Development of Low-cost Solder Paste Material

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Abstract

In the market trend of car navigation system, the price competition becomes intensified because of the commoditization of products, and the cost reduction of raw material is required for improvement of price competitiveness. To respond to this demand, we worked on the development of general solder paste which can decrease the nitrogen usage in mounting process and solder paste cost. Currently used solder paste has two problems as follows.

① It needs a large amount of nitrogen which causes high nitrogen cost.

② It is a custom product and its material cost is expensive because of securing quality.

To overcome these problems in solder paste development, we changed the current method to remove an oxide film in solder melting area to the new one to always keep removing the oxide film in all area from pre-heat process to melting. Then we have developed the material which can secure soldering quality equivalent to the current material even with a little nitrogen, and can decrease nitrogen cost and solder paste cost. We introduce the detail in this paper.

1. Introduction

Looking at trends in the car navigation system market, price competition is intensifying due to the commoditization of products, and companies must lower the cost of raw materials in order to improve their price competitiveness. Raw materials include the direct materials, such as purchased parts listed on the parts list, and auxiliary materials not listed on the parts list, such as nitrogen and solders. Here, we decided to attempt to reduce the cost of auxiliary materials, which were not included in conventional cost reduction efforts.

We noticed that the costs for nitrogen and solder paste used in the reflow soldering method **(Fig. 1)** covered a high share of the purchase price of auxiliary materials used in the mounting process **(Fig. 2)**, so we put our focus here.

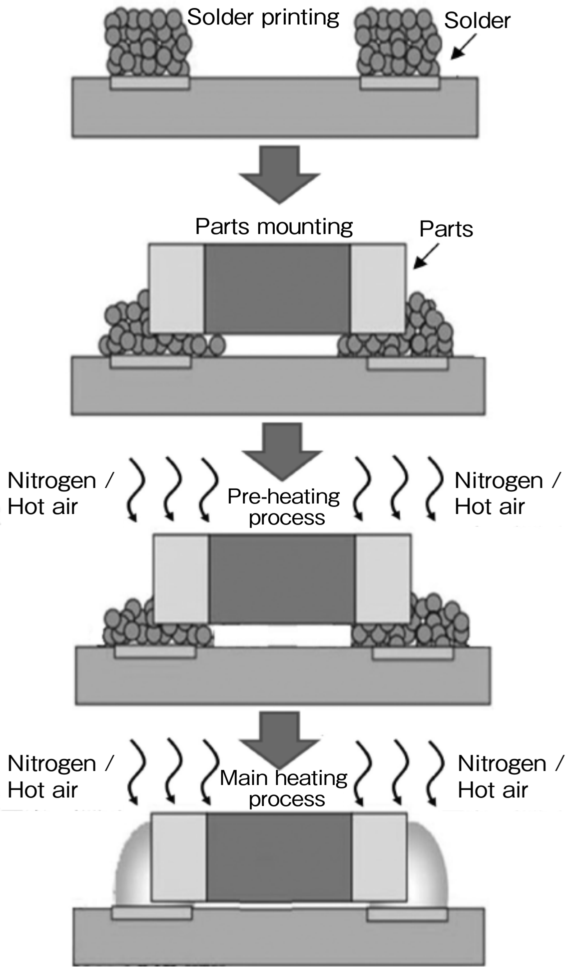


Fig. 1 Reflow Soldering Method

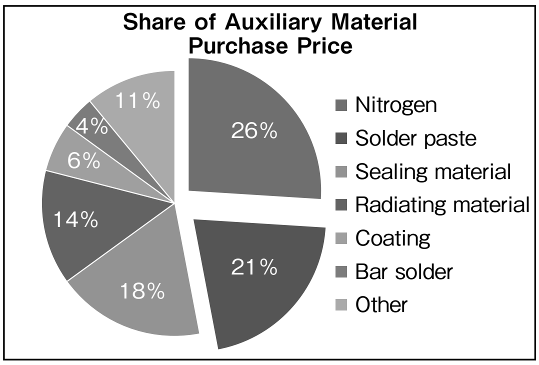


Fig. 2 Share of Auxiliary Material Purchase Price

In the reflow soldering method, in order to ensure soldering quality (wettability, insulation), currently we use a solder paste that contains small amounts of the activator which decreases insulation. We fill the reflow device with large amounts of nitrogen and suppress oxidation of the substrate, part lead, and solder paste in an environment with an oxygen concentration of 500 ppm or less, thus ensuring soldering quality. Soldering is an important material, where neglecting to ensure quality can lead to market defects due to thermal fatigue.

The solder paste we are currently using has the following two issues. ① A large amount of nitrogen is required, and the cost of nitrogen is high. ② The current solder paste is a customized product with high material costs to ensure quality. Therefore, we engaged in developing a generic solder paste that can reduce the amount of nitrogen used and reduce the cost of solder paste while also ensuring quality.

2. Issues in Solder Paste Development

Simply cutting the amount of nitrogen to reduce costs causes the following issues.

2.1 Decreased Wettability

If the oxygen concentration in the reflow furnace increases, the progressing oxidation of the parts lead or soldering materials causes decreased wettability, increasing the risk of wetting defects **(Fig. 3)**. Also, decreased wettability also decreases the examination accuracy by an automatic visual inspection machine.

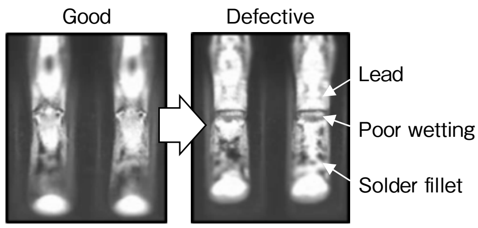
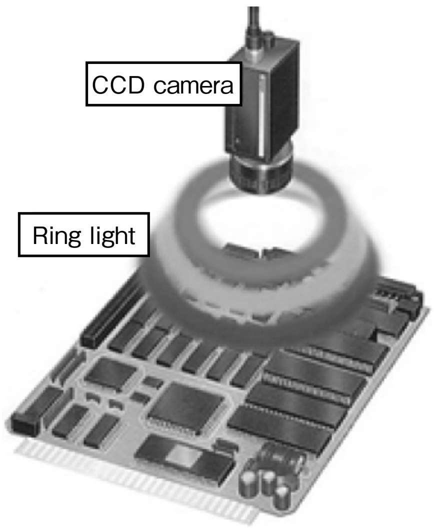
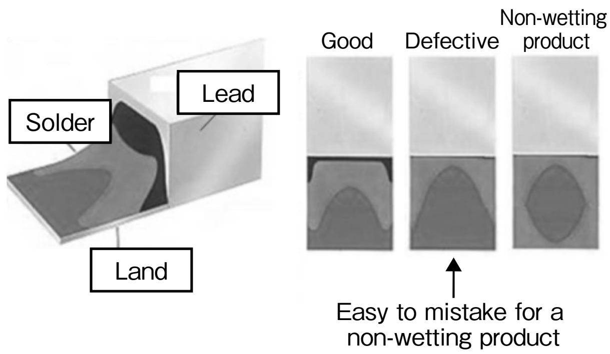


Fig. 3 Decreased Wetting on Lead Edge

The principle of visual inspection is to confirm the fillet status and determine if it is defective or not by shining light consisting of three primary colors, RGB, located in a ring shape, and looking at the color reflected from the solder fillet using a CCD camera. Therefore, if the wetting is poor on the lead edge, the solder shape resembles that of a non-wetting defective product. This means that over-detection, where a good product is judged to be defective, occurs more easily, the work hours for visual re-inspection must be increased, and costs rise **(Fig. 4)**.



(a) Visual inspection machine



(b) Inspection image

Fig. 4 Visual Inspection

2.2 Increase of Solder Voids

Advance of oxidation in the solder paste causes the fluidity of the melted solder to decrease, and the gas that occurs remains inside the solder as a void **(Fig. 5)**. This may affect the solder's service life.

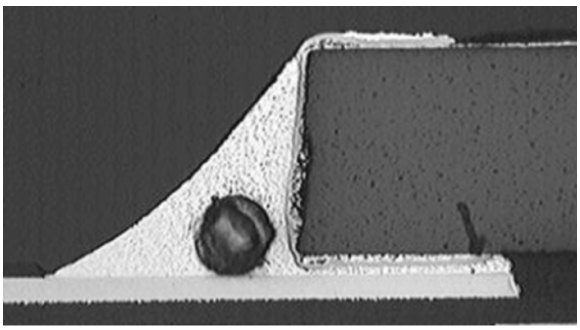


Fig. 5 Example of Solder Void (Cross-section)

2.3 Solder Ball

Advance of oxidation in the solder paste causes the cohesive force during solder melting to decrease, and solder drops remain on the substrate **(Fig. 6)**. This may affect electric short-circuits.

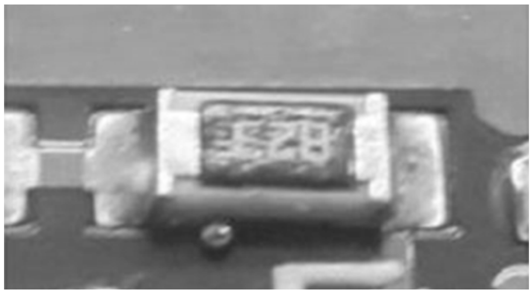


Fig. 6 Example of Solder Balls

2.4 Decreased Soldering Properties in Post-Processes

Advance of oxidation in the copper foil of the substrate through-holes causes the properties of flow soldering, a post-process, to decrease, and solders cannot be filled in through-holes **(Fig. 7)**. This may affect the solder's service life.

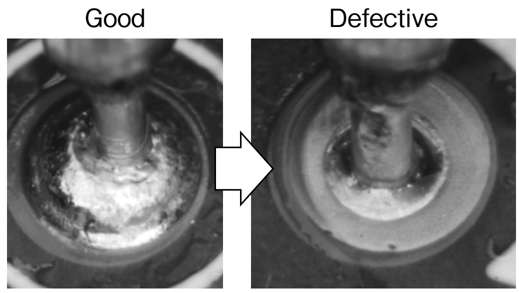


Fig. 7 Example of Insufficient Solder Finishing in Through-hole

The soldering quality (wettability, insulation) and workability required for solder paste is controlled by the flux characteristics contained in the solder paste. Therefore, in order to overcome these issues, flux properties that can suppress oxidation even with limited amounts of nitrogen are required. With solder paste we developed in the past, the solder paste become oxidized during the pre-heating range and affected the wettability. Based on that experience, we decided we needed to review our concept of flux effects, and engaged in joint investigation with the material manufacturer.

3. Solder Paste Material Development

3.1 Flux Development

With the conventional solder paste material, the concept was to remove the oxide film in the solder melting range **(Fig. 8)**. However, with the new material, we changed to a concept where the oxide film is continuously removed in all ranges from pre-heating to melting **(Fig. 9)**, and together with the material manufacturer, we investigated combination of activators, etc., that could be used in the flux material.

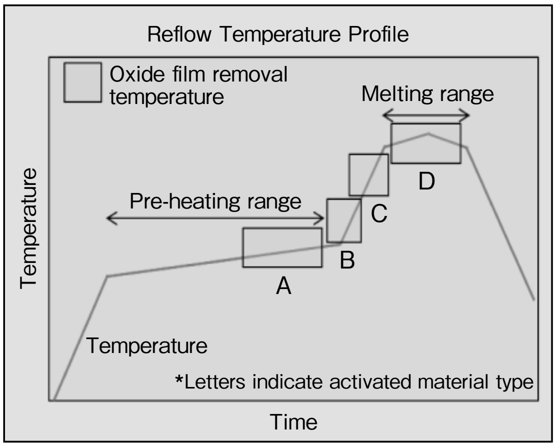


Fig. 8 Oxide Film Removal Temperature with Conventional Material

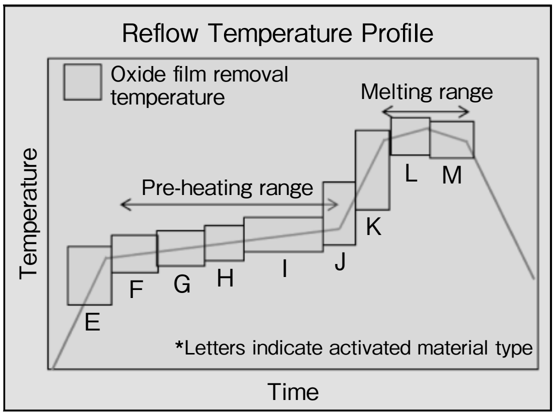


Fig. 9 Oxide Film Removal Temperature with New Material

During development, we were able to ensure wettability at an early stage, but solder balls occurs on the chip parts. We recognized how difficult it would be to develop solder paste that balances all the aspects of soldering quality well. The following section introduces how we efficiently solved the issues.

As we investigated the cause, we discovered that gas generated by the oxide film removal action in the pre-heating process pressed the solder down against the part and spread it out. Thus, the solder remained on the substrate during melting, forming solder balls **(Fig. 10)**.

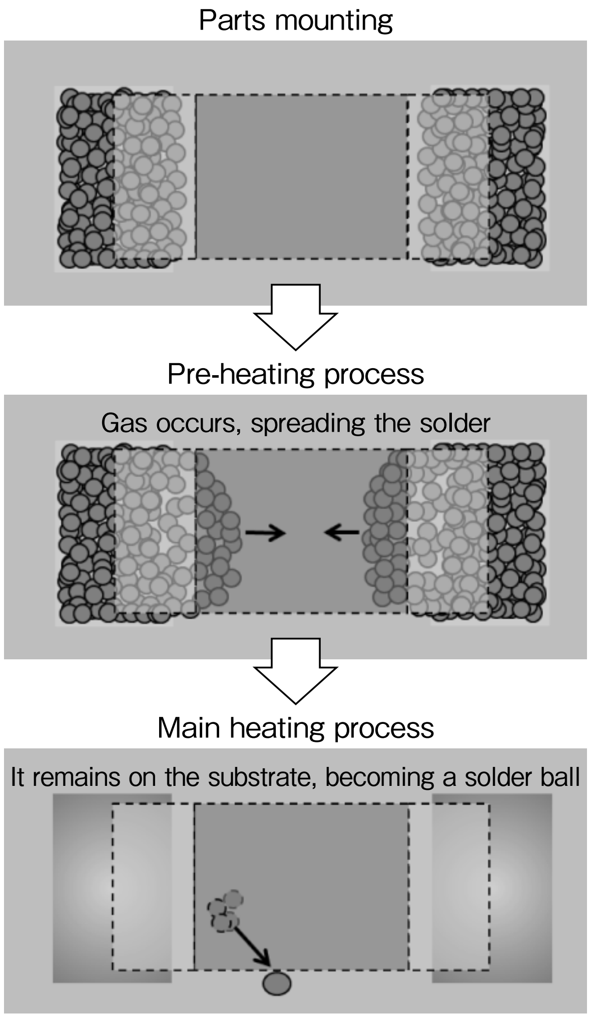


Fig. 10 Mechanism of Solder Ball Occurrence

This is because when a part is mounted, the part covers the solder paste, and the gas that occurs can only escape sideways.

With this issue, it would take too much time for development if we performed mounted verification each time, so we investigated a method that would allow us to evaluate the solder behavior under the parts quickly and easily.

We considered an evaluation method where we would observe the solder paste behavior while heating it with an X-ray heating device, but we decided against this method as the X-ray transparency images could not provide clear images **(Fig. 11)**.

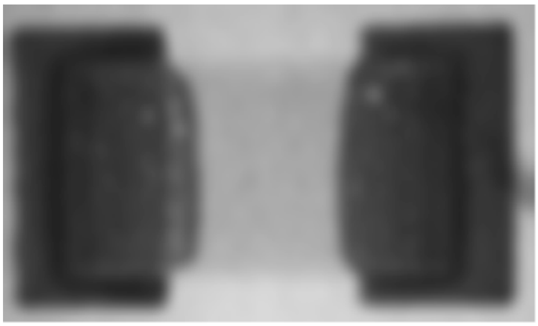
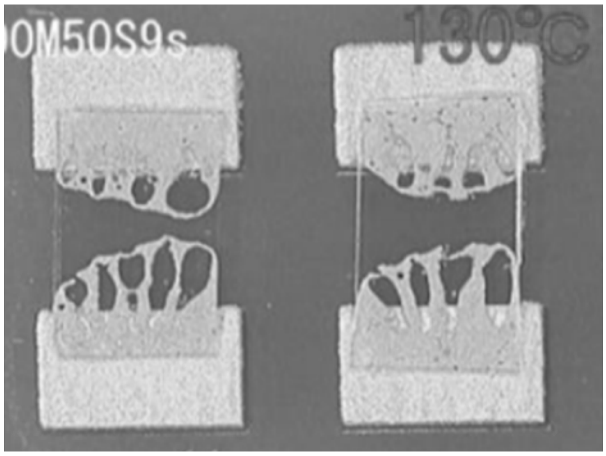


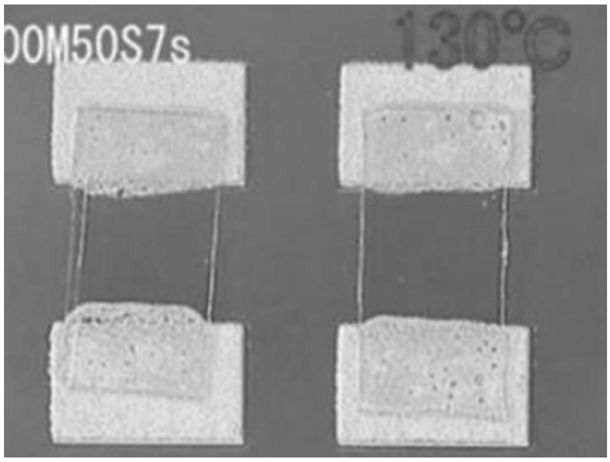
Fig. 11 X-ray Heating Device Observation Image

Next, to enable direct observation of the chip parts, we realized that using a transparent chip would allow us to observe the bottom of the parts, so we used glass that was the same size as the chip parts, establishing a method for observing with the reflow simulator **(Fig. 12)**.

This method made it possible to investigate the optimal combination of flux components in a short amount of time.



Before material improvement



After material improvement

Fig. 12 Evaluation Method Using Glass Chips
(Observation of solder behavior in the pre-heating process)

3. 2 Oxygen Concentration Verification

Lastly, we performed verification regarding the applied oxygen concentration. The smaller the printed volume of solder paste is, the smaller the absolute content of flux is. Therefore, if the oxygen concentration during reflow is high, oxidation of the solder paste will advance. Even if it melts, it will not have cohesion, resulting in soldering defects. Also, during the reflow process, oxidation in the copper foil of the substrate through-holes advances and the flow soldering properties for post-processes decrease. Therefore, it is necessary to determine an oxygen concentration that achieves both wettability with a small printed volume and flow soldering properties for post-processes.

We believed it was necessary to reliably achieve melting even with a solder amount (land size) that allows for high-density mounting in the future, so we verified an oxygen concentration that allows for melting with the 0402 chip size. As a result, we confirmed that while poor wetting occurs with a land equivalent to the 0402 chip at 5000 ppm, it does not occur at 3000 ppm or below **(Fig. 13)**.

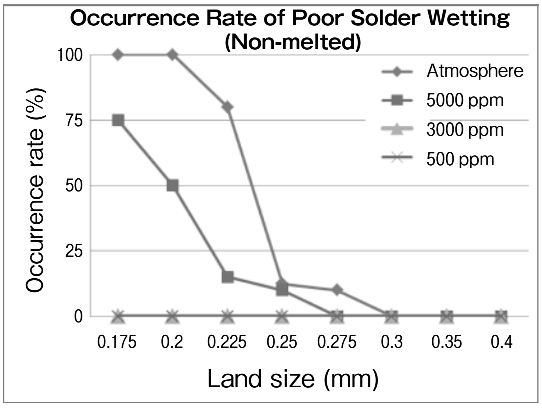


Fig. 13 Poor Wetting and Land Size Due to Oxygen Concentration

We also verified the flow soldering properties for post-processes, confirming that they also would not decrease **(Fig. 14)**.

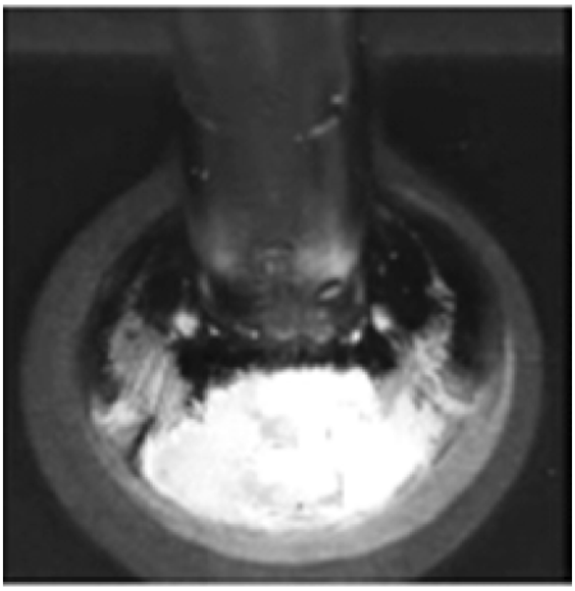


Fig. 14 Through-hole Solder Finishing After Fluidity at 3000 ppm Oxygen Concentration

Through the above development, we completed development of a solder paste that can achieve the purposes of reducing the amount of nitrogen used and the reducing the cost.

4. Cutting Costs for Manufacturing Management at the Manufacturer

We also investigated cutting the cost of the manufacturing inspection process at solder manufacturers. Conventional products were pastes developed in the initial stages of deleading, and therefore required management costs for special inspection requirements and management costs due to customized composition.

Though many years of experience in deleading, quality maintenance management at solder manufacturers is possible with inspection items equivalent to generic products. Therefore, we engaged in activities to cut manufacturing management costs, achieving our goal for solder paste costs as well. The following introduces the heat sagging test, as an example of inspection items we deleted.

After solder printing is performed using a standard printing pattern with an allotted print interval and then the solders are heated with a standard profile, this test examines whether adjacent solder pastes come into contact **(Fig. 15)**.

Through over 10 years of management results, we determined that it was possible to abolish these special inspections by implementing capability verifications accounting for the unevenness in flux balance during solder paste development.

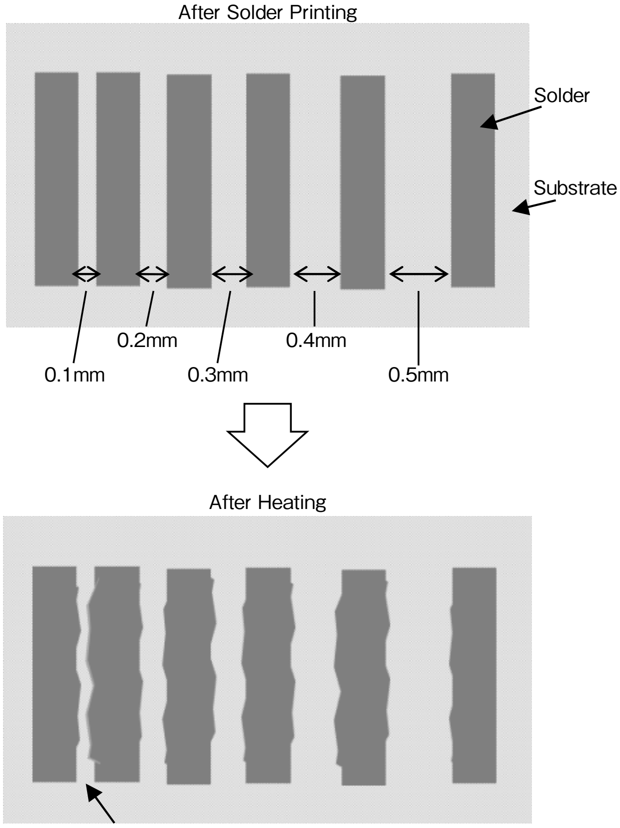


Fig. 15 Heat Sagging Test

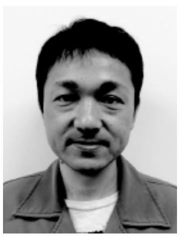
5. Conclusion

Here, we developed a material that allows us to change the atmosphere oxygen concentration in a reflow furnace from 500 ppm to 3000 ppm. This material not only ensures the same soldering quality as the current material, it is also a low-cost solder paste material that reduces the amount of nitrogen used to 2/3.

As products gain new functions and become more compact in the future, soldered parts will become even more refined. We believe this technology will be very effective in the development of new solder paste material that handles the needs for high-density and high reliability in the future.

Lastly, we would like to thank, in writing, the material manufacturers who offered significant cooperation in the material development for this technical development.

Profiles of Writers



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