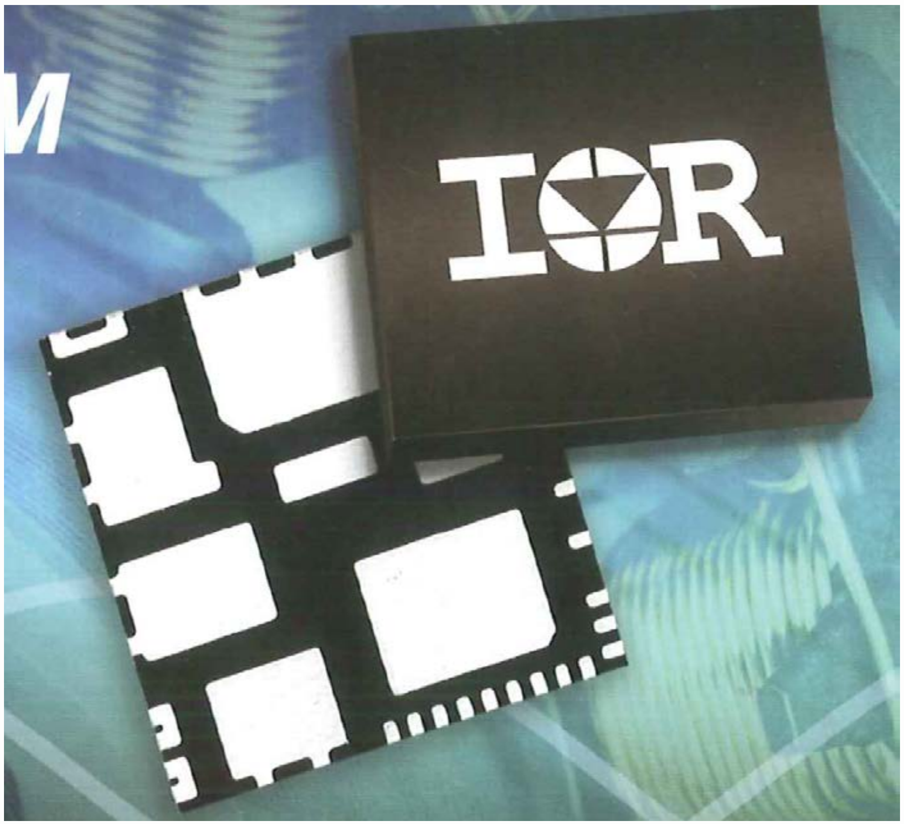
Outline/Agenda

- Introduction
- Flux Penetration Under Components
- Practical Investigation With QFN Components
- High Voltage Investigation
- Conclusions
- References
- Q & A

Introduction

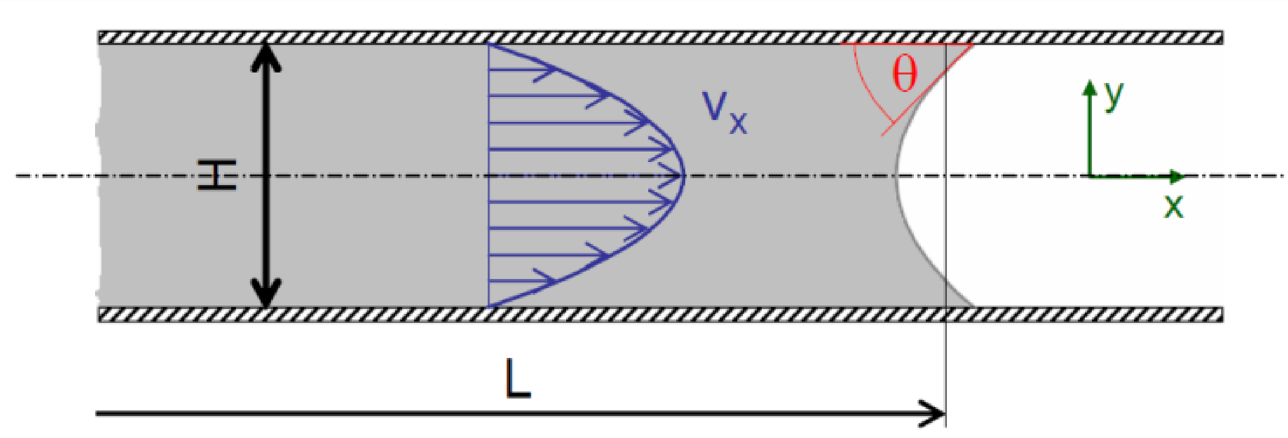


New Generation of power components

e.g. 250-500V

→ Electrical field

Flux Penetration Under Components



	$\gamma_{SL} = \gamma_S - \gamma_L \cos\theta$	**(1)**
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Flux Penetration Under Components

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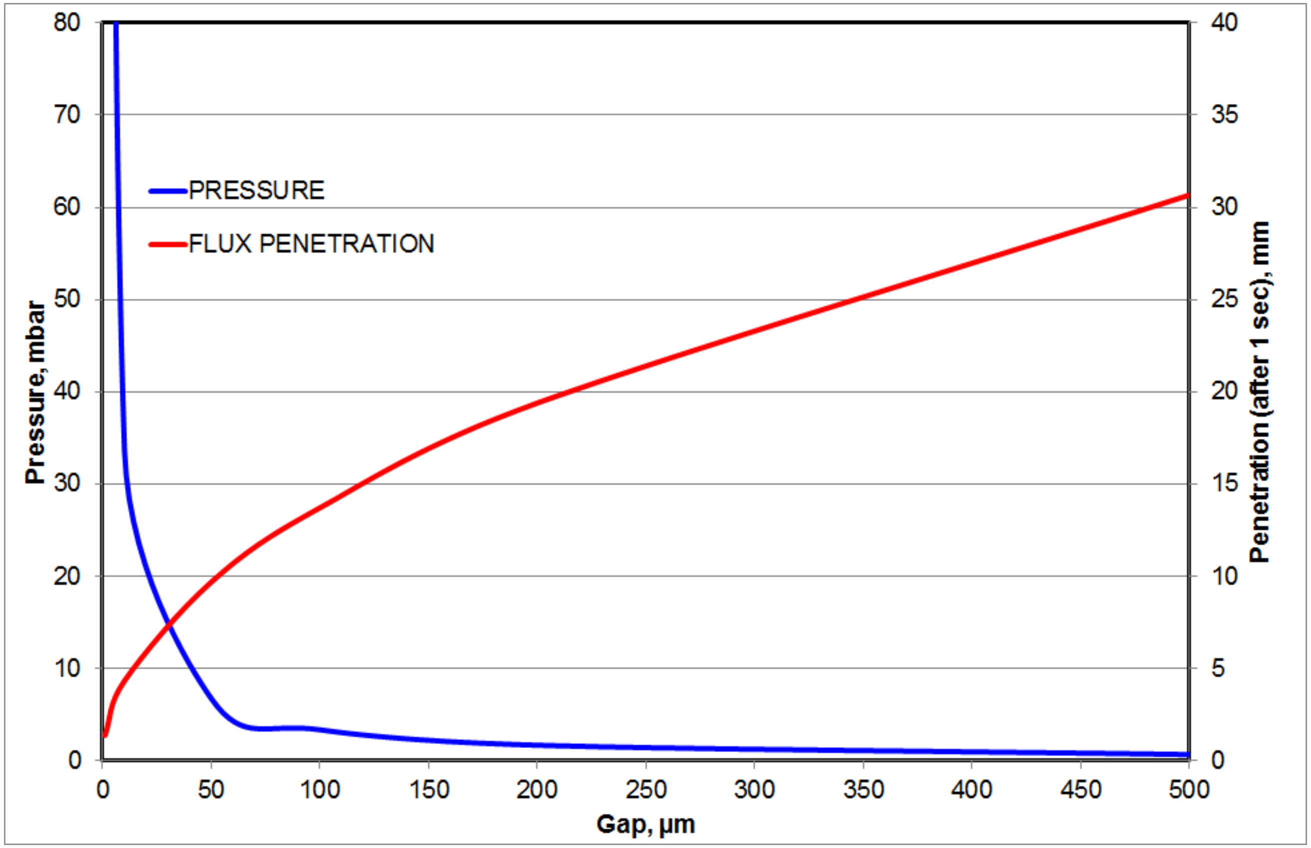
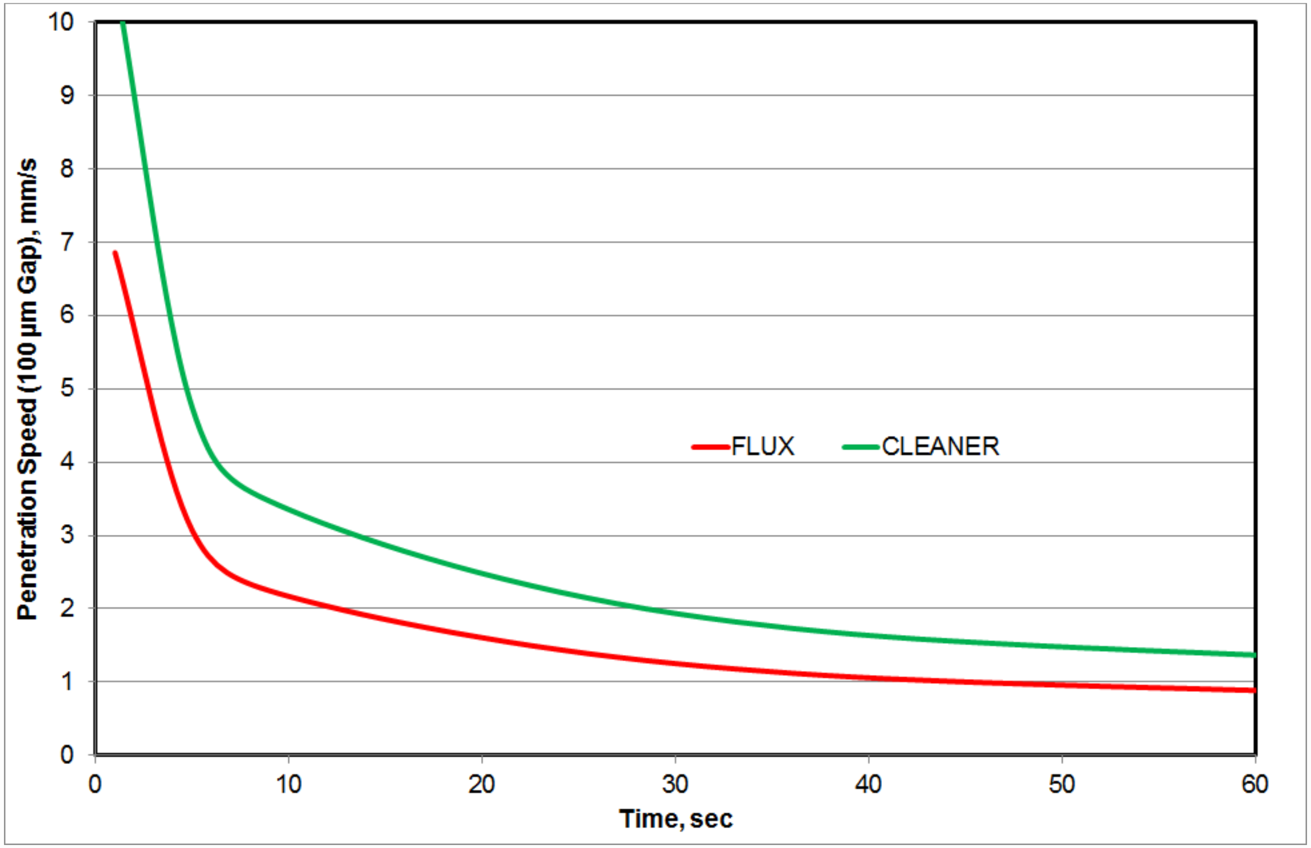


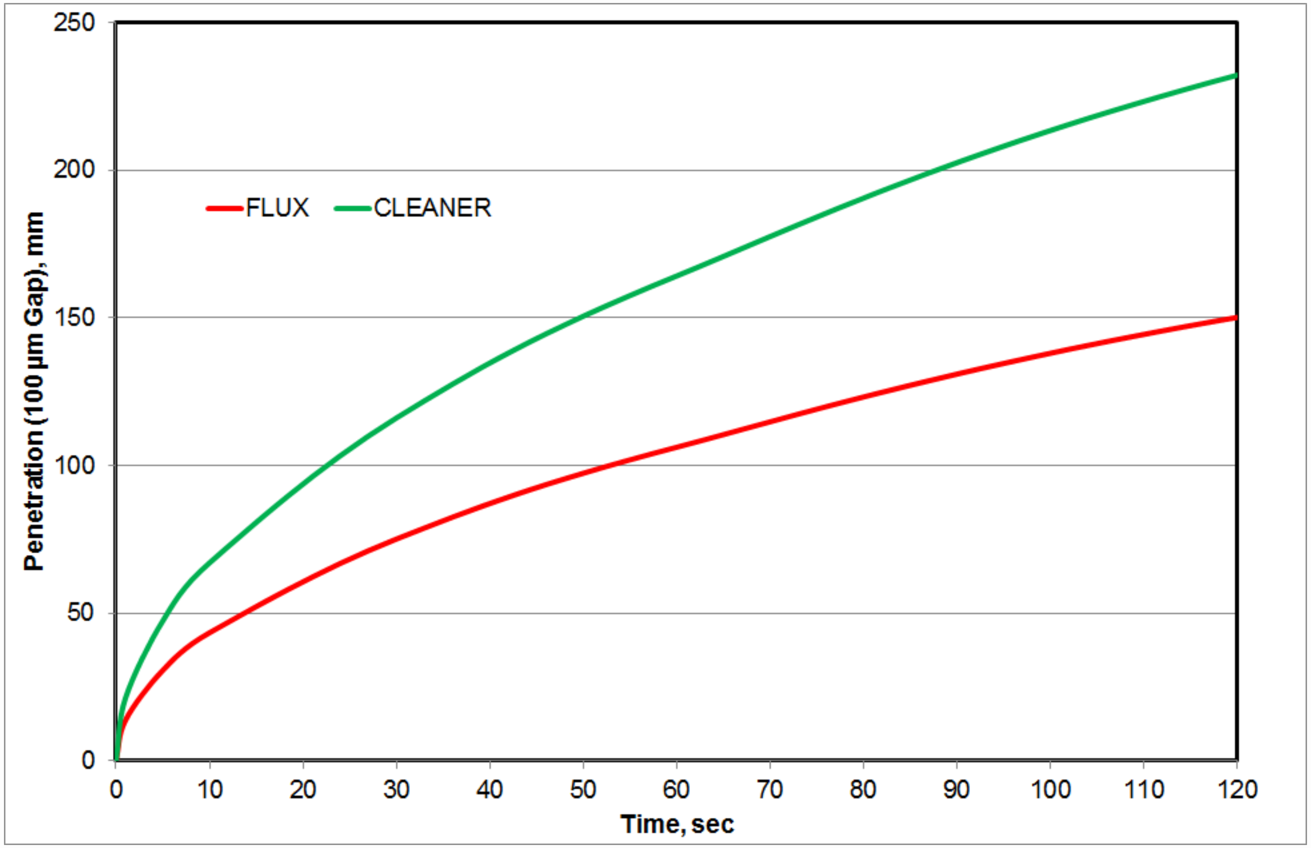
Capillary Pressure and Penetration Depth of the Flux

Flux Penetration Under Components



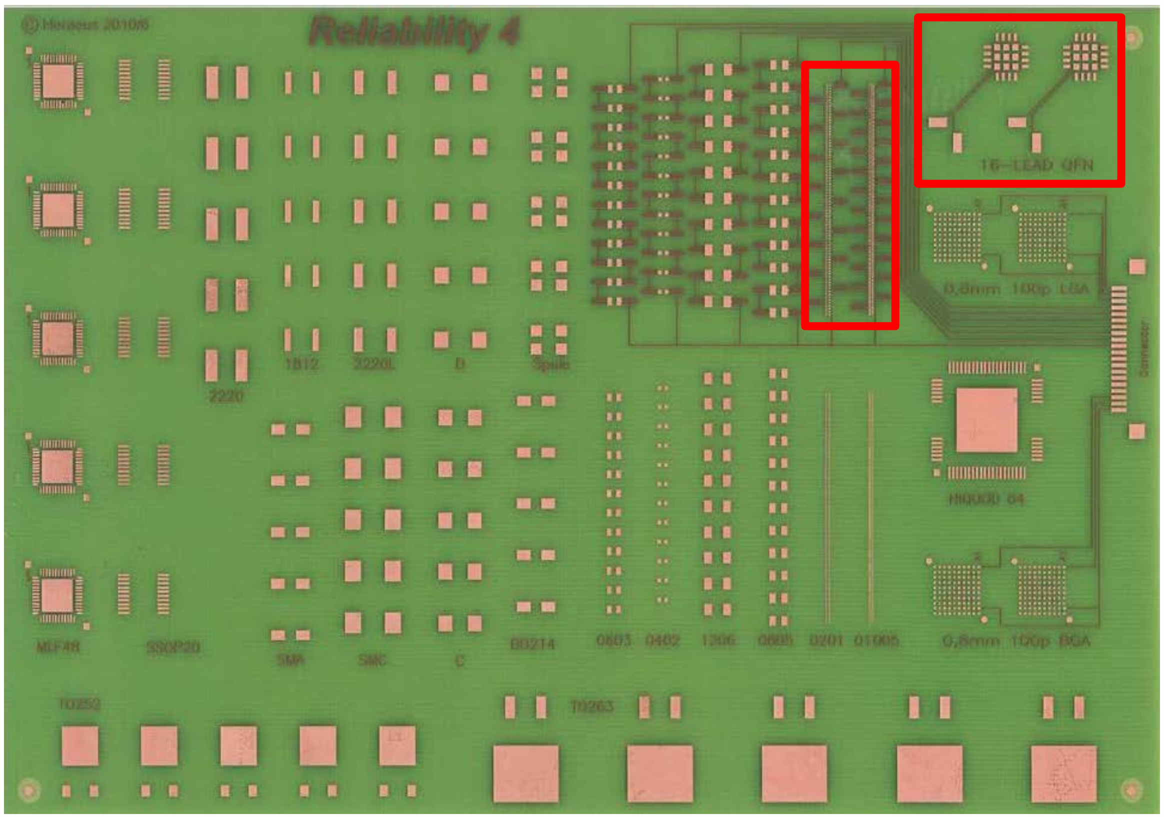
Dynamic of Penetration for Flux and Cleaner

Flux Penetration Under Components



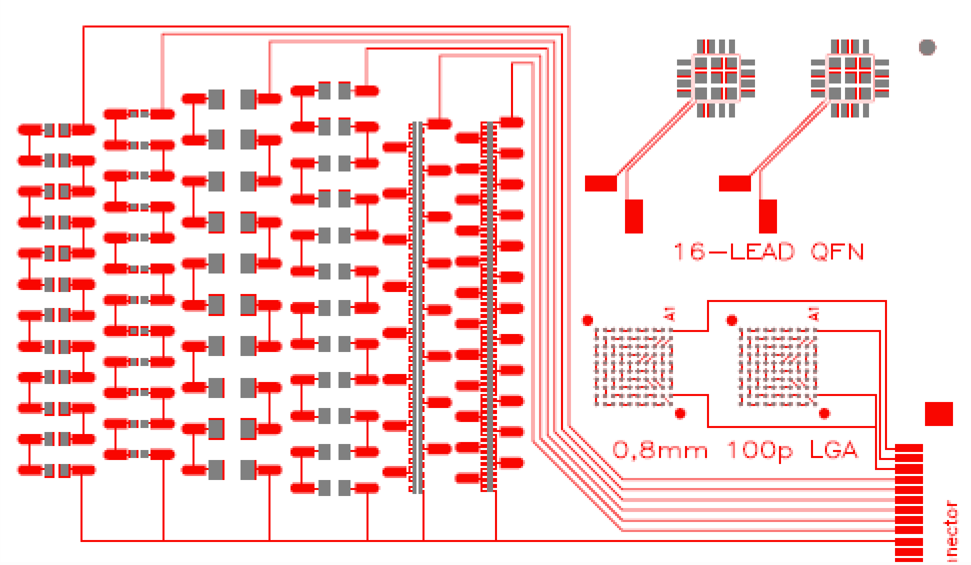
Penetration Length depending on Time

Practical Investigation With QFN Components

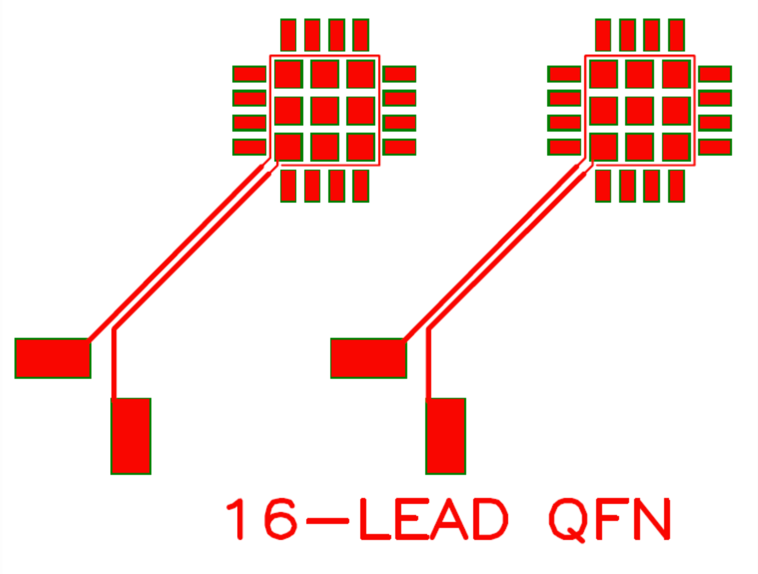


Test Board

Practical Investigation With QFN Components



Layout Structure



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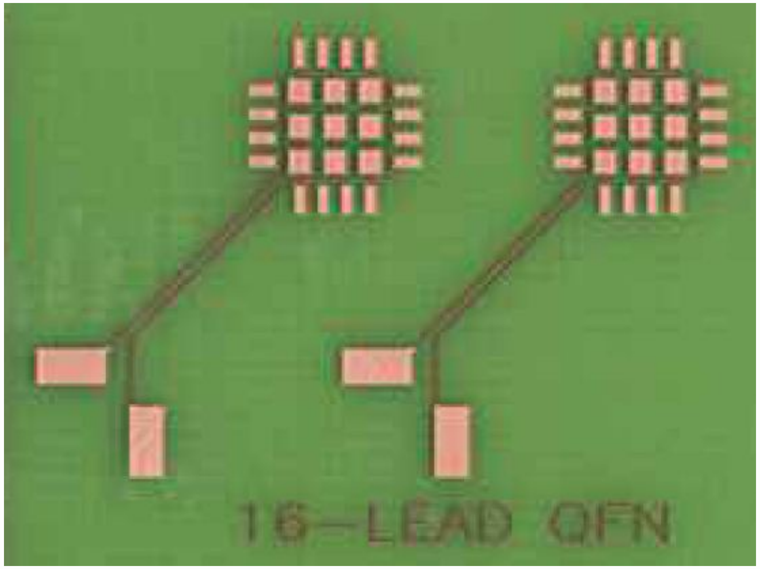

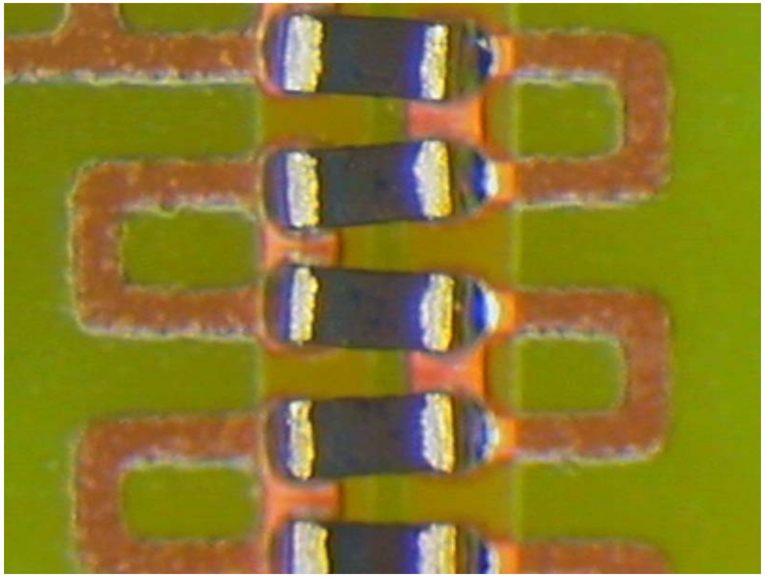

Example: 01005R with 20µm stencil thickness

Practical Investigation With QFN Components

<table>
<tr><td>Paste-system A</td><td>Paste-system B</td><td colspan="3">Paste-system C</td></tr>
<tr><td colspan="2">NC</td><td colspan="3">WW</td></tr>
<tr><td>Zestron</td><td>Not cleaned</td><td>DI-H2O</td><td>Zestron</td><td>Not cleaned</td></tr>
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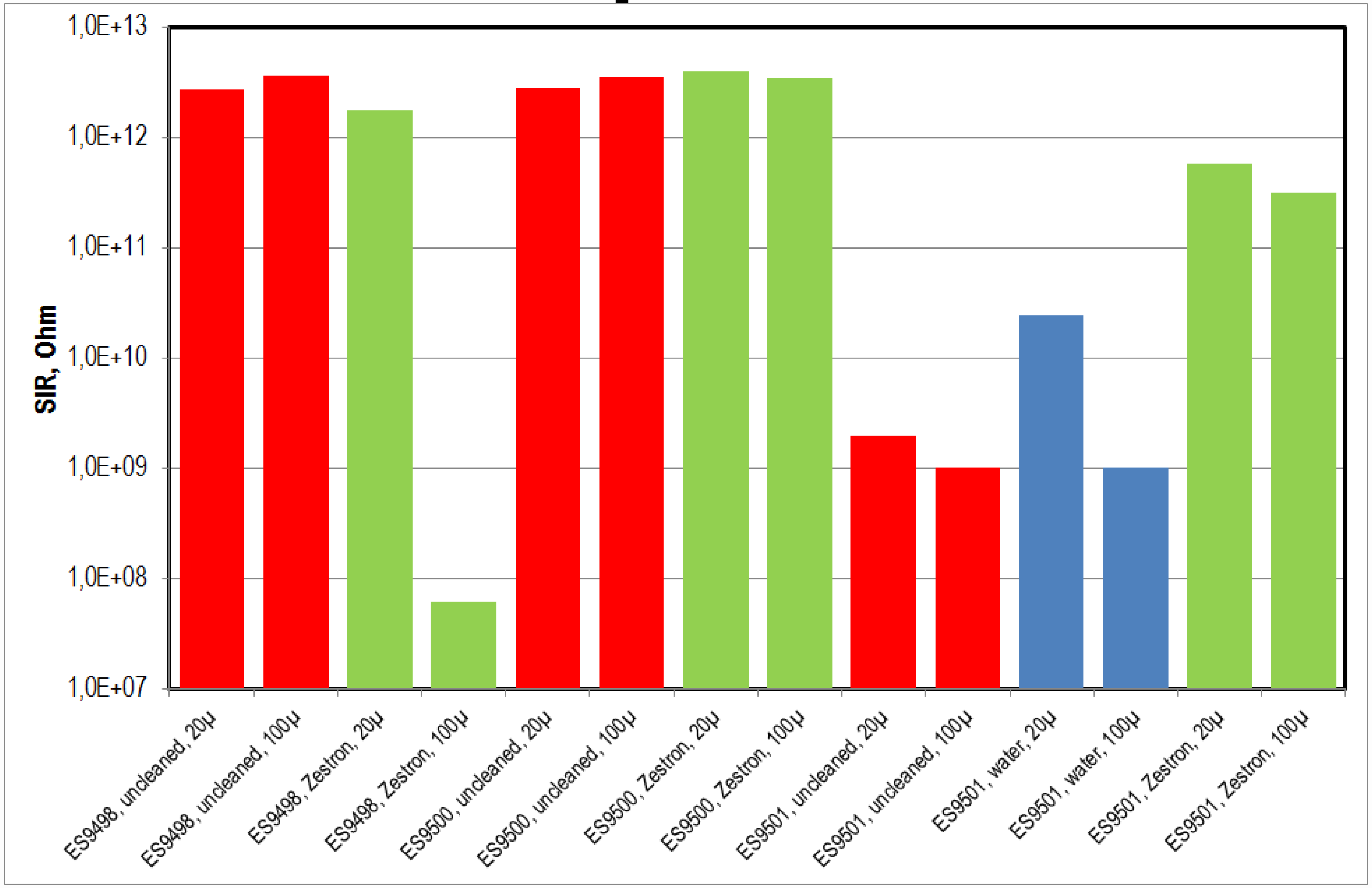
Practical Investigation With QFN Components



High Voltage Investigation

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initial PCB	677 E9	496 E9	665 E9	692 E9

Requirements: 85° C/85r.H. U_{test}=1000V

Conclusion

- New types of components create new mechanism for SIR properties (gap between substrate and component body)
- Cleaning (Solvent od DI H2O) must be adjusted and verify
- First results with high voltage seems to be uncritical
- New application / technology needs additional investigation due to SIR

References

WAN-06	Jinlin Wang: "The Effect of Flux Residue and Substrate Wettability on Underfill Flow Process in Flip Chip Packages", IEEE 56th Electronic Components and Technology Conference, San Diego 2006
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Thank You!