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Application of ultrasonic immersion testing for evaluating flexible printed circuit (FPC)

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1. Background

Since flexible printed circuit (FPC) with Cu foil is lighter than conventional wire harness with Cu cable, it is increasingly used in the field of in-vehicle electric equipment. However, excellent flexibility may cause the possibility of fatigue cracking under vibration load, whose management is more rigorous than that in mobile electronics for safety assurance. The fatigue property is characterized by MIT folding endurance test (MIT test), where the FPC is repeatedly bent with a clamping jig with defined top curvature.[1,2] **Fig. 1** shows schematic illustration of the sample cross section after testing. The entire thickness of polyimide (PI) laminate is about 50 µm. The thickness of Cu foil is about 20 µm including numerous cracking with the height less than 20µm. To measure the height by ultrasonic immersion testing, it is required to use several hundred MHz focused transducer.[3-5] However, it is impossible to evaluate Cu foil through PI and adhesive complex film with high attenuation. In this study, we aim to evaluate the occurrence of cracking by water immersion testing with low frequency transducer easily penetrating to subsurface Cu foil.

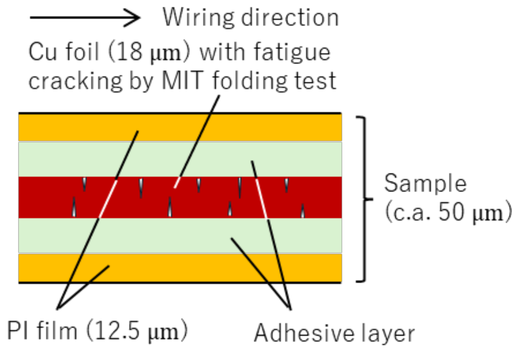

Fig. 1 Schematic illustration of cross section of flexible printed circuit (FPC) after MIT test.

2. Experiment

The water immersion system was composed of spherical lens PVDF probe (Krautkramer, 25 MHz, ϕ 5 mm, F12.5 mm), spike pulser receiver (Krautkramer, HIS3, pulse energy, 6.2J), and waveform acquisition system (1 GS, record length 1400 points) with liner motor scanner (pitch and position repeatability 1 µm). C scope was processed using MATLAB® from 200 million waveforms.

Figure 2 shows an appearance of MIT test sample, where ten Cu foil wirings with line and space of 100 µm/100 µm was covered with PI and adhesive complex film. The color of the tested region became darker than that of raw region [**Fig. 2(a) and (b)**]. **Fig. 2(c)** represents the height profile along broken line in Fig. 2(b), converting the arrival time of surface reflection echo by longitudinal speed in water (1480 m/s). There was a corrugation with a height of 5 µm due to buried Cu foil wiring.

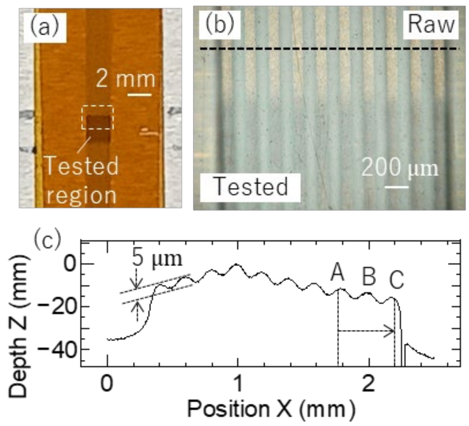

Fig. 2 Appearance of MIT test sample. (a) Preparation fixed on stainless steel substrate. (b) Micrograph near the tested boundary. (c) Profile along broken line in (b) converting arrival time of surface echo at – 20 mV using 1480 m/s.

3. Results

Figure 3 shows waveforms extracted along line segment AC in Fig. 2(c) with 10 µm interval. Note that the delay by height difference was removed. Broken curve (S) represents the result on flat stainless-steel substrate. The peak frequency was 37.2 MHz despite nominal value of 25 MHz The waveform in solid sample probably longer than the entire thickness because of 39.8 µm in water. There was clear difference between rf waveforms on Cu

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foil and PI separator regions [**Fig. 3(a)**]. The envelope amplitude tended to highlight Cu foil region at 0.170 µs [**Fig. 3(b)**]. On the other hand, in the frequency region, amplitude at peak frequency (37.1 MHz) enhances the contrast between them. [**Fig. 3(c)**].

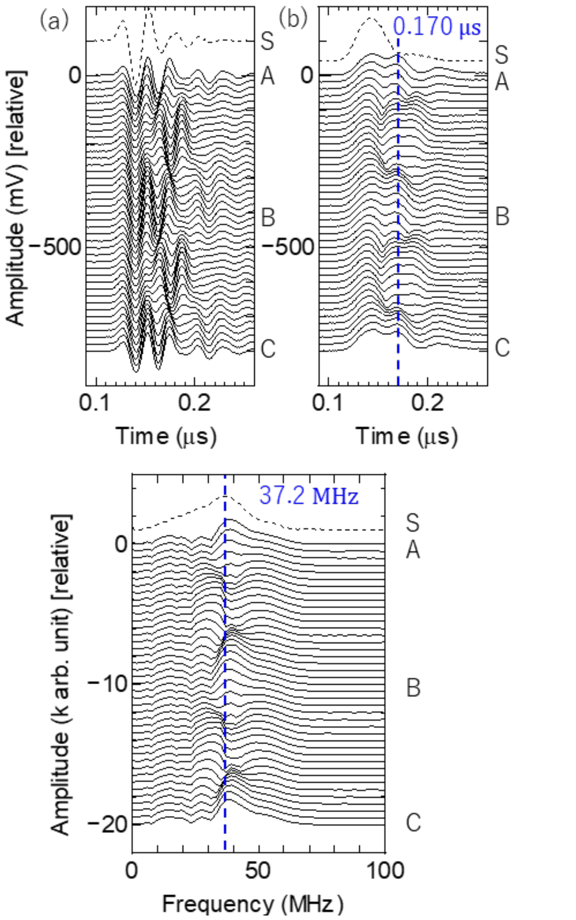

Fig. 3 Waveforms measured from A to C in Fig. 2(c). (a) rf signal and (b) envelope. (c) FFT spectrum of each waveform in (a). Broken curves show the results measured on the stainless-steel substrate.

Figure 4 shows C scope with envelope amplitude at 0.170 µs. Significant difference on Cu foil region due to MIT test was not observed, although there were several darker spots on PI separator region. **Fig. 5** shows C scope with spectrum amplitude. Although the contrast of Cu foil region was enhanced, there was no significant difference similarly to Fig. 4.

4. Conclusion

Conventional water immersion imaging with 25 MHz failed to detect fatigue cracking of FPC Cu foil wiring introduced by MIT test. It is necessary to use ultrasound that propagate in a direction that increases scattering by the cracking.

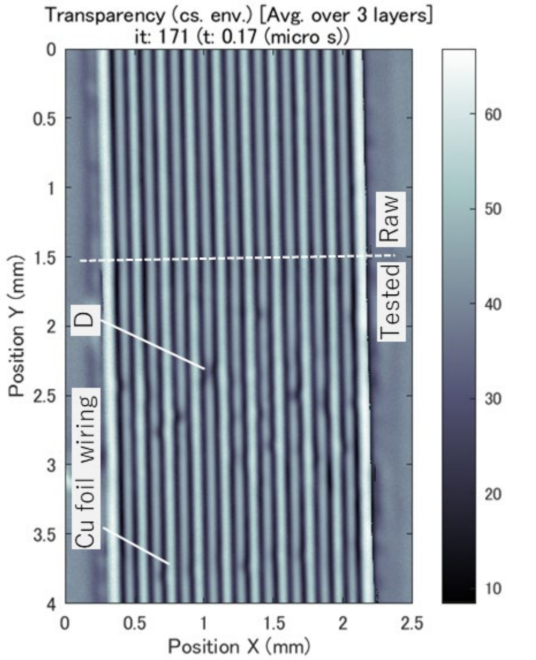

Fig. 4 C scope using envelope at 0.170 µs with magnitude on Cu foil wiring maximum.

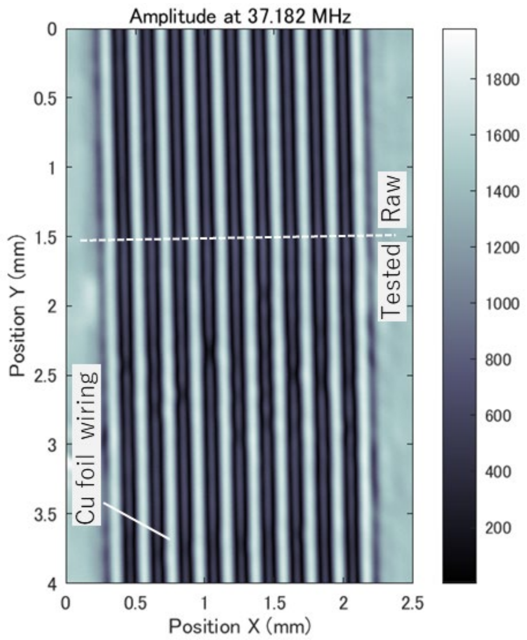

Fig. 5 C scope using amplitude of FFT spectra at 37.2 MHz, where the contrast between the regions of Cu foil wiring and PI separator was the maximum.

References

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