DESIGN OF NON-THERMAL DICING SYSTEM FOR QUARTZ WAFERS

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In the manufacturing process of light emitting diodes (LED), wafer dicing that separates fabricated chips into pieces from quartz wafer is one of the most important processes because it determines the brightness and the productivity. Traditional methods using grinding wheel and relatively long pulse lasers have been used, which, however, induce mechanical or thermal effects such as debris, crack, the heat affected zone (HAZ), and large dicing width. Here, in this paper, we designed and constructed a novel high-brightness LED wafer dicing system with minimized mechanical and thermal effects with aid of the ultrafast femtosecond pulse lasers. Thereby, mechanical and thermal effects according to various parameters of irradiated laser on quartz substrate are examined by irradiating tunable high repetition rate femtosecond laser pulses of several tens of MHz under ambient condition.

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1. Introduction

Since 2000, the market for LEDs has grown at an average annual rate over 9.0 % to reach a value of 1.6 billion USD in 2008. This growth has been driven by the novel emerging market of flat panel display, automotive, signage, amusement and lighting industry. As the whole market size increases, the improvement of the overall manufacturing process is getting more critical to meet the customer's diverse requirements. In chip production among the LED manufacturing process, the separation of fabricated chips into pieces is one of the most important procedures for high brightness of LED, which is so called wafer dicing process. Here, we present design parameters of the LED wafer dicing machine based on the interaction between ultrafast femtosecond (fs, $1/10^{15}$ s) pulse laser and a designed dicing system with minimized mechanical and thermal effects with aid of the ultrafast femtosecond pulse laser to find out contributions of design parameters to dicing quality.

2. The interaction between ultrafast femtosecond laser pulse and material

The representative factor for dicing quality is 'high brightness'. In terms of the brightness, mechanical and thermal defects of wafer dicing such as debris, cracks, and heat affected zone (HAZ) severely limits the LED performance which stem from the melting process of the target material. The conventional dicing method makes unwanted vibration and high temperature which results in residual stress, debris, cracks, and HAZ on LED wafer. Novel non-thermal laser dicing method is adopted here by using high-peak power of ultrafast fs pulses for LED wafer. Contrary to conventional thermal laser dicing, fs pulses directly convert the target material into plasma without temperature induced phase change from solid to liquid or vapour. This enables non-thermal dicing of the LED wafer without any performance degradation. Design parameters of dicing system are qualitative and quantitative aspects of physical and functional characteristics of the LED dicing machine, which can be defined through the interaction between fs laser pulse and LED wafer.

To remove atoms or molecules from a target material by laser pulses, one should deliver energy well over the binding energy of target atom or molecule. This kind of removal phenomenon in excess of the binding energy is called ablation, and it can be analyzed by two-temperature model (TTM) [1]. The ultra-short pulse irradiated material is divided into two sub systems for the TTM analysis; the electron sub-system and lattice sub-system. The TTM defines the whole ablation procedure into three steps as electron ionization, heat transfer from electron to lattice, and ion separation as shown in Fig. 1. The detailed study for each process is required to determine the design parameters. When ultra-short pulses are irradiated to a target material, the energy is firstly absorbed by electron sub-system. Then, energetic electrons escape from the parent material, which is called ionization [2]. Second step is heat transfer from the electron to the lattice sub-system. Energy transfer from the electron to the lattice sub-system by Coulomb collisions takes time less than several picoseconds. Therefore, fundamental principle of laser-material interaction changes when the pulse duration is significantly shorter than the energy transfer time. The ultra-short pulse duration (< 10 ps) implies the conventional hydrodynamics motion not to occur. The ion separation is the third step of ablation. The force of electrostatic field pulls the ions out of the material if the electron energy is larger than the binding energy of ions in the lattice [3]. Based on the interaction between ultrafast fs laser pulse and material, design parameters are deducted as repetition rate, intensity and pulse duration.

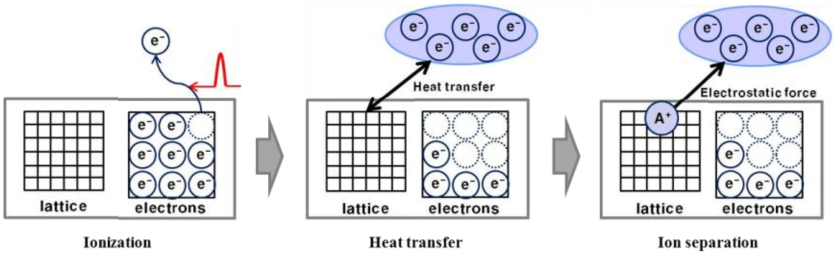

Fig. 1 Process of the interaction between ultrafast femtosecond laser pulse and material

3. Designed Dicing system

The schematic diagram of the dicing system is shown in Fig. 2. The system consists of a fiber laser oscillator, am amplifier and a grating compressor. Due to their compactness, excellent beam quality and high efficiency, Ytterbium-doped fiber laser is served as oscillator which is used a seed source for a chirped pulse amplifier (CPA) with photonic crystal fiber (PCF) for the generation of high energy pulses. The oscillator produces 20 ps pulses at 1035 nm signal wavelength with 50 MHz pulse repetition frequency and 120 mW average power. Repetition rate is controlled by acousto-optics modulation (AOM) from 1 MHz to 50 MHz and intensity is controlled by pump laser diode power in amplifier from 0 to 10 W. A grating compressor can control pulse duration in the range from 200 fs to 20 ps.

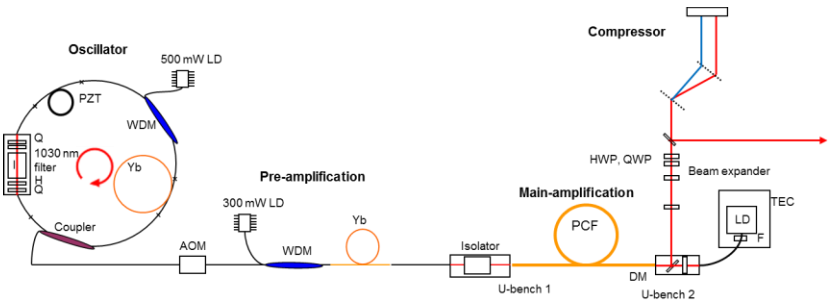

Fig. 2 Designed dicing system using ultrafast fs pulse laser

4. Conclusions

In conclusion, we deduct design parameter which is related to dicing quality from theoretical ablation mechanism then we design and construct a tunable dicing system to find out contributions of design parameters.

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