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宇宙火災安全性向上に向けた電子回路基板材料の試験片形状確定に向けた研究

Research on Determination of Test Sample Shape for Electronic Circuit Board Materials to Improve Space Fire Safety

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1. Introduction

Fire safety is one of the most important issues in manned space missions. Because a large number of electrical devices and cables are installed in manned spacecraft, electrical fire is the most likely cause of fire during manned spacecraft missions. Electrical fire is generally initiated by electrical overheating and it grows by the flame spread phenomenon over the electric wires and printed circuit boards. To improve the fundamental understanding of the fire growth mechanism in spacecraft environments, a lot of fundamental studies regarding ignition and flame spread of solid material have been performed by numerous researchers. However, to simplify the combustion processes of the solid material, most of the previous studies have focused on the combustion phenomena of single combustible solids.

As mentioned before, in electric fires, composite materials represented by electric wires and printed circuit boards consisting of flammable polymer and metal conductors are involved in fire growth. Therefore, the fundamental understanding of the flame spread mechanisms over composite materials is required to improve fire safety in spacecraft.

A long-term objective of this study is to elucidate the flame spread mechanism over a printed circuit board made of phenolic resin (Bakelite) and copper foil.

In the present study, we have investigated to find a way to ensure two-dimensional flame spreading over a printed circuit board during the microgravity experiments on orbit to obtain data with better generality such as flame spread rate and limiting oxygen concentration under maintaining two-dimensional phenomena. Since the printed circuit board is a composite material, the difference between the thermal expansion coefficient of Bakelite and that of copper foil causes deflection. To avoid such a situation, we investigated the effects of the sample shape and sample holding method on the deformation of the sample during the flame spread test. The results in this paper could be useful information for the determination of the experimental configuration in future space experiments.

2. Experimental

Figure 1 shows a schematic diagram of the sample holder and the wind tunnel used in this study. The sample holder is made of a stainless-steel plate with a thickness of 1 mm. The sample holder consists of upper parts with a hook for installation of the sample holder in the wind tunnel and side bars to control the size of air gap between the sample and the sample holder. The sample is supported by clamping it from back and front side bars. A glass cloth tape is attached to the sample holder to reduce heat loss from the sample to the sample holder. The air gap between the sample holder and the sample has a significant effect on the combustion characteristics of the test specimen due to the heat loss from the copper foil to the holder.[1)] Therefore, the holder designed in this study allows to control the air gap.

A commercially available circuit board (FR-1 paper phenolic copper clad laminate, Panasonic Electric Works Co., Ltd.) was used as the experimental samples. This board material consists of 35 μm thick copper foil attached to one side of 0.8 mm and 1.6 mm thick Bakelite. In this study, the oxygen concentration was fixed at 40% and the bulk flow velocity in the tube was set to 4cm/s or 10cm/s, and the sample was ignited using electrically heated wire. The air gap between the sample and the sample holder was fixed at 2.5 mm.

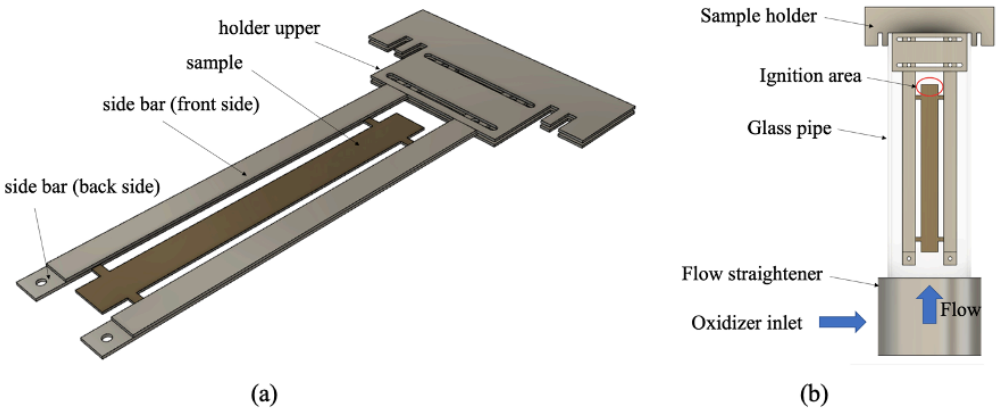


Fig. 1 Schematics of sample holder (a) and flow duct (b) used in this study

Experiments were conducted with three types of samples. The basic sample shape is a rectangle with a length of 130 mm and a width of 13 mm. In addition, a sample with a protruding part (notch) for pinching on both sides was also prepared. The shape of samples is shown in Fig.2.

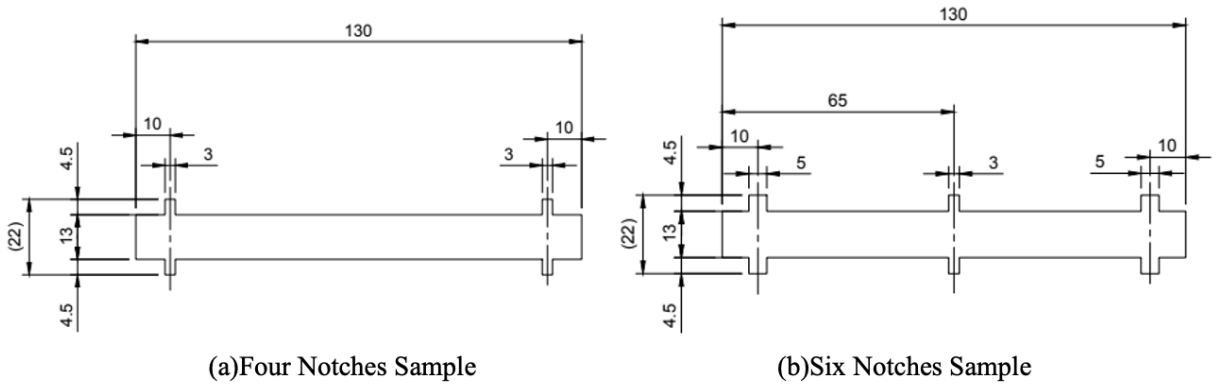


Fig. 2 Shape of samples

3. Result and Discussion

3.1 Rectangular Sample

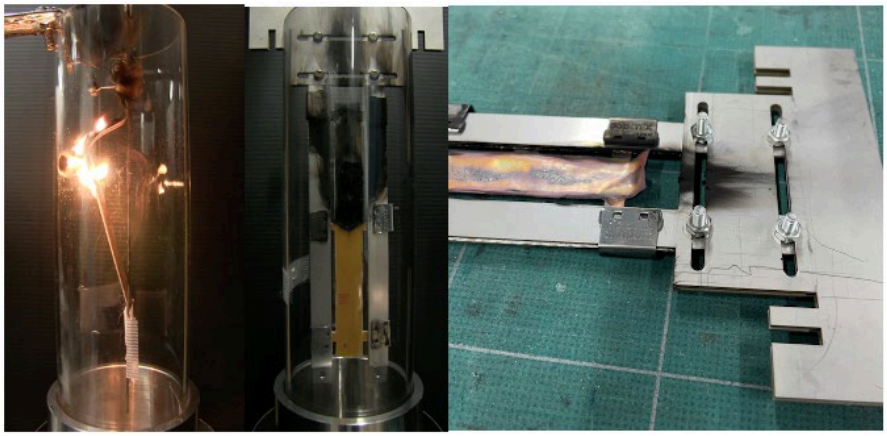
The sample strip without notch needs to be fixed at the top and bottom end of the sample. This method results in serious deflection due to thermal expansion. This situation is shown in Fig.3(a). Such a deflection is unacceptable. Because this method cannot examine the gap effect.

3.2 Six Notches Sample

To avoid the deflection, the six notches are added to the sample strip as shown in Fig.2 (b). This configuration can avoid the deflection and keep the air gap constant, but the flame suddenly extinguished near the middle notch. Therefore, the sample shape is inappropriate for this experiment. This situation is shown in Fig.3(b).

3.3 Four Notches Sample

Lastly, the sample which has four notches was tested. With this sample, bend and extinguishing near the middle notch can be avoided and the gap can be kept appropriately. However, the part above the notch has curled up as shown in Fig.3(c). It is not expected to have any effect on experiments on the ground, but in space experiments, depending on the size of the curl, it could destroy the experimental equipment.



(a)deflection (b) extinguishing (c) curled up

Fig. 3 The result of the rectangular sample(a), the six notches sample(b), and four notches sample(c)

3.4 The validity of the notch

In this study, we have found that the notches are effective in avoiding bend. On the other hand, in the six notches sample, extinction occurs near the middle notch. This is due to the instantaneous increase in heat capacity and increase in heat loss to the sample holder. We conclude that the four notches sample is the most promising configuration for the purpose of this experiments because it is not desired to disturb the steadiness and two-dimensionality of spreading flame in the middle of the sample strip.

4. Conclusions

In this study, we found that notches were effective in avoiding sample deflection due to thermal expansion. The optimal number of notches is four. If there are six notches, the flame spread phenomena is strongly affected by the presence of middle notch. One the other hand, the four notches sample was curled up at the part above the notches. Therefore, the sample shape is inappropriate for this experiment. This is because it is not allowed for the sample to jump out of the sample holder in the space experiment equipment. In the future, it will be necessary to consider the position of the notch and the aging of the copper foil.

Acknowledgements

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References

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