
**Application note**

# Laser cutting of silicon wafers

## Introduction

Silicon wafers are used in a number of industries including photovoltaic and semiconductor device manufacture. Both forms of silicon, mono and poly-crystalline, are produced in wafers that are typically 0.2-1.8mm thick and in diameters of 100-300mm. In the case of photovoltaic devices, these are cut from rectangular wafers that undergo further processing to produce a solar cell. For high volume manufacture, the cutting speed and yield are important factors in reducing costs.

Silicon wafers are conventionally diced into smaller individual wafers by a thin diamond saw blade before they are packaged. The problems encountered in blade dicing include chipping, kerf-loss and low productivity. Currently 532nm wavelength (frequency doubled Nd:YAG) lasers and micro-jets are used but both of these processes are slow and expensive to operate. Millisecond timescale low power pulsed Nd:YAG lasers and high beam quality continuous wave fiber lasers are also being used to cut these materials. The cut quality is poor in these cases. Micro-cracking, however can occur due to excessive heat input, which can lead to failure of some components during process down stream steps with associated reduction in yields. The length of micro-cracks can range from 15µm to 100µm depending on the laser source being used.

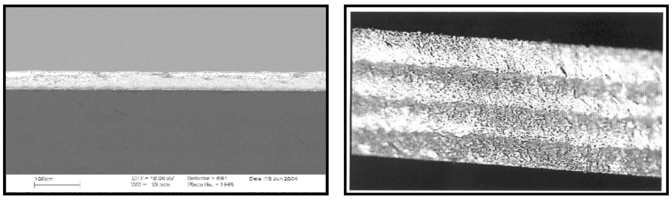
So what determines and good wafer cut? A wafer must not have corner cracks that are larger than a certain specification and must survive a 125Mpa strength test. The strength test is an automated test and is based on applying a bending force to a number of parts (typically 25) and determining the average force required to break the wafer. Generally the wafers have strengths of about 50MPa after being cut by conventional techniques, and further processing is required to etch away the micro-cracked regions around the periphery of the wafer. This typically requires 100s seconds of etching to meet the 125MPa strength requirement.

The main requirement for cutting of silicon wafers is dross free cut edges in a range of thicknesses. The cutting trials have been performed in a range of thicknesses, with two different laser sources, a high beam quality CW single mode fiber laser and a high beam quality pulsed Nd:YAG laser.
Considering the differences in beam quality and pulsed performance between the two types of laser, there are different operating regimes for each. The lamp-pumped Nd:YAG laser is characterised by long high-energy pulses but poorer beam quality, and the fibre laser with high repetition rate on-off type modulation, single-mode beam quality but with low pulse energies. From an applications perspective, both these regimes have their advantages and are discussed in the following sections.

## Results

### SM Fiber laser:

GSI Group Laser Division have introduced its new range of Industrial fiber lasers to complement its JK Nd: YAG based industrial processing lasers for cutting, welding and drilling. The SM fiber laser with its high beam quality is capable of giving a very small spot (<20µm diameter) that produces good quality cuts in a range of materials including silicon wafers. The initial cutting trials with the fiber laser, with up to 200W average power, are very encouraging in wafers up to 1mm thick in terms of cutting speed with no evidence of micro cracking. The edge quality was slightly better than that achieved with a pulsed Nd:YAG lasers because striations appeared to be several orders of magnitude less.



***400uµm thick polyrystalline silicon material, cutting speed > 4m/min showing very good edge quality and no signs of micro-cracking***

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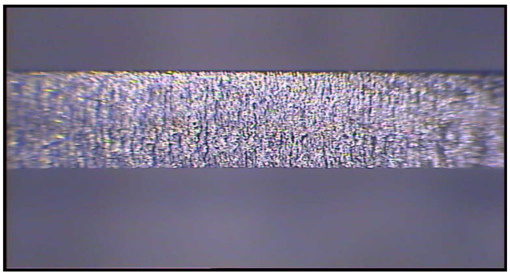
Tests were also carried out to cut thick section mono-crystalline wafers (1.8mm). The results show that it is only possible to cut this thickness with modulated output. The single mode fiber laser used in this work can also be pulsed by gating at a high frequency (20 kHz) and pulse widths as short as 5µs can be achieved. With CW output the cut quality was poor in terms of micro-cracking because of excessive heat input. With the modulated output there was no sign of micro-cracking but the cut edge quality was not as good as the thin sections, indicating that the power density at the work-piece is not sufficient to give a clean cut.

The table below highlights typical cutting speed achieved with SM fiber laser for several thicknesses of mono and polycrystalline silicon wafers.

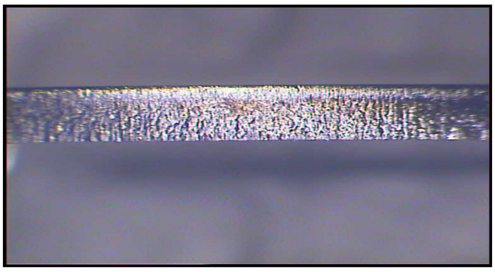
| Material | Thickness (mm) | Laser power (W) | Cutting speed (m/min) |
|---|---|---|---|
| Poly Si | 0.25 | 100 | >3.5 |
| Poly Si | 0.3 | 100 | >3.0 |
| Mono Si | 0.4 | 100 | >2.5 |
| Mono Si | 1.0 | 200 | >1.5 |
| Mono Si | 1.8 | 200 | >0.2 |



*2mm thick monocrystalline silicon material, cutting speed >0.15m/min, very smooth cut edge and no signs of micro cracking*

## JK100P (Pulsed Nd: YAG Laser)

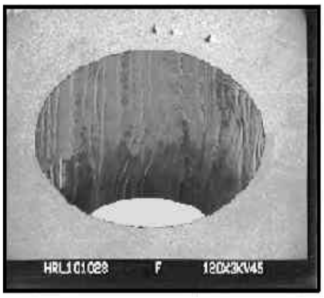
The combination of high peak power (10kW), short pulses (15-200µs) and high repetition rates (2000Hz) makes this laser ideal for cutting thick sections of silicon wafers. Cutting results show that very smooth cut edges with no micro- cracking can be achieved with this laser. Compared to the SM fiber laser, the cut quality of the thick sections is much better due to the increased pulse energy and peak power.



*1.4mm thick monocrystalline silicon material, cutting speed >0.3m/min, very smooth cut edge with no signs of micro cracking*

The JK100P pulsed laser can also be effectively used for scribing or drilling holes in silicon wafers.

***Percussion drilled hole in 2mm thick monocrystalline silicon material***




The table below highlights typical cutting speeds achieved with the JK100P for various thicknesses of mono– and poly- crystalline silicon wafers.

| Material | Thickness (mm) | Laser power (W) | Cutting speed (m/min) |
|---|---|---|---|
| Poly Si | 0.25 | 80 | >2.7 |
| Poly Si | 0.4 | 80 | >1.2 |
| Mono Si | 0.5 | 80 | >0.8 |
| Mono Si | 0.6 | 80 | >0.65 |
| Mono Si | 0.8 | 100 | > 0.5 |
| Mono Si | 1.0 | 100 | >0.4 |
| Mono Si | 1.4 | 100 | >0.3 |
| Mono Si | 2.0 | 100 | >0.15 |

## Conclusions

Both SM fiber and pulsed Nd: YAG lasers can be used to cut mono– and poly- crystalline silicon material. Results show that the SM fiber is very good for producing very smooth cut edges with no microcracking in thin sections <1.0mm whereas JK100P is very good for cutting thicker sections of the wafer, up to 1.8mm.

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