electroscope

Solderability Dependence on Surface Roughness

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Abstract:
The article deals with results of solderability testing of printed circuit boards. The wetting balance test was used for solderability testing. This test makes wetting force measurement possible as a function of time. Measured values are recorded automatically. Surface roughness is one of parameters, which influence surface wetting. The article will present the results and comparison of tested printed circuit boards with different surface roughness. Differences were in levels of roughness and orientation of scratches. This comparison will be made for testing samples of printed circuit boards with surface pure copper (Cu). The test samples were purposely roughened by different abrasive paper before solderability testing. Roughness made on surface finishes was oriented vertically and horizontally. These orientations are relative to attachment tested sample in tester.

INTRODUCTION

Soldering is one of the most important processes in electronic device production. The objective of soldering is to achieve mechanically unyielding, electrically conductive, and in the long term reliable joint. There are several tests to estimate how suitable for soldering process material is. For use in soldering, materials must have suitable solderability.
Solderability is not only an ability of solder flushing on the surface. Solderability is a complex of properties which designates how much is the material suitable for industrial soldering. These properties are for example good wetting, mechanical and chemical straining immunity during cleaning, or thermal straining immunity of Printed Circuit Boards (PCBs). Solderability is not invariable parameter. During time, it changes according to surrounding effects which influence material surface. Solderability gets worse in consequences of surface corrosive change, inception of intermetallic adducts on material surface or the way of holding in storage. The material can be kept on air, where can oxidize, or can be kept in boxes with inert atmosphere.
Wetting is nearly related to solderability, which has already been mentioned. Wetting can be explained as an ability of surface, which determines how the surface could be wetted by molten solder. To achieve good wetting, the surface must be quit of all contaminations. Surface roughness has influence on wetting as well. To determine the influence of surface roughness on solderability, several tests of solderability on sample of PCBs with different roughness level were performed. During surface wetting with molten solder, physiochemical activity of surface atoms between connecting parts and molten solder occurs. Further, one interphase coupling from connecting surface and molten solder arises. Surface wetting is divided into several levels. Critical parameter of surface wetting is contact (wetting) angle between drop of molten solder and wetting surface. Contact angle θ is shown in figure Fig.1.
Material can be designated as “good wetting” if the contact angle θ is between 0° and 50°, when contact angle θ is between 50° and 90° the material is “poorly wetting”. Materials are “non-wetting”, when contact angle θ is above 90° [1].

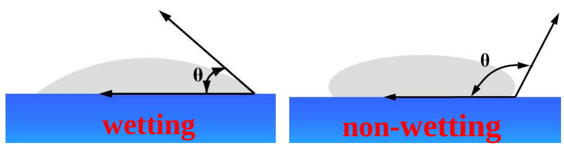

Fig. 1: Contact angle θ.

SURFACE ROUGHNESS

Real surface differs from the ideal surface by various asperities. Surface roughness is geometrical asperities with relatively small spacing. These asperities arise in production or owing to production. Surface roughness is one of factors affecting soldering process. It mainly affects the process of wetting and flushing of molten solder. Surface roughness reduces effective contact angle θ^+, which is related to ideal plain surface contact angle θ. It describes equation (1) [2]:

$$\cos\theta^+ = r \cdot \cos\theta \qquad (1)$$

where r is defined as proportion of roughness of real and ideal plain surface.
As ensue from equation (1), contact angle θ^+ is smaller than θ. It means that solder will spread better on roughness surface than on ideal plain surface. Further, surface roughness should provide better

mechanical gripping of solder on wetting surface [2],[3].

Surface roughness is characterized by two basic statistical parameters. First parameter is arithmetic mean of roughness Ra, i.e. average value of absolute values of profile deviations y_i in the range of primary length L, see equation (2). Next parameter is quadratic mean value Rq, sometimes marked as RRMS (root mean squared). It is quadratic average value of all profile roughness deviations, see equation (3). Values of deviations are deducted from the middle curve of profile. Middle curve divides real profile into two parts in which the sum of areas on both sides is equal in whole range of primary length L [2],[3].

$$\text{Ra} = \frac{1}{L}\int_0^L |y(x)|\,dx \qquad (2)$$

$$\text{Rq} = \sqrt{\left(\frac{1}{L}\int_0^L |y^2(x)|\,dx\right)} \qquad (3)$$

Surface topography is most often established by microscope. SPM (Scanning Probe Microscopy) are scanning microscopes, which create increased 3D scan of surface. There are two basic types of SPM, Atomic Force Microscope (AFM), and Scanning Tunnelling Microscope (STM) [3].

SOLDERABILITY TESTING

For solderability testing, several tests could be used, for example: dipping test, globular test, wetting balance test.

To determine the effect of surface roughness on solderability and solderability testing, the wetting balance test was used.

Wetting Balance Test

This method rests in dipping tested sample into bath with molten solder and monitoring vertical forces acting on sample. Wetting force and lifting force are measured as a function of time. Process of testing the sample and resulting curve of wetting force are shown in figure Fig.2.

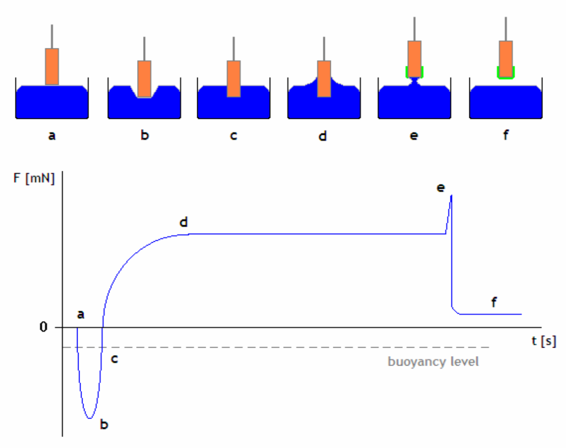

Fig. 2: Relation between the solder meniscus and the wetting curve.

Tested Samples

For determination of solderability, samples of PCBs with dimensions 25 mm x 15 mm, see Fig.3, and 1.5 mm thickness were tested. Tested samples were made of PCBs with surface finish pure copper. To determine the effect of surface roughness, the samples differed in surface roughness too. Surface roughness of single sample was made by abrasive paper. Applied abrasive papers had five levels of roughness (120 – 400). Scratches made by abrasive papers were oriented horizontally for the first group of samples and vertically for the second group. To determine the effect of surface roughness, samples without additional roughage were tested as well. Sample marking of scratches orientation and size of surface roughness is shown in Tab.1.

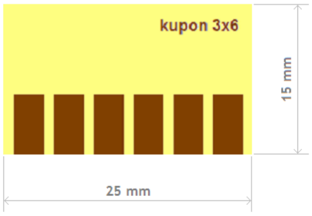

Fig. 3: Tested sample.

Table. 1: Marking of samples surface roughness.

Marking	***H_400***	***V_400***	***H_320***	***V_320***	***H_240***
Horizontal orientation	yes	no	yes	no	yes
Vertical orientation	no	yes	no	yes	no
Abrasive paper	400	400	320	320	240

Marking	***V_240***	***H_180***	***V_180***	***H_120***	***V_120***
Horizontal orientation	no	yes	no	yes	no
Vertical orientation	yes	no	yes	no	yes
Abrasive paper	240	180	180	120	120

RESULTS OF MEASUREMENT

Measured values of solderability are presented in following figures. Measured values of roughness are described in Tab. 2. Samples without roughness are marking as Cu. Comparison and evaluation of measured values is resumed in “Conclusions”.

Table. 2: Expected Volumes of the Magazine

Surface roughness	***Cu***	***Cu_400***	***Cu_320***
Ra [μm]	0.2741	0.7015	1.4229
Rq [μm]	0.3395	0.8994	1.7907
Surface roughness	***Cu_240***	***Cu_180***	***Cu_120***
Ra [μm]	1.5443	1.7001	1.9480
Rq [μm]	2.0408	2.1771	2.6044

For visual demonstration, pictures of surfaces of tested samples were made by microscope Olympus LEXT 3000. Chosen surfaces are shown in Fig. 4 and Fig.5. Graphic dependencies of wetting forces on tested samples are shown in Fig. 6. Final values were defined as average value from measured values.

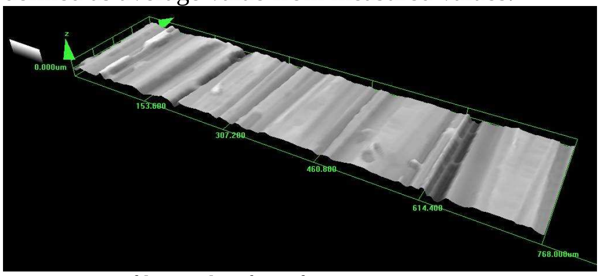

Fig. 4: 3D profile tested surface of Cu_120.

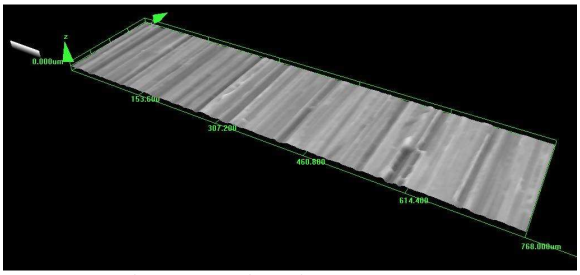

Fig. 5: 3D profile tested surface of Cu_400.

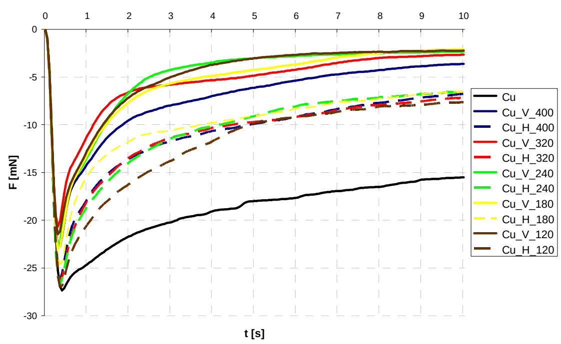

Fig. 6: Wetting forces of samples.

Parameter F_2 $/t_{2/3}$ was defined as the second parameter for better comparison and evaluation of measured values. F_2 is maximum wetting force and $t_{2/3}$ is time, when wetting force achieve 2/3 of maximum wetting force. Evaluation of F_2 $/t_{2/3}$ is shown in Fig.7.

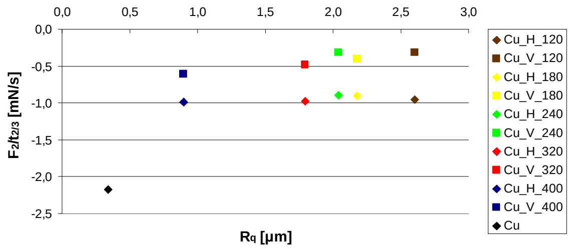

Fig. 7: Evaluation of wetting forces according to parameter F_2 $/t_{2/3}$ for copper surface.

CONCLUSIONS

It is perceptible from measured values, that horizontally oriented surface roughness reduces wetting force compared to vertically oriented scratches. Bigger roughness makes bigger differences between measured values of samples with horizontal and vertical oriented roughness. Fig. 6 shows wetting forces curves of tested samples. In Fig. 7 is shown summary of comparison of all combination sizes and orientations of roughness by parameter $F_2/t_{2/3}$. Smaller wetting force for samples of pure copper without roughness could be caused by thin film of oxides compared to wetting forces of others samples. Thin film of oxides was displaced by abrasive papers on samples, which were roughened. Always we want to achieve biggest wetting force. Therefore value of $F_2/t_{2/3}$ parameter is to be biggest, because of it is relation wetting force into time. It ensues from Fig. 7, that tested samples with bigger roughness reach to bigger value of $F_2/t_{2/3}$ parameter.

ACKNOWLEDGMENTS

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