Effect of Halogen Freeing on Fatigue Properties of Electronics Printed Plasitic Board

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ABSTRACT

Recently, it is important to develop new packaging technology that is gentle for environment and human body in electronic packaging fields. The printed circuit board of electronic equipment will be developed using materials for substrates without halide fire retarding material (that is halogen-free material) as dioxin does not arise. However, reliability assurance becomes an important problem for substrates using halogen-free fire retarding material, since there are fears that strength and heat-resistance are inferior to conventional circuit materials.

In this study, fatigue reliability of halogen-free substrate noticed as an environmental harmony type printed circuit board material was evaluated. The difference of fracture mechanism between halogen-free material and halogen material in fatigue fracture was demonstratively examined from mesoscopic viewpoint. Fatigue life of halogen-free material was longer than that of halogen material, though mechanical property of halogen-free material was almost equal to it of halogen material. From fractography using by SEM, it was indicated that the difference of fatigue life in halogen-free material and halogen material was controlled by the difference of a size of characteristic destruction pattern named "Unit Fracture Area". It was thought that difference of resinoid type between halogen-free material and halogen material appears in the difference in fatigue life, since matrix resin was a weakest link in fatigue fracture, on the other hand, strength of halogen material and halogen-free material was equal in static fracture, since the glass fiber was a strongest link.

KEYWORDS

Fatigue Reliability, Halogen-free- Electronics Substrate, Fractography, Reinforced Plastics

INTRODUCTION

Recently, the miniaturization is required in electronic equipment products. As the result, high-density packaging technologies such as buildup substrate have rapidly advanced. In the meantime, the environmental problem becomes serious, and they worry about the effect of pollution to environment and to human body. Therefore, it is important to develop the gentle packaging technology for environment, namely ecological design technology in electronic packaging fields.

There have been a series of research of fatigue reliability assurance of recycling engineering plastic material by authors, as it is shown in Fig.1 and Table 1. As the result, it was shown that the control of mesoscopic factor could improve the reliability of recycling engineering plastic materials.

At present, the use of halide fire retardant that is included in printed circuit board has been controlled. This is because dioxin and furan of which the toxicity is high arise, when halide fire retardant burns. Therefore, the use of halogen-free system fire retardant such as phosphorus system fire retardant has increased year by year. However, the improvement of reliability of substrates using halogen-free system fire retarding material becomes an important problem, since there is fears that strength and heat-resistance are inferior to conventional substrates. . The safety assessment of halogen-free substrates is only to carry out simple evaluations by tensile test, etc. So the evaluation on fatigue reliability has not been almost carried out.

Then, fatigue reliability of halogen free substrate was evaluated in this study. Especially, this study was demonstratively carried out by investigating the difference of fatigue fracture mechanism between conventional halogen substrate and halogen-free substrate from a viewpoint of mesoscopic fracture mechanism.

EXPERIMENTAL METHOD

Sample materials used in this investigation were halogen free-laminated material MCL-RO-67G made by Hitachi Chemical Co., Ltd. New aromatic system addition reaction type thermosetting resin (RO resin) of which fire resistance was high had mainly been used for this laminated material. Therefore, fire-retardant UL94V-0 has been achieved, even if this material does not use the halide fire retardant such as halogen compound, antimony and red phosphorus. Especially, it has high elastic modulus and heat-resistance under the high temperature environment, since it mainly has the aromatic skeleton in molecular structure, (Table 2). And, the general FR-4 laminated material was prepared in order to compare characteristics of a conventional halogen laminated material. The molecular structure of halogen resin is shown in Fig.2. In either sample, the glass cloth has been used as reinforcement. Test specimens were machined in dambell-type. Fatigue test with a minimum/maximum load ratio R of 0.1 were carried out under 10Hz-loading rate at sine wave in ordinary-temperature. And the fatigue test equipment was computer control servo fatigue testing machine made of Shimadzu Co.,Ltd..

Tabel 1 A series of research result on reliability assurance of recycling engineering plastic

Matrix	Reinforcement material	Tested Method	Environment	Recycling property
PA66	Carbon fiber	Fatigue test	Above Tg/Bellow Tg	△
		Fatigue crack propagation test	Above Tg/Bellow Tg	△
	Glass fiber	Fatigue test	Above Tg/Bellow Tg	×
		Fatigue crack propagation test	Above Tg/Bellow Tg	×
PA46	Carbon fiber	Fatigue test	Above Tg/Bellow Tg	△
		Fatigue crack propagation test	Above Tg/Bellow Tg	△
	Glass fiber	Fatigue test	Above Tg/Bellow Tg	×
		Fatigue crack propagation test	Above Tg/Bellow Tg	×
	Aramid fiber	Fatigue crack propagation test	Room	△
PEEK	Carbon fiber	Fatigue test	Above Tg/Bellow Tg	◎
		Fatigue crack propagation test	Above Tg/Bellow Tg	◎
	Glass fiber	Fatigue test	Above Tg/Bellow Tg	○
		Fatigue crack propagation test	Above Tg/Bellow Tg	○
PPS	Glass fiber	Fatigue crack propagation test	Room	×
	Carbon fiber + Tetrapoded fiber	Fatigue crack propagation test	Room	△
PA・MXD6	Glass fiber	Fatigue crack propagation test	Room	×

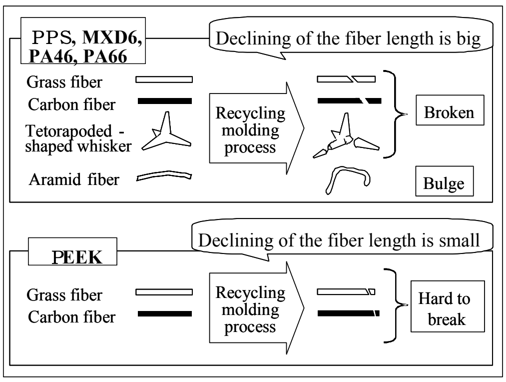


Fig.1 Schematic of influence of recycling molding process of FRTP on previous study

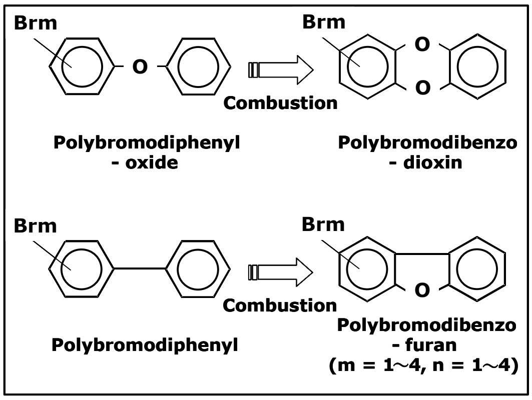


Fig.2 Formation of dioxin and furan

EXPERIMENTAL RESULT

A relationship between number of cycles to failure and stress amplitude in halogen free material and halogen material were shown in Fig.3. From Fig.3, it was proven that the fatigue life of halogen-free material is longer than that of conventional halogen material. That is to say, the fatigue life of halogen free material was longer than that of halogen material. Generally, the material of which the static strength shown by the stress-strain chart is similar becomes also similar on fatigue characteristics. However, there was a remarkable difference in fatigue life of both materials in spite of not recognizing the difference of static strength clearly. Then, in the following chapter, fatigue destructive mechanism are considered from a meso-scopic viewpoint, in order to clarify the difference of the fatigue characteristic of both material.

CONSIDERATION

Relationship between crack initiation life and fatigue fracture life

The relationship between crack initiation life and fatigue fracture life of sample materials is shown in Fig.4. Still, number of crack initiation cycles was decided when main crack length became 0.5 (mm) by visual observation. From Fig.4, it was proven that the crack initiation of halogen free material was comparatively an early time in fatigue life. On the other hand , it was proven that the crack initiation of halogen material was late in fatigue life, halogen material was immediately fractured after a main crack was initiated. Then, Fig.5 shows the relationship between crack initiation life ratio (NI ;Number of crack initiation life / Nf ; Number of failure life) and stress amplitude in both materials. From Fig.5, it was proven that the value of crack initiation life ratio of halogen free material was smaller than that of halogen

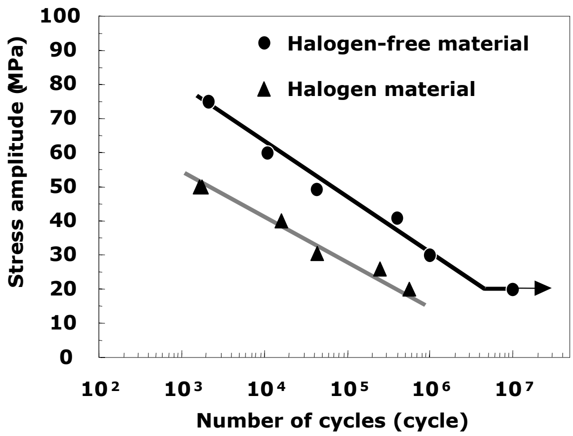


Fig.3 S-N curves

Table 3 Mechanical properties of Halogen-free and halogen material

Item	Halogen-free material	Halogen material
Elastic modulus(GPa)	1.51	1.44
Tensile strength(MPa)	363.7	364.7
Total elongation	3.36	3.32

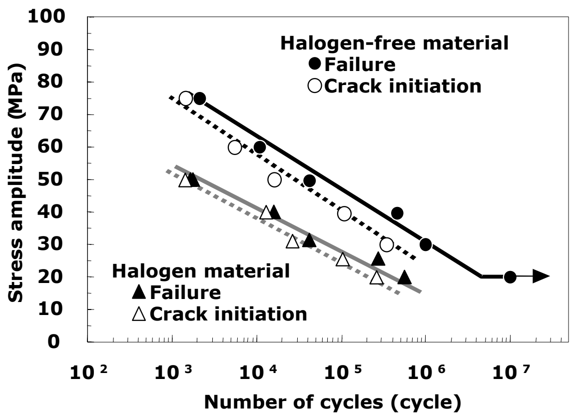


Fig.4 Relationship between number of cycles to failure and crack initiation

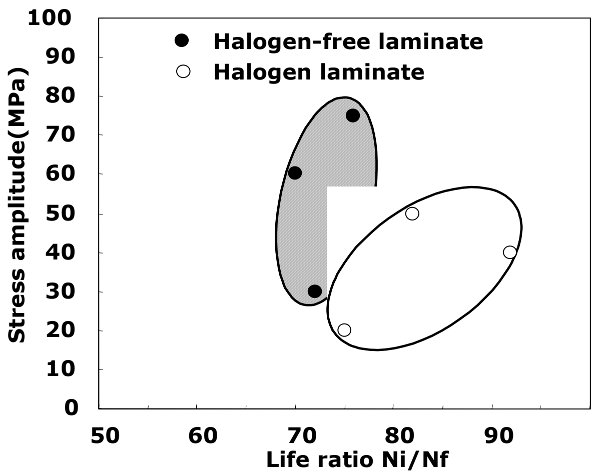
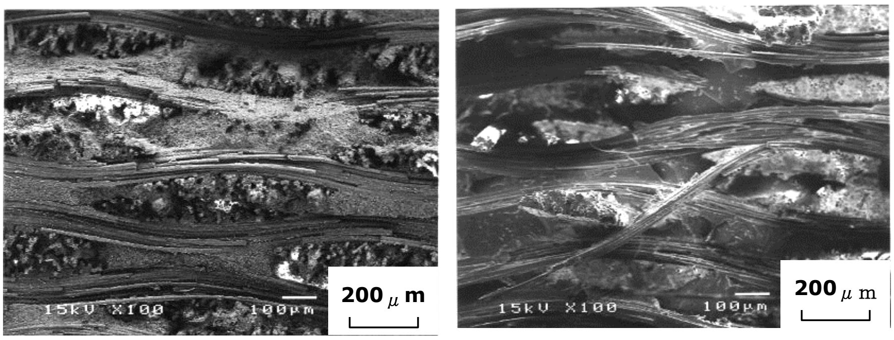


Fig.5 Ratio of number of cycles to crack initiation in fatigue life

material. That is to say, crack initiation life ratio of halogen free materials were 70～75%, and it of halogen materials were 80～90%.

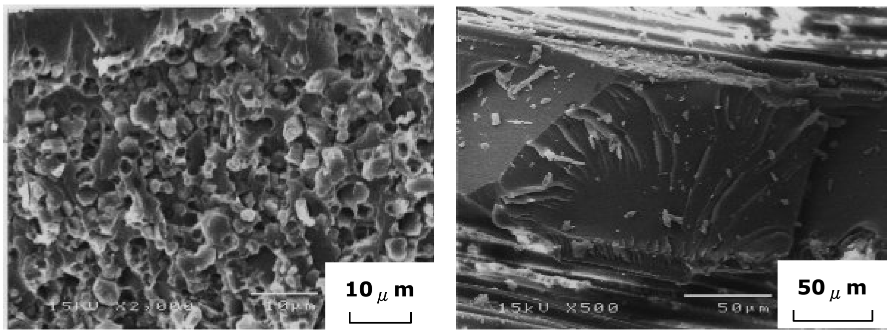
Difference of destruction unit area in fracture surface of resin

Fig.6 (a) and (b) shows fracture surface photographs of halogen free material and halogen material by scanning electron microscope (SEM) at low magnification. In addition, fracture surface photographs at a high magnification are shown in order to compare the difference of fracture morphology of matrix resin of both materials. Examination of fracture surface by SEM revealed that a fracture surface of halogen free material differed from that of halogen material. It was proven that the fracture surface of matrix resin of halogen free materials have been formed in granular form, and a size of that grain was about 4 μm diameters, and the resin comparatively adheres to glass fibers from Fig.7 (a). In the meantime, it was proven that the fracture surface of matrix resin of halogen materials have been formed in the shell state form of about 100～200 μm diameters, and the resin does not adhere to glass fiber shown in Fig.7 (b). In



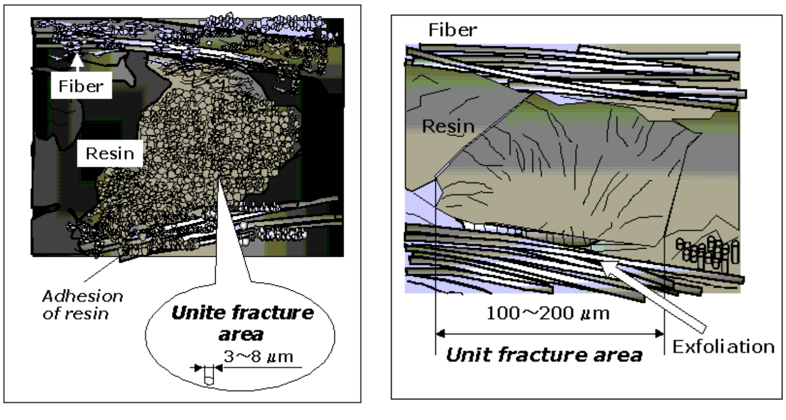
(a) Halogen-free material （×100） (b) Halogen material （×100）

Fig.6 Fracture surface of halogen-free material by using SEM



(a)Halogen-free material （×2000） (b)Halogen material （×500）

Fig.7 Difference of the pattern of fracture of resin in halogen-free and halogen mater



(a)Halogen-free material (b)Halogen material

Fig.8 Schematic of fatigue fracture mechanism of halogen-free and halogen material addition, its fracture surface was flatter than halogen material, and it has shown frail fracture morphology. And, there was peeling between resin and glass fiber in the central region of the base of these shell state form. One region of the fracture surface pattern of matrix resin of each material like superscription was named Unit Fracture Area. The difference of this UFA seems to greatly affect the difference in fatigue life of each material. A cause of the difference of size of UFA between halogen material and halogen free material was considered to be due to the difference of a molecular structure of matrix resin.

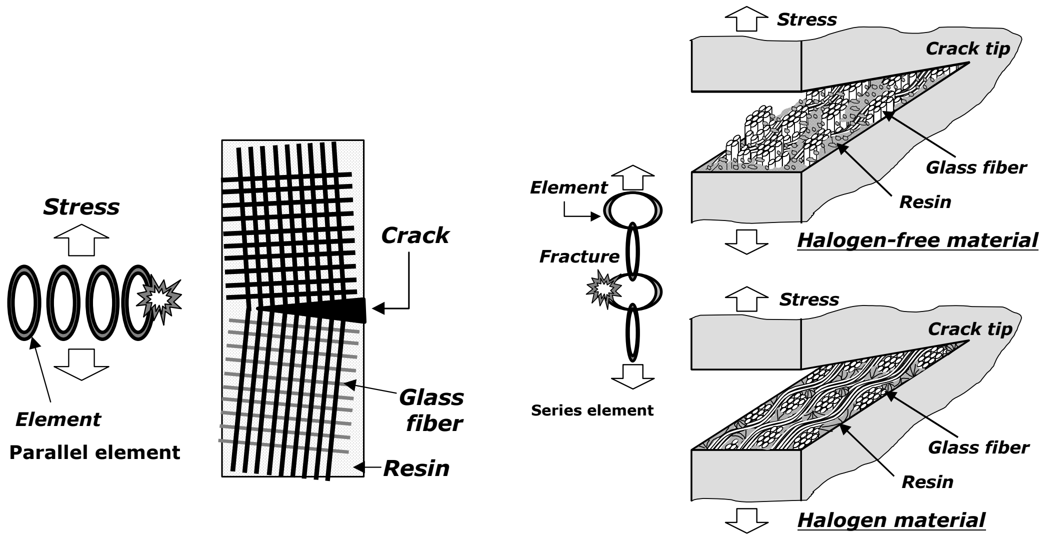
Criteria of fatigue fracture in composite material

From this fatigue test result, the fatigue life of each material differs in spite of the equal of mechanical property. This was considered to be due to the difference of criteria of fracture between static fracture and fatigue fracture. Then, sample materials are caught as a resin/glass fiber composite in order to explain criteria of fracture.

Fig.9(a) shows a way of list of the element link of each material in static fracture. Each element link seems to parallelly range in static fracture. Therefore, the whole material was not fractured immediately, even if the weakest element was destroyed, because the material strength was kept by the more resistant elements. That is to say, its strength is dependent on the most resistant element in the static destruction. The glass fiber is the most resistant element in this material. So the static strength seemed to be equal, since an equal glass fiber has been used in sample materials.

Fig.9 (b) shows a way of list of the element link in fatigue fracture. Each element link seemed to ranks for the series in fatigue fracture. Fatigue fracture is caused by crack generating and developing at repeated stress that is smaller than yield stress (or, tensile strength). Therefore, a crack initiation and propagation is most important role in failure mechanism in fatigue fracture. Since a crack is generated from the weakest element in the material, its element decides the whole life in the fatigue fracture. So, it is considered that the fatigue life was controlled for the weakest link hypothesis. By the consideration to the previous paragraph, a weakest element in this material seemed to be an interface between resin and reinforced fiber or resin. That is to say, it is thought that a difference of the fatigue life of halogen material and halogen free material is based on a difference of the strength of the interface between glass fibers and resin by difference of the kind of resin. Fatigue cracks in halogen material were initiated from the interface of fiber and resin, and in addition, it develops, while the resin was exfoliated from fibers.

In the meantime, fatigue crack in halogen-free material develops inside of matrix resin, since adhesive property of the interface of fiber and resin was comparatively good. And since the resistance for fracture of the resin was bigger than halogen material, a fatigue crack comparatively slowly develops on the halogen free material. So, fatigue life of halogen-free materials seemed to be longer than that of halogen materials.



(a)Static fracture mode (b)Fatigue fracture mode

Fig.9 Criteria in static fracture and fatigue fracture , and fracture mechanism

CONCLUSION

In this study, fatigue reliability of halogen free substrate noticed as an environmental harmony type printed circuit board backing was evaluated. And, the examination was demonstratively carried out on the difference of fracture mechanism in fatigue fracture and static fracture from mesoscopic viewpoint. Main results were as follows; (1) Fatigue life of halogen free material was longer than that of halogen material, though mechanical property of both materials was same. (2) Fatigue crack of halogen-free material has comparatively been generated at the initial stage in fatigue life. In the meantime, halogen material was immediately broken , after the crack was generated, and the fracture morphology was brittle. (3) From the fractographic study, it was indicated that size of the characteristic destruction pattern; Unit Fracture Area influenced the difference of fatigue life between halogen free material and halogen material. (4) The difference of fatigue life between halogen material and halogen free material was explained in weakest link model in fatigue fracture. That is to say, the resin or the interface between fiber and resin is a weakest link in fatigue fracture. In the meantime, the effect of difference of resin didn't appear in the difference of static strength between halogen material and halogen free material, because the reinforcement glass fiber undertook the material strength in static fracture.

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