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355 nm DPSS UV laser cutting of FR4 and BT/epoxy-based PCB substrates

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Abstract

The 355 nm DPSS UV laser cutting of electronics printed circuit board (PCB) substrates including FR4, and BT/epoxy-based PCB substrates was investigated. The effects of various laser conditions such as scanning speed, assisting gas, repetition rate, and interval between scans on the heat affected zone (HAZ) and charring were studied. The quality and morphology of laser cut PCB substrates were evaluated with optical microscope, and scanning electron microscope (SEM). It was found that multi-pass cutting at high scanning speed can achieve high quality cutting with little charring. It was also found that with O_2 assist gas, a certain amount of interval time between scans and higher repetition rate led to less HAZ and less charring. High quality laser cutting of PCB substrates with no delamination, very little charring and minimum HAZ was demonstrated. The developed process has important potential applications in the electronics industry.

Keywords: Laser cutting; PCB substrate; Heat affected zone; Charring; Cutting speed

1. Introduction

It is known that electronic products such as cellular phone, digital camera, PDA, and computer are getting smaller, lighter, and thinner, whereas their functions have markedly increased. As a consequence, miniaturization, function integration, and high density interconnection are manufacturing demands in the electronics industry. These demands necessitate thinner rigid and flexible printed circuit board (PCB) substrates to be used in the electronic devices [1,2]. Therefore, the cutting of thin rigid and flexible PCB substrates is critical in the manufacturing of electronic products.

It is well known that mechanical cutting is commonly used for singulating hard and thick PCBs. But for thin PCB substrates of less than 300 μm, mechanical cutting methods encounter many problems, such as delamination, deformation, as well as frequent changes in the complex tooling and fixtures to meet the change in board design and thinner PCBs. Also, the decreasing spacing between components makes accessibility of mechanical routing difficult. Such issues create opportunities for laser cutting as a viable alternative for thin PCB substrates [3,4]. As a non-contact process, laser cutting is able to precisely cut contours with clean edges and minimum burrs. Also, there are minimum thermal and mechanical stresses which avoid delamination and distortion. Being a non-contact process, fixturing requirements would be less complex with laser cutting. It can cut various material thickness and composition in single-step process [2]. So, there is a pertinent interest and actual need for laser cutting of thin PCB substrates.

However, there are challenging issues for laser cutting of PCB substrates, which include laser-induced heat affected zone (HAZ), charring, redeposition, and residue [5]. Another difficulty stems from the fact that the fibre reinforced PCB substrate is inhomogeneous, as the glass fibre has very different thermal–physical properties from the epoxy resin. This leads to different ablation threshold energy density for glass fibre and epoxy resin.

In this paper, a systematic investigation of FR4 and BT/epoxy-based PCB substrates was conducted. The effects

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of various laser conditions on the cutting quality in terms of HAZ charring were studied. The mechanism for the reduction of HAZ and charring was discussed. The high quality laser cutting of FR4, BT/epoxy-based PCB substrates was demonstrated.

2. Experimental

The PCB substrates used in the experiments were FR4 and BT/epoxy-based PCB substrates. The sample thickness ranges from 0.1 to 0.5 mm. A Coherent Avia X 10 W Q-switched diode pumped solid state (DPSS) ultraviolet (UV) laser system was used for the experiments. The laser wavelength was 355 nm. The laser pulse frequency ranged from 10 to 100 kHz. The pulse duration of the laser beam was 20–35 ns depending on the laser pulse frequency used. The output beam profile was Gaussian shape. The spatial mode is TEM_{00} ($M^2 < 1.3$). The beam divergence is less than 0.3 mrad. The laser beam with a diameter of 3.5 mm (at $1/e^2$) was introduced to the PCB substrate using galvanometric scanner with an f-theta flat field lens achieving a spot size of 25 μm ($1/e^2$). In order to achieve good quality cutting in terms of charring and HAZ, O_2 side jet was used in the cutting process.

The morphology and cutting quality of the laser cut PCB substrates were analysed using optical microscope and scanning electron microscope (SEM).

3. Results and discussion

Fig. 1 shows the optical images of a 0.3 mm thick FR4 substrate laser cut at different scanning speeds with different pass numbers. In all cases, the cumulative speed was the same to be at 100 mm/s. Here, the cumulative speed was defined as the scanning speed divided by the pass number. As shown in Fig. 1(a), there is significant melting, charring, and HAZ along the cutting line. However, with an increase in the scanning speed but maintaining the same

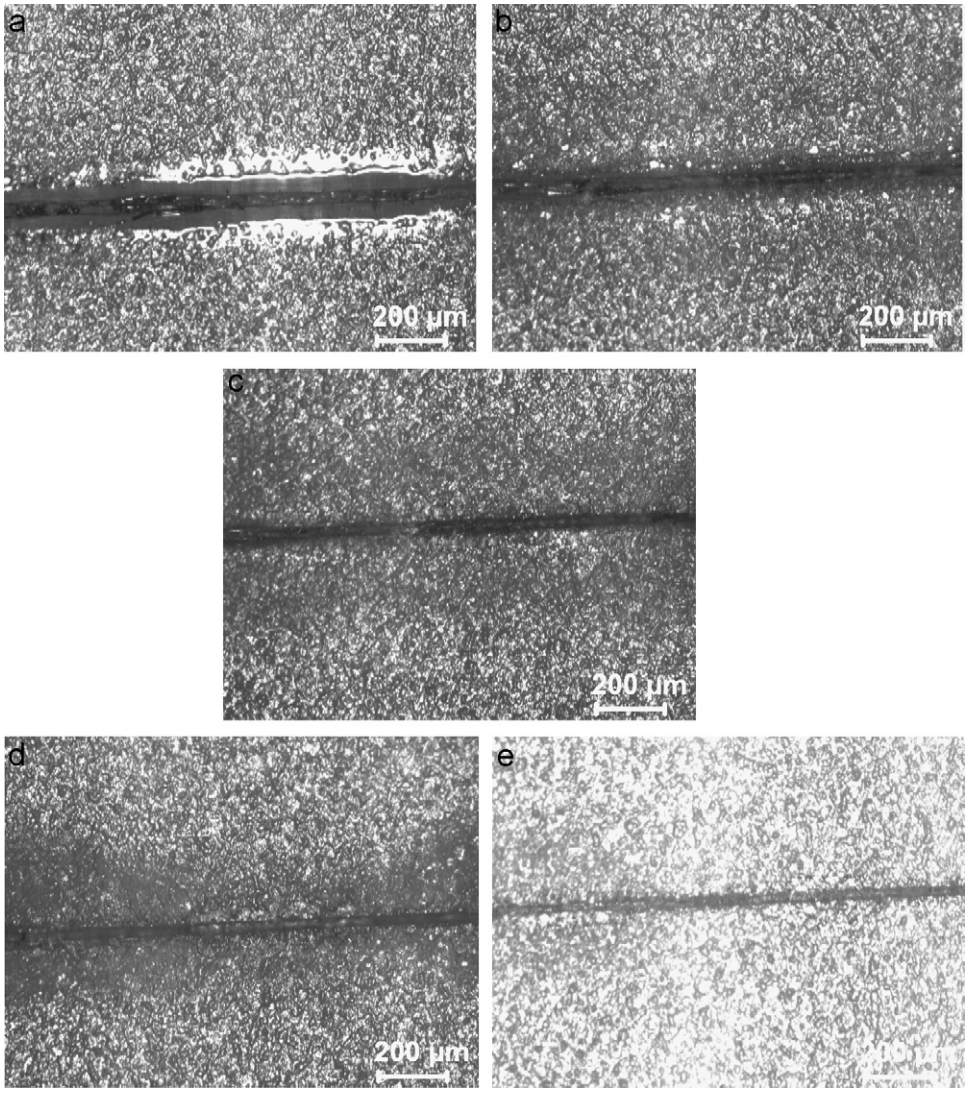

Fig. 1. Effects of scanning speed on HAZ and charring: (a) 100 mm/s for 1 pass, (b) 200 mm/s for 2 passes, (c) 500 mm/s for 5 passes, (d) 1000 mm/s for 10 passes, and (e) 2000 mm/s for 20 passes.