

## 学位論文の要旨

## Abstract of Thesis

研究科 School	Graduate School of Natural Science and Technology
専攻 Division	Division of Industrial Innovation Sciences
学生番号 Student No.	51426313
氏名 Name	Imaduddin Helmi Bin Wan Nordin

学位論文題目 Title of Thesis (学位論文題目が英語の場合は和訳を付記)

Micro-welding of transparent materials by picosecond pulsed laser  
ピコ秒パルスレーザーによる透明体材料の微細溶接

学位論文の要旨 Abstract of Thesis

Despite advancement in the development of ultrashort laser pulses, there are many works need to be determine in order to understand the fundamental mechanisms that govern the interaction of ultrashort laser pulses with transparent materials. The propagation of this short pulses in transparent media is great practical importance for developing a reliable direct joining technique of the material. This thesis deals with micro-welding of two kind of different material combinations involving transparent glass, which are joining of glass-glass and glass-silicon by using a picosecond pulsed laser. In direct joining of transparent materials, laser beam was focused at the interface of two materials without inserting any intermediate layer. Laser energy is deposited solely in the focal region, which leads to local melting at the interface of two materials, and the resolidification of the molten material forms strong bonds between two materials. Several authors have reported on the geometrical characteristics of the molten area, which is mostly dependent on the laser irradiation conditions. However, all these reports on micro-welding of transparent materials could not clarify the laser-matter interaction sufficiently.

In the case of micro-welding of glass material by using a picosecond pulsed laser, influence of focusing condition on micro-welding of glasses was experimentally investigated by using an objective

lens with and without spherical aberration correction, and their molten areas were characterized. Also, influence of pulse interval on the molten area characteristics was discussed. Lastly, the breaking strength of the weld bead joint was evaluated under various processing conditions. The usage of objective lens with spherical aberration correction led to a larger molten area inside the bulk material of glass even under the same pulse energy, which related to the efficient micro-welding of glass materials. In addition, an optical system with the spherical aberration led to a stable absorption of laser energy inside the bulk glass material, stabilizing the shape of molten area, which resulted in the reliable weld joint. On the other hand, breaking strength of the specimens with spherical aberration correction was higher than that without spherical aberration correction. Therefore, it is concluded that the focusing condition with spherical aberration correction led to a larger and stable molten area, which resulted in higher joining strength in micro-welding of glass materials.

On the other hand, anodic bonding technique has become the most commonly used technique for joining dissimilar material of transparent material (glass) and silicon in MEMS packaging industries. However, some limitations such as longer processing time and requirement for wide flat surface have become restrictions of this method. Therefore, direct joining technique by ultrashort laser pulses was introduced to overcome this limitation. Influence of the processing parameters on micro-welding of monocrystalline silicon and glass was experimentally investigated, and characteristics of the molten area were discussed. Finally, the breaking strength was evaluated for the overlap weld joint with various processing condition and the optimum condition is discussed. A splash area of molten silicon around the weld bead line was obvious in the nanosecond pulsed laser. On the other hand, there was no remarkable molten splash around the weld bead line in the picosecond pulsed laser. Breaking strength of specimens with 1064 nm wavelength was higher than with 532 nm wavelength in the nanosecond laser, whereas breaking strength of laser irradiated specimen by picosecond pulse duration was higher than that by nanosecond pulse duration. It is concluded that the combination of picosecond pulse duration and infrared wavelength led to the stable molten area appearance of the weld bead and higher breaking strength in micro-welding of glass and monocrystalline silicon.