Study on Optimization of Fatigue Test of Nanosilver Solder

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Abstract: Nanosilver solder paste due to its high melting point, low sintering temperature and good electrical/thermal conductivity and mechanical reliability Sex, more and more attention by the electronic packaging industry. And, as a new type of lead-free thermal interface Materials, nano-silver solder paste has the potential to gradually replace traditional solder and conductive silver paste, used in high-temperature power electronics In the device packaging, according to the isothermal mechanical fatigue test, a temperature-dependent fatigue life prediction model is proposed, and the cycle life of the nanosilver solder paste lap joint at different temperatures is accurately predicted.

1.NANO-SILVERSOLDER PASTE SINTERING

At present, due to the low-temperature sintering characteristics of nano-silver particles, nano-silver has been widely used in the electronic field, such as low-temperature connection process, inkjet printing technology, metal-metal bonding, etc. . CP Wong et al. applied the low-temperature sintering characteristics of nanosilver to ECAS[1,2]. It was found that the surface chemistry of nanosilver particles played an important role in the low-temperature sintering of nanosilver. The low-temperature pyrolysis of surface organics can achieve the nanosilver particles in the conductive paste. Sintered below 200°C . Fuller et al. introduced an ink-jet technology based on nano-silver and gold solder pastes for the production of conductive metal lines on a substrate. The solder paste has good flow ability and low viscosity. The results of the study show that when the sintering temperature is as low as 300°C, a metal line with high conductivity can be obtained In addition, nanosilver paste can also be printed on flexible substrates Bell et al. prepared a silver paste containing nano-scale and micro-scale mixed silver particles, and evaluated the sintering process with an operating temperature lower than 250°C by measuring the conductivity .

2. FAILURE FORM

Reliability of Solder Joints in Electronic Packaging The failure of semiconductors and microelectronic devices is often the result of factors such as thermal, mechanical, electrical, and chemical, either alone or in combination. Therefore, failures of electronic devices can be classified into thermal/mechanical failures, electro-failures, and electrochemical effects. Since most of the failures in the package structure are caused by the mechanical failure of the connection material, the reliability of the electronic package is mostly focused on the thermal mechanical properties of the solder joints [3,4]

3.STUDY AND EXPERIENCCE

3.1 Experimental Method

The nano-silver solder paste lap joint structure used was tested on a miniature uniaxial fatigue tester. The test ambient temperature was provided by an external heating furnace. The isothermal mechanical fatigue study uses a symmetric cyclic displacement control method to apply load to the joint. The waveform uses triangular waves[5,6].The loading conditions for isothermal fatigue test of sintered nano-silver joints are shown in Table 1. The displacement rate control in the test was 2.07×10^{-3}

mm/s. In the isothermal mechanical fatigue test, joint damage continues to accumulate under cyclic loading, and the ability of the joint to withstand deformation gradually decreases. Therefore, under the conditions of constant displacement amplitude, the measured load response of the joint will be continuously tested. reduce. Therefore, the decrease of the bearing capacity in the joint fatigue cycle indicates the joint fatigue resistance at different temperatures and displacement amplitudes. In this study, the number of cycles when the joint was finally broken was used as the fatigue life.solomon has suggested that the fatigue damage accumulation proces of materials under reciprocating loads can use load reduction factors[6].

To represent. Its definition is as follows:

$$\varphi = 1 - \frac{\Delta p}{\Delta p_m} \qquad (3\text{-}1)$$

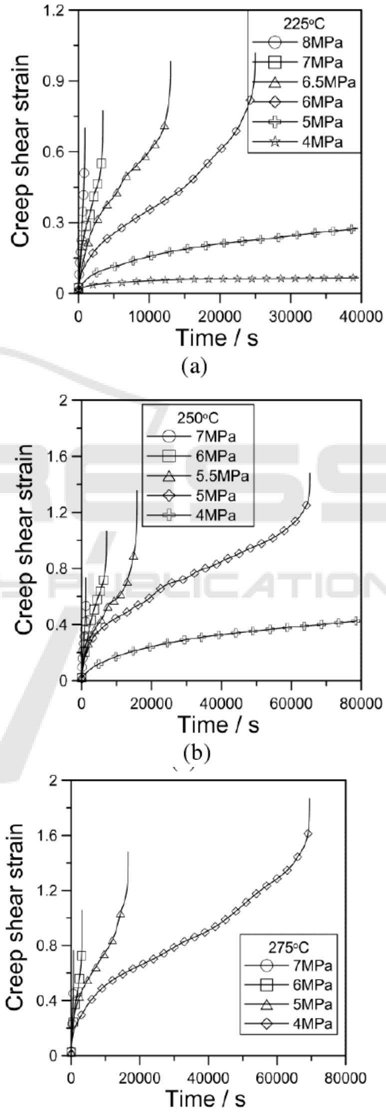
Among them, Δp is the loading stress range for a cycle,The maximum loading stress range is Δp_m.According to the definition of load reduction factor, it is believed that in the cyclic process, the continuous action of the load causes the accumulation of damage within the joint, the carrying capacity of the material is continuously declining, and the load factor gradually increases. When 0, the material or structure is considered to be completelydestroyed [7].

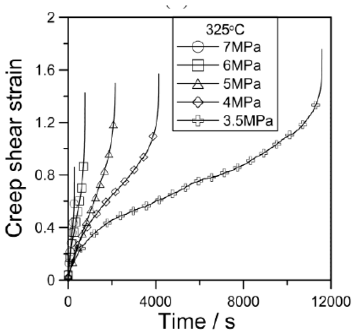
Table 3-1 Isothermal fatigue test loading conditions of sintered nano-silver joints.

Spec. ID	Temperature (℃)	Displacement amplitude (×10^{-3}mm)
F1	25	10.36
F2	25	7.77
F3	25	5.18
F4	25	4.14
F5	125	5.18
F6	225	5.18
F7	275	5.18
F8	325	10.36
F9	325	7.77
F10	325	5.18
F11	325	4.66

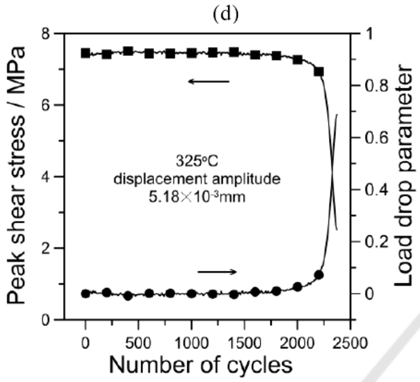
3.2 Effect of Temperature on Isothermal Fatigue Behavior of Sintered Nanosilver Joints

In order to study the effect of different ambient temperature on the fatigue behavior of sintered nano-silver joints, the displacement amplitude Symmetrical cyclic fatigue tests at different temperatures under 5.18× 10^{-3} mm conditions,Table Figure 3-1 shows the stress response of the joint at different temperatures as a function of the number of cycles . As can be seen from the line, the peak stress and cycle life that the joint .Under low temperature conditions, the fracture of the joint suddenly occurs after a certain number of cycles, and as the temperature rises, the joint undergoes a continuous decline in the carrying capacity of the joint beforebreaking.





(d)



(e)

Fig.3-1 Fatigue test for displacement amplitude of 5.18× 10^{-3} mm at temperature of: (a) 25℃; (b) 125℃; (c) 225℃; (d) 275℃; (e) 325℃.

As can be seen from the figure, both the increase in the amplitude of the displacement and the increase in the ambient temperature Reduce the cycle life of the joint.

4.EXPERIMENTAL RESULTS AND ANALYSIS

In order to verify the predictive power of the model, the determined model parameters are brought into equation and the displacement amplitudes are both5.18 × 10^{-3} mm, the isothermal mechanical fatigue life of the sintered nano-silver structures with different test ambient temperaturesis predicted[8] .The relationship between the predicted lifetime and temperature is shown in 3-1 It can be seen from the figure that the fatigue life prediction model based on structural displacement has a good prediction of jointfatigue life at different temperatures.

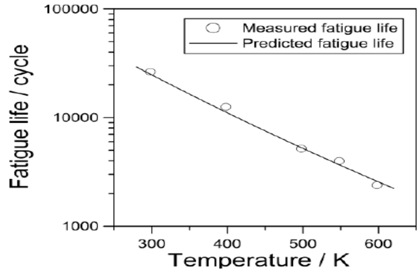


Fig.4-1Fatigue life versus temperature for structure displacement amplitude of 5.18×10^{-3} mm

Compare the measured lifetime and predicted lifetime of sintered nano-silver bonding structures obtained in the test From Fig. 4-2, it can be seen that the proposed temperature-dependent fatigue life prediction model based on structure displacement is The test results are within the double dispersion band. The predicted results of this model are in good agreement with the experimental results, indicating that the model It can be used to predict the fatigue life of sintered nano-silver structures at different temperatures.

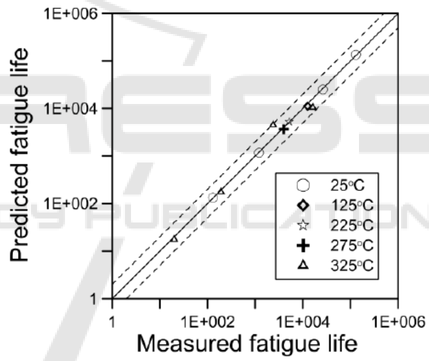


Fig. 4-2 Comparison of predicted and fatigue life

5. CONCLUSIONS

At 325°C, microscopic cracks formed in the grains of the joints are formed as a result of the cyclic action.the expansion begins, resulting in a progressive reduction of the load bearing capacity of the sintered nanosilver joints from the beginning of the Cycle [8]. Falling, so the load drop at high temperatures is evident at lower temperatures,especially at relatively high displacement amplitude levels.

In this process, the micro-cracks in the joints start to sprout gradually, absorbing a certain amount of energy and keeping the joints at a certain stress level. Subsequently, the fatigue cracks rapidly expanded, and the load-bearing capacity of the joints dropped to a level close to zero, resulting in breakage of the joints. In general, the initiation and propagation of cracks in the joints leads to a decrease in the effective load-bearing area of the joints. Therefore, the stress required to maintain constant joint deformation also decreases. The optimization prediction method can effectively predict the mechanical fatigue life, and has important guiding significance for the subsequent research on the sintered nano-silver structure.

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