Soldering Temperature and Wetting Temperature†

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KEY WORDS: (Micro-Soldering) (Soldering Defects) (Wetting Velocity) (Wetting Time)

It is well known in many soldering engineers that a sound soldered joint can be achived by using an appropriate soldering temperature which is given by the rule of thumb. The rule is a sort of "know how". In this point of view, soldering is one of emprical joining techniques in Japan and also in the world, up-to-date. But, the author think that the rule is the meaningful deta which can be explained physically.

Soldering temperatures for Pb-Sn solders are given with a band as shown in Figure 1, which is seen in the "Solders and Soldering" written by H. H. Manko[1]. The band falls under the rule of thumb. In the figure, what is the physical meaning of the temperature range between the lowest soldering temperature in the band and the liquidus temperature of each solder, except for the higher-liquidus temperature with a higher lead content? The answer for this question will be introduced below, together with discussions.

Figure 2 shows a schematic of wetting curve which is well known. In the figure, t_I is the time that wetting begins at the bottom edge of a specimen through dipping process. What is the temperature of the bottom edge at t_I? Its temperature is wetting temperature and it is 183°C which is the melting point of the eutectic Pb-Sn solder used. It should be kept in mind that the wetting temperature is not the surface temperature of a molten solder but the temperature of the surface of the part to be joined. Well then, what is the surface temperature of the molten solder which touches the bottom edge of the specimen at t_I? This also is 183°C, because when the specimen with room temperature touched the surface of the molten solder held to a predermined soldering temperature, for example the surface temperature of 215°C at the soldering temperature, the surface of the molten solder in-

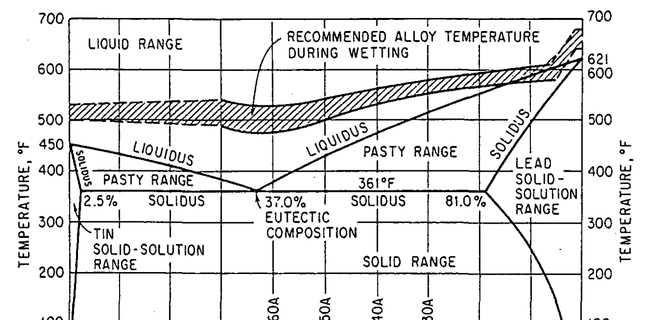

Fig. 1 Recommended soldering temperatures for Pb-Sn solders (by H. H. Manko).

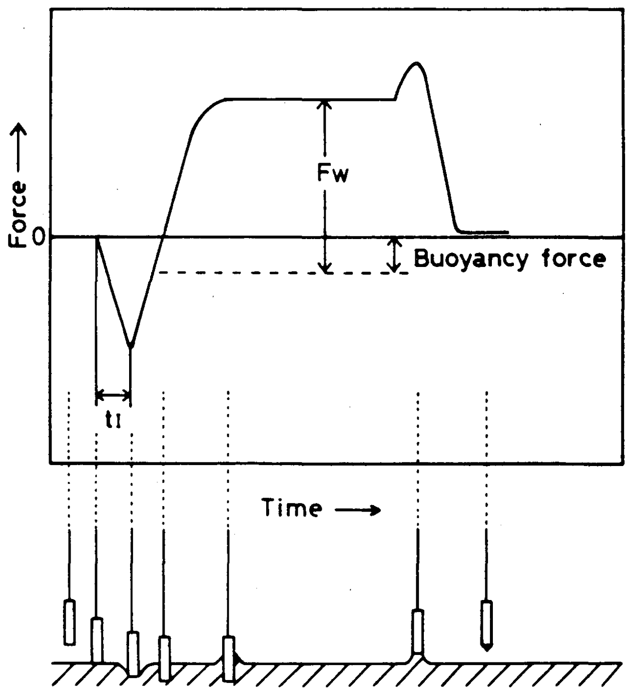

Fig. 2 Schematic of wetting curve in dip soldering.

† Received on Nov. 4, 1987

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Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan

stantaneously solidifies. The solidified surface remelts at t_I, therefore, it is 183°C. Whether the surface solidifies or does not, it will be attributed to two facts that the thermal diffusivity of a liquid solder is about one-sixth of that of the specimen, for example copper, and also as published in our report[2], the measured value of t_I agreed with the calculated value based on one-dimensional heat conduction theory. From this agreement, furthermore, it is considered that the heat transfer coefficient between the bottom edge of the specimen and the surface of the molten solder is infinite. This is very important in soldering of the fluxed specimen and may be justified by the instantaneous solidification mentioned above. After t_I elapsed, of course, the surface temperature of the molten solder rises from 183°C to 215°C of the surface temperature at the predetermined soldering temperature with increasing time. This temperature rising is not the increase of the wetting temperature but the increase of the temperature of heat source for the bottom edge of the specimen. The wetting temperature is 183°C as mentioned above.

Here, what is the physical meaning of t_I? It is the time required until the bottom edge is heated to 183°C by the heat given from the solidified surface of the molten solder. Namely, it is the time of heat conduction. Within this time, if an oxide film on the bottom edge is removed by fluxing action, the wetting temperature is 183°C, whereas if it is impossible, the wetting temperature, i.e., the temperature of the bottom edge rises from 183°C to the temperature that depends on the prolonged time in fluxing action. Such a wetting temperature is possible to calculate by using the equation that is the first order of kinetics on fluxing action, as published in our report[3]. But, such a high wetting temperature should be avoid for such reasons as the excessive formation of an intermetallic compound at the interface between a solder and a base metal, and heat damage of a base material in practical soldering.

From the discussions mentioned above, two soldering operations that are necessary to obtain a sound soldered joint will be introduced as follows;

1) Before dipping into a molten solder bath, the surface of a part to be joined should be cleaned enough by fluxing action. By doing it, wetting begins at the lowest wetting temperature of 183°C.
2) Before dipping into the molten solder bath, the surface of the part to be joined should be pre-heated at least to just below the melting point (solidus line) of the used solder. By doing it, t_I approaches to zero second and also the temperature of the surface of the molten solder is possible to lower to just above the melting point (liquidus line) of the used solder. Here, soldering temperature has been measured generally at the position of about 4 mm below from the surface of the molten solder. The temperature difference between the temperature of the surface and the temperature of the 4 mm depth in the molten solder is the answer for the first question in this paper. Generally, the temperature differences are 30° to 50°C, which agree with the temperature range that is given by the rule of thumb. It has been said generally that the temperature range between the melting point and the lowest soldering temperature is necessary to ensure proper flow of the solder. But, this is not true because, in Figure 1, the temperature range in the eutectic solder having a low viscosity is wider than those in other compositions solders having a high viscosity. The temperature range is necessary to make up heat loss from the surface of the molten solder, whereas the higher soldering temperature than the lowest soldering temperature is necessary to increase the area heated to the wetting temperature of 183°C on the specimen by heat conduction, namely, to increase the wetted area.

From doing Items 1) and 2), a very fast wetting speed and a very short soldering time will be ensured at the desirable lowest soldering temperature shown in Figure 1. Furthermore, the above conclusion will be applied not only for dip soldering, but also for other soldering methods such as iron soldering, flame soldering and furnace soldering including reflow soldering, and also for brazing.

Acknowledgements

The author would like to express their thanks to Associate Prof. M. Naka, Dr. T. Takemoto and Mr. M. Mizutani, Welding Research Institute for their useful comments in this note.

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