A SEMICONDUCTOR FUSE-LINK ON A CERAMIC SUBSTRATE

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1. Foreword

A fuse-link having element(s) of thin copper film, deposited on a ceramic tab and provided with high-precision small holes with electrolytical process, has been introduced as a new type of semiconductor fuse-links with very small operating I^2t.

Ratings, construction and distinguished features of this fuse-link, as well as the test circuitry built especially for the development of this type of fuse-links are explained below.

2. Construction of the new fuse-links

Thin film of high purity copper is deposited on one side or both sides of a ceramic tab of thickness 1 mm.

The film thickness depends on the current rating, and the tab legth on the voltage rating of the fuse-link. The highest current rating of a single tab is 60 A, with films deposited on both sides of the tab. For fuse-links of higher current ratings, two or more tabs in parallel are used.

The copper film on the tab is provided with high precision small holes by electrolytic process as illustrated in Fig.1. These holes give rise to a series of small parallel arcs between the neighbouring holes along the whole length of the tab when large overcurrent flows through it.

The surface of the tab is covered with thin film of silicon resin to protect the copper element from oxidation.

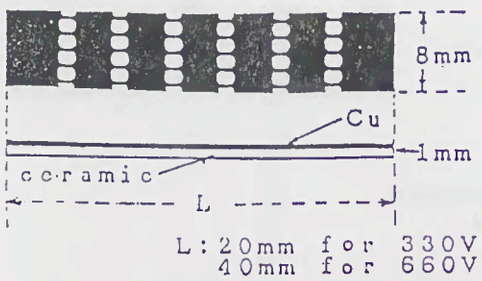


Fig.1 Structure of fuse element

The barrel containing the tab is filled tightly with sand in just the same way as ordinary semiconductor fuse-links.

List of the fuse-links developed thus far is given in Table 1.

Table 1 List of fuses

AC 330V Fuses

TYPE	RATED VOLTEAGE	RATED CURRENT	RATED BREAKING CURRENT	SIZE(mm) A	B	C	D
UR31	AC : 330V	20 · 30 · 40 · 50 · 60A	100KA	56	26	19	18
UR32		60 · 80 · 100 · 120A		58	28	22	21
UR33		90 · 120 · 150 · 160A		60	30	27	27
UR36		150 · 200 · 250 · 300A		85	32	39	36

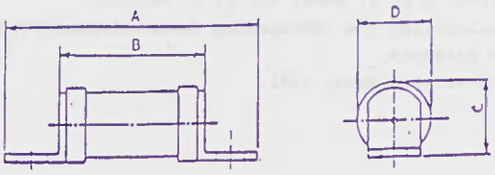
AC 660V Fuses

TYPE	RATED VOLTEAGE	RATED CURRENT	RATED BREAKING CURRENT	SIZE(mm) A	B	C	D
UR61	AC : 660V	20 · 30 · 40 · 50 · 60A	100KA	76	47	19	18
UR62		60 · 80 · 100 · 120A		90	48	22	21
UR63		90 · 120 · 150 · 160A		90	50	27	27
UR66		150 · 200 · 250 · 300A		106	52	39	36

AC 660V Fuses (combination type)

TYPE	RATED VOLTEAGE	RATED CURRENT	RATED BREAKING CURRENT	SIZE(mm) A	B	C	D
UR66-D	AC : 660V	390 · 495 · 580A	100KA	106	52	39	36
UR66DD		750 · 940 · 1128A		106	52	39	36

※ D:Double type
DD:Tow double type



3. Technical merits of the new fuse-links

Thanks to the high thermal conductivity due to high density of the substrate, heat generated in the narrow paths between the holes can easily be carried away into the substrate. This makes it possible to hold temperature rise of the narrow paths at a moderate level for normal current, although the electric resistance at the narrow paths is rather high.

The small cross-section of the narrow paths greatly reduces pre-arcing I^2t of this fuse-link for large overcurrents.

On the other hand, the high precision of the perforations equalizes voltage and current, hence power, of the multiple parallel and series arcs, preventing concentration of arc-energy on limited number of arcs. In addition to this, strong cooling of arcs by the ceramic substrate remarkably reduces arc time and arcing I^2t of the new fuse-links.

The combined very low value of total operating I^2t of the new fuse-links for large overcurrent is tabulated in Table 2.

Table 2 Test result of new fuse

TYPE	RATED VOLTEAGE (V)	RATED CURRENT (A)	POWER DISSIPATION (W)	OPERATING I^2t (A^2t)
UR61	660	20	6.5	100
		60	15.5	1,300
UR62	660	60	18.5	750
		120	21.6	7,500
UR63	660	90	21.3	2,400
		180	32.0	18,000
UR66	660	150	30.4	9,200
		300	50.0	58,000
UR66-D	660	390	77.0	92,000
		580	98.0	300,000
UR66DD	660	750	123.0	413,000
		1128	172.0	1,220,000

Fig.2 shows pre-arcing time-current characteristic of 660V/30A fuse-link, which depicts that adiabatic fusion of its element takes place only for very large currents for which pre-arcing time exceeds 0.3 ms.

The quick absorption of the heat generated in the narrow paths of the fuse-element by the substrate and the fast sticking of the paths onto the substrate prevent deformation of the narrow paths

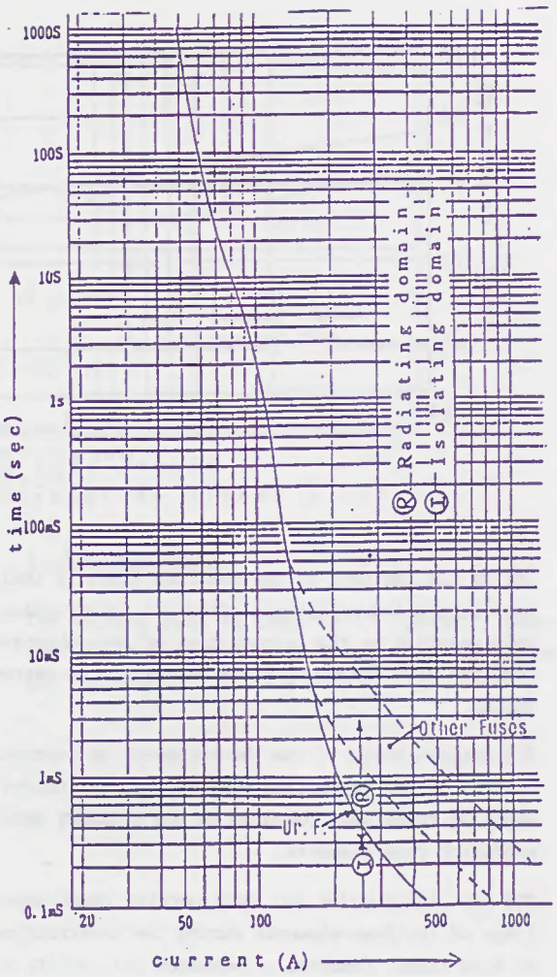


Fig. 2 Preacing time-current characteristic of UR61-30A fuse

caused by the temperature fluctuation by repetitive overloads.

Fig.3 shows the number of repetitive current cycles(on-period 1 sec/off-period 300 sec) that can be imposed on a 60 A fuse-link until its fusion as the function of the test current given in % of its 1-sec fusing current. It indicates that at a current of 70% 1-sec fusing current the fuse-link withstands 50,000 cycles of repetitive overload, which must be quite a remarkable value for a semiconductor fuse-link.

In general, low operating I^2t of a semiconductor fuse-link is incompatible with the longevity. However, in the case of the new fuse-links, they are compatible with each other.

The perforation through the element makes it rather easy to control arc voltage of the fuse-link. Hence, arc-voltage is no great a problem for our fuse-links.

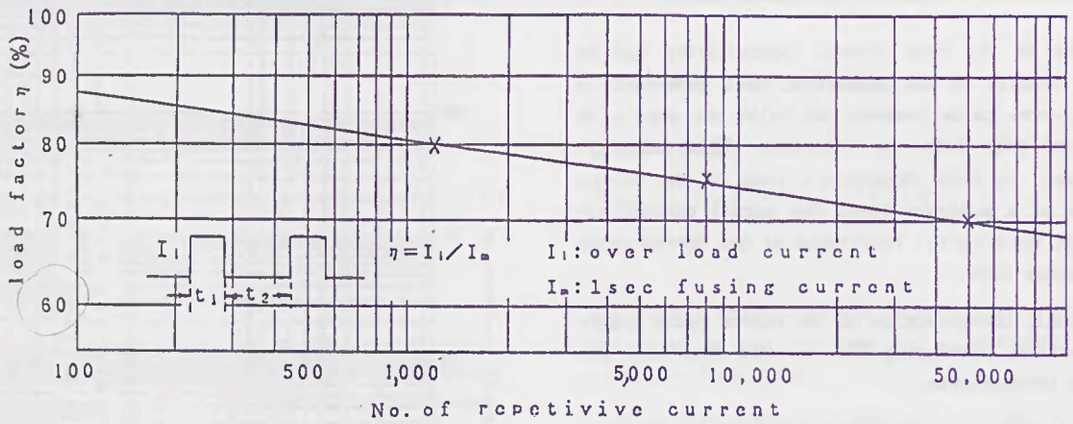


Fig. 3 Result of repetivive life test using UR62-80A

One of the features of the new fuse-links is their high insulation resistance after the interruption; made possible by the introduction of the substrate combined with the appropriate design of the narrow paths.

The largest merit of the fuse-element on ceramic, in view of the production engineering, is its outstanding robustness compared to the ordinary semiconductor fuse-elements.

The new construction not only permits rough handlings of the fuse-elements during the construction of fuse-links, remarkably increases reliability of the product.

4. Breaking test facilities

To facilitate the development of new fuse-links, a special test circuit as indicated in Fig. 4 was introduced, where the capacitor charged up to about 5,000 V was discharged through the upper part of the coil to the fuse-link producing near-sinusoidal current of 50 kA at 100 Hz.

The initial rate of rise of the test current was set at 44.4 x 10 A/s which corresponds to test current of 100 kA at 50 Hz as indicated in Fig.5.

The highest arc voltage did not exceed 1.3 times the peak recovery voltage.

After the interruption of the current by the fuse-link, the discharge current flows through the entire coil and its frequency turns to 50 Hz producing recovery voltage of 50 Hz. Test results by this resonance circuit, which was very useful in developing our new fuse-links, were compared with those by a short-circuit test machine. The result showed good coincidence.

5. Conclusion

A new type of semiconductor fuse-links with fuse-elements depisited on ceramic substrate has been introduced.

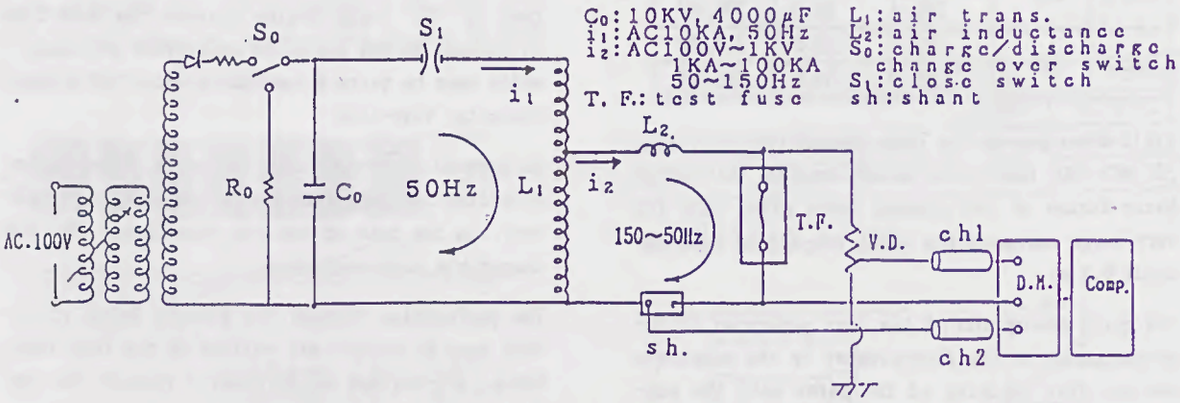


Fig. 4 Interrupting test circuit of AC660V, 100KA fuses

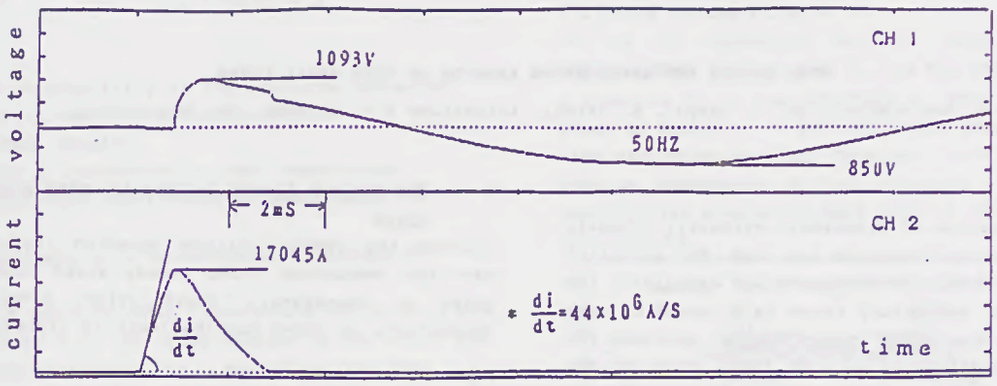


Fig. 5 UR66D-600A fuseing test result by AC660V, 100KA circuit

Very low operating I^2t without sacrificing longevity is the most outstanding feature of this type of fuse-links.

Also the inherent sturdiness of the fuse-element has made handlings during the fuse production easy, resulting in higher reliability of new fuse-links.

6. Acknowledgement

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