CONFIGURATIONS OF ULTRASONIC COMPLEX VIBRATION SYSTEMS FOR VARIOUS APPLICATIONS IN MICROELECTRONICS

Jiromaru Tsujino, Yoshiki Harada, Shigeru Ihara, Kohei Kasahara and Norihide Sakamaki
Faculty of Engineering, Kanagawa University, Japan
tsujino@cc.kanagawa-u.ac.jp

Abstract
Newly developed three types of ultrasonic complex vibration system with a welding tip vibrating elliptical to circular locus effective for packaging in microelectronics were studied. These systems are effective for direct welding of various electronic devices without solder. The complex vibration sources are using (1) a longitudinal-torsional vibration converter with diagonal slits, (2) a complex transverse vibration rod with several stepped parts driven by two longitudinal vibration systems and (3) a longitudinal vibration circular disk and three longitudinal transducers.

Introduction

Two- or three-dimensional ultrasonic complex vibrations are effective for various ultrasonic high power applications [1]-[5]. There are no commercially available complex vibration welding systems especially for various packaging in microelectronics. Three types of ultrasonic complex vibration system with a welding tip vibrating elliptical to circular locus for packaging in microelectronics were studied.

Complex vibration are effective and essential for welding of various specimens including the same and different metal specimens, and for direct welding of semiconductor tips and packaging of various electronic devices without solder.

The configurations of the complex vibration sources are as follows,

(1) Complex vibration system using a longitudinal-torsional vibration converter with diagonal slits that is driven only by a longitudinal vibration source.Vibration sources of 27 kHz to 100 kHz were made and tested.

(2) The second system uses a complex transverse vibration rod that is driven by two longitudinal vibration source crossed at a right angle. The two driving longitudinal vibration transducers are driven two independent power amplifiers with phase difference 90°. The transverse rod has several stepped parts for amplifying vibration velocity. The systems of 40 kHz to 200 kHz were tested.

(3) The third type system consists of a longitudinal vibration circular disk and three longitudinal transducers that are installed at the circumference of the disk. The disk vibrates in almost circular locus by driving only three transducers with phase difference 60°. This vibration source is characterized by small vibration amplitude normal to the vibration surface (welding tip part). Small normal vibration is required for flip-chip bonding of a semiconductor chip with a large number of bumps on a substrate uniformly. The longitudinal vibration sources of 100, 125 kHz were tested.

Several examples of packaging in microelectronics including direct bonding of small tip parts were tested.

Configurations of three type complex vibration systems.

Complex vibration system with a longitudinal-torsional vibration converter

The 130 kHz complex vibration systems are shown in Fig.1. The 130 kHz complex vibration system consists

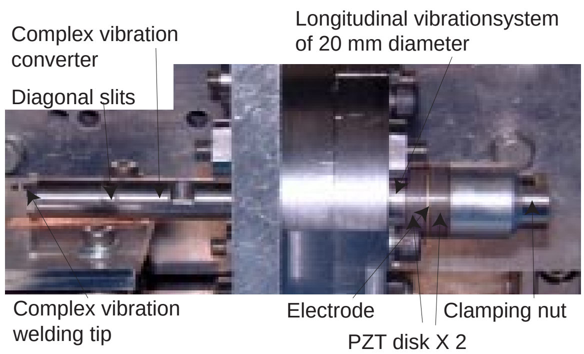


Figure 1: Configuration of a 130 kHz ultrasonic welding equipment using a longitudinal-torsional complex vibration converter with diagonal slits.

of a complex vibration converter, a stepped horn and a 20-mm-diameter BLT transducer. The complex vibration converter is driven using a longitudinal vibration system and longitudinal vibration is partially converted to torsional vibration. The free edge of the converter where four welding tips are installed, vibrates in elliptical to circular locus. The vibration locus is circular or elliptical in the case where the longitudinal and torsional resonance frequencies of the converter are almost same and the vibration phase difference of the converter is 90° or near to 90°.

Complex vibration source with a stepped complex transverse rod

The complex vibration system is shown in Fig.2. The complex vibration system consists of a stepped complex transverse vibration rod and two driving longitudinal BLT transducers crossed at a right angle. The two driving longitudinal transducers are driven using two amplifiers with phase difference of 90º to drive the welding tip in circular vibration locus. To overcome the mutual interference, the two transducers are set in bridge circuits to neglect dumped admittance of the transducers and the motional currents of each transducer are detected. One transducer is driven using a PLL auto-resonance-frequency-tracking and constant velocity control system, and the other transducer is driven with adequate phase difference of those motional currents using another driving system. Thus, the welding tip is driven in circular vibration locus that can be monitored using the two motional currents of the transducers.

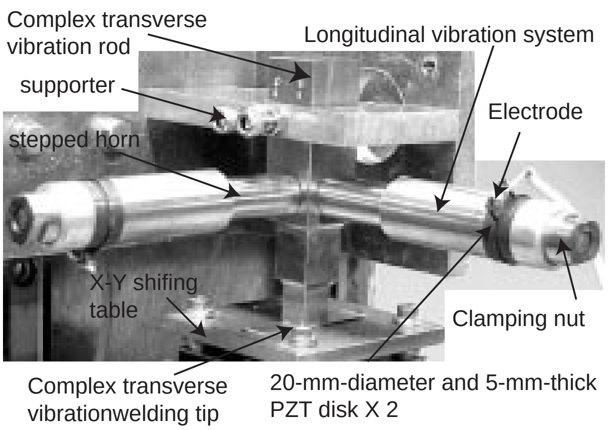


Figure 2: Configuration of a 40 kHz ultrasonic welding system using a stepped complex transverse vibration rod of 21 mm square with two stepped longitudinal vibration systems crossed at a right angle.

Complex vibration system with a longitudinal vibration circular disk

The complex vibration source consists of a longitudinal vibration circular disk with a welding tip at the center of the disk and three bolt-clamped Langevin type PZT longitudinal vibration converters of 20 mm diameter (Fig.3). The circular disk of one longitudinal wavelength diameter is driven using three longitudinal vibration transducers installed in the side circumference of the disk at 60° angle difference. The vibration source can be driven in elliptical to circular vibration locus using three amplifier with phase difference of 60°, and also can be driven by one power amplifier in the case where the transducers are arranged in sequence of the resonance frequencies.

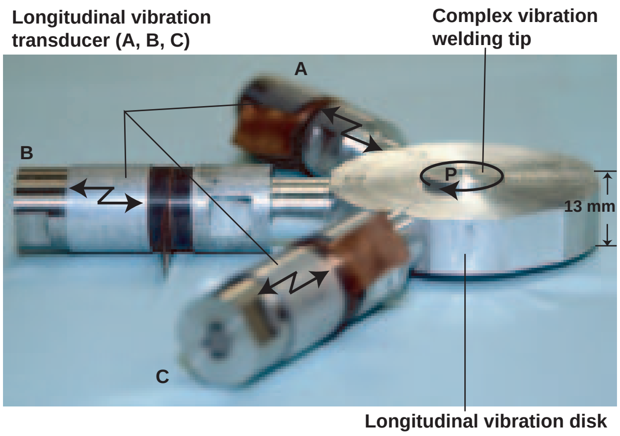


Figure 3: Configuration of a 100 kHz ultrasonic complex vibration source using a longitudinal vibration disk and three longitudinal vibration transducers of 20 mm diameter installed along the circumference of the disk.

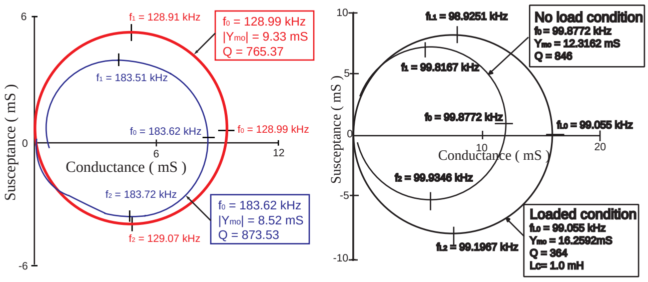


Figure 4: Free admittance loops of the 130 kHz and 180 kHz complex transverse vibration systems using a complex vibration converter measured at no load condition.

Vibration characteristics of the complex vibration systems

Free admittance loops of the 130 kHz and 180 kHz complex vibration systems (1) using a complex vibration converter with diagonal slits are shown in Fig.4. ***Quality factors*** and ***motional admittances*** of the systems are 765, 873 and 9.33 mS, 8.52 mS. The values of high-frequency 180 kHz system are larger than that of the 130 kHz system.

Transverse vibration distribution along a complex transverse vibration rod with two stepped parts of the 40 kHz system (2) is shown in Fig.5. The vibration rod vibrates in transverse vibration mode with four vibration nodes. Vibration velocity at the welding tip increases four times compared with driving position due to the two stepped parts.

Longitudinal vibration velocity distributions along the longitudinal vibration disks 20 mm and 13 mm in thickness and the welding tips of the 100 kHz complex vibration systems (3) measured at the side surface of the disk is shown in Fig.6.

Vibration loci of the welding tips of (1) the vibration systems of 128 kHz and 180 kHz, (2) the transverse vibration system, and (3) the vibration system with a disk in the cases where (a) the complex vibration system is driven using a three-amplifier-system driving equipment and (b) using a one power-amplifier-system equipment are shown in Fig.7. The vibration loci are elliptical to almost near to circular and the loci are sufficiently effective for ultrasonic welding.

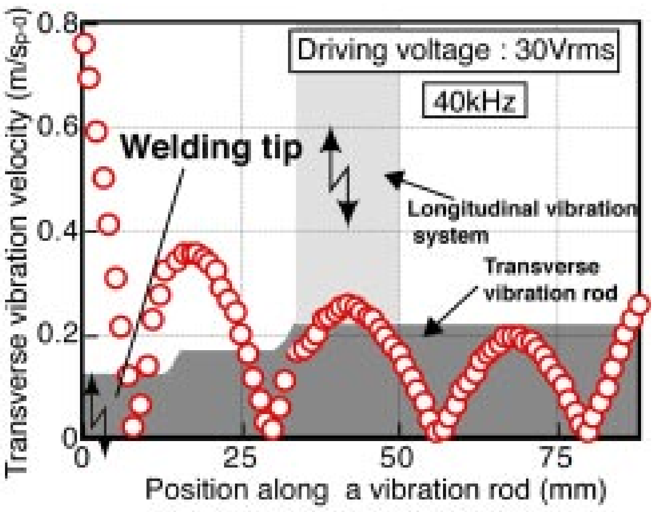


Figure 5: Transverse vibration velocity distribution along a 40 kHz stepped complex transverse vibration rod driven by two longitudinal vibration systems.

Several electronic elements welded using the complex vibration systems.

Figure 8 shows (a) a welded tip resistor on solder coated copper substrate, (b) a cross section of a tip resistor di-

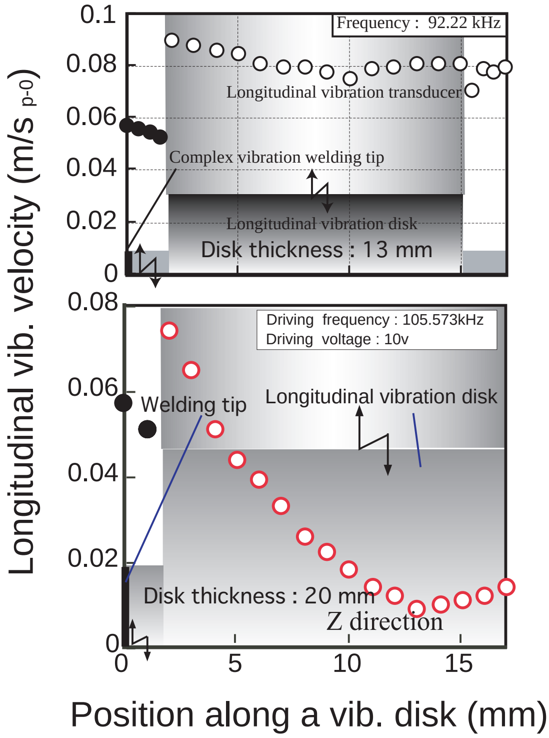


Figure 6: Longitudinal vibration distribution along the outer surface of the longitudinal vibration disk and the welding tip at the center of the disk.

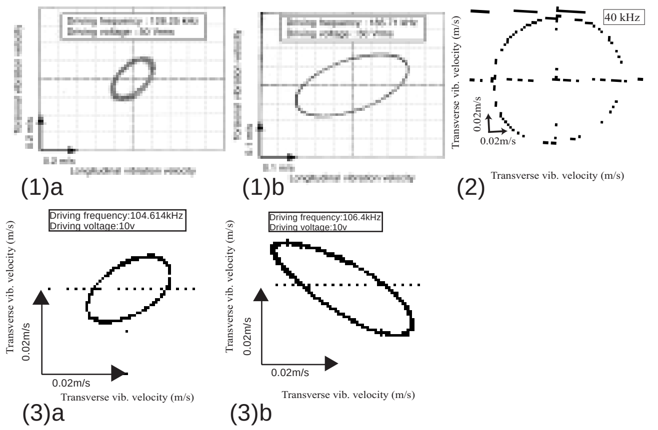


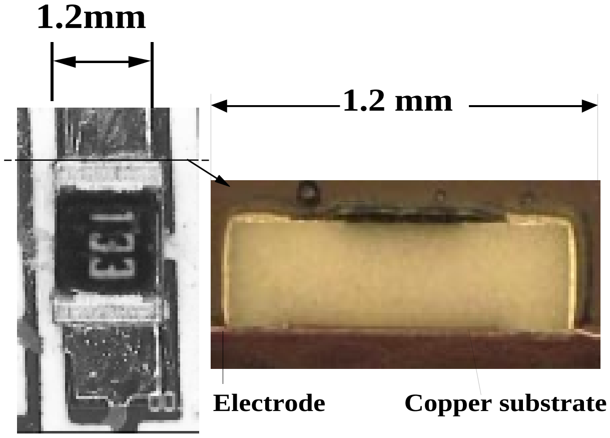
Figure 7. Vibration loci of (1) a welding tip of (a) the 128 kHz and (b) 180 kHz complex vibration system (1), (2) a welding tip of the 40 kHz complex transverse vibration rod, and (3) a welding tip of the complex vibration system (3) with a longitudinal vibration disk in the cases where the transducers are driven using one amplifier (a) and three amplifiers (3).

rectly welded on copper substrate using the complex vibration system. Electrode of the tip element was completely welded on the substrate. Figure 9 shows a welded condition of 0.5-mm-thick and 1.5-mm-wide polyester-polyimide coated flat copper wire and a nickel-plated phosphor bronze terminal.

Conclusions

Three types of ultrasonic complex vibration system with a welding tip vibrating elliptical to circular locus for packaging in microelectronics were studied.

(1)The first type systems used a complex vibration converter with diagonal slits and were driven by a longitudinal vibration source



(a) (b)

Figure 8: Welded conditions of (a) a tip resistor (1.2 mm x 2.0 mm) welded to a solder-plated substrate, (b) Cross section of a tip resistor welded to a copper substrate using a complex vibration system.

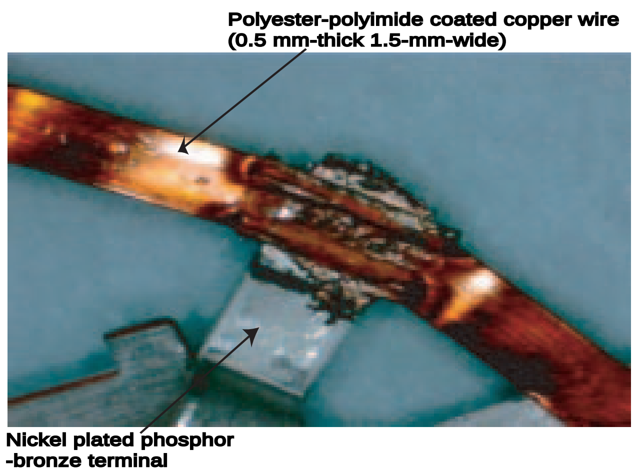


Figure 9: Welded condition of 0.5-mm-thick and 1.5-mm-thick polyester-ployimide coated flat copper wire specimens and Nickel plated phosphor-bronze terminal.

(2)The second systems used a stepped complex transverse vibration rod that is driven by two longitudinal vibration source crossed at a right angle. The large-area welding tip is installed at the free edge of the complex vibration rod. The systems of 40 kHz to 200 kHz were tested.

(3) The third type system consists of the 100 kHz and 125 kHz longitudinal vibration circular disks and six or three longitudinal transducers that are installed at the circumference of the disk. This vibration source is characterized by small vibration amplitude normal to the vibration surface (welding tip part).

It is shown that various electronic elements can be directly welded without solder (lead free) and any adhesives using the high-frequency complex vibration systems.

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