Stealth laser dicing engine lineup

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Abstract

Stealth dicing (SD) technology, centered around flash memory (for which ultra-thinning has been progressing the most) has been rapidly expanding the market for Si materials, such as RFIC for high-speed wireless communication, MEMS, etc. SD technology can be used not only for Si materials, but also for sapphire, glass, SiC, GaAs, and GaN. In principle, SD technology requires the laser beam to be guided into the inner material and focused on a arbitrary position, which means that a laser engine with a long wavelength and a high transmission rate for each material must be used. In this review, we discuss this topic in detail and present DISCO's SD engines. DISCO is the official alliance partner of Hamamatsu Photonics, and we have been given a comprehensive license for the SD technology patent portfolio of Hamamatsu Photonics. We have also been given the patent license for all the SD engines presented in this review.

1. Principle of stealth dicing

Fig. 1 shows the basic principle of stealth dicing (SD) technology[1]. In SD, a laser beam at an optically transparent wavelength is focused onto any point within a workpiece. The optical system used here is adjusted so that the energy density exceeds the processing threshold value of the target material near the focus point. Then, a modified layer (SD layer) is locally formed inside the workpiece. Because the laser beam is focused inside the material and the processing starts there, if the beam is well absorbed inside the material before reaching the focus point, a sufficient SD layer cannot be formed.

Thus, we have developed various SD engines (SDEs) suitable for specific materials. This review presents details and processing results of each SDE.

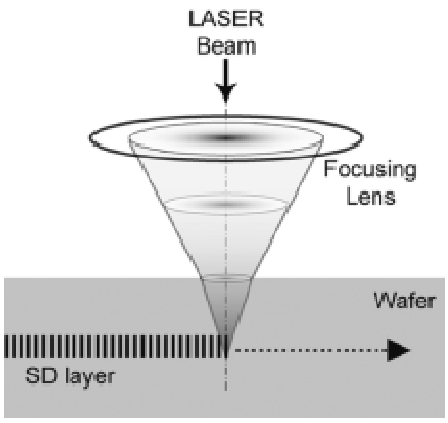


Fig.1 Formation of a modified layer by absorbing

2. SDE lineup

Each material has a specific transmission wavelength region. Fig. 2 shows the transmission wavelength regions of various materials.

The transmission rapidly starts at approximately 1000 nm in single-crystal silicon (Si). However, with the other materials, the laser beam transmits, even at the shorter-wavelength side.

Actual Si semiconductor devices are often used after impurities are doped by the ion implantation method or thermal diffusion method. With more impurities (and therefore lower resistance), the transmission region shifts to the longer-wavelength side.

There is a strong correlation between the transmission region of the material and its band-gap energy. Table 1 lists the band-gap energy of each material.

With a smaller the band-gap energy, the beam transmission range tends to be at the

Table 1 Band-gap energy of each material

Material	Band-gap energy E(eV)	Wavelength λ(nm)*1
Si	1.11	1,117
GaAs	1.43	867
4H-SiC	3.26	380
LiNbO3	3.70	335
LiTaO3	4.60	270

longer-wavelength side. Therefore, it is necessary to select an SDE having a wavelength suitable for the material to be processed.

Single-crystal Si (thickness: 780 µm) can be processed at a high speed with less energy by using the wavelength band that causes almost no absorption in Si (1150 nm or more). For this reason, we have developed SDEs having unique long-wavelength bands (SDE03 and SDE06 in Table 2). Table 2 lists SDEs that DISCO has developed and made available.

Table 2 DISCO SDE lineup

Material	SDE	Wavelength
Si	SDE01/SDE05 SDE03/SDE06	Near infrared light
Sapphire	SDE31/SDE34	Near infrared light
LiTaO3 LiNbO3 GaN Sapphire	SDE33	Visible light
Glass	SDE12	Visible light
SiC	SDE41	Visible light
GaAs InP	SDE21	Near infrared light

3. Processing examples

Processing examples using materials other than Si and sapphire, which are already well known, will be described hereinafter. The materials to be introduced here have attracted attention as cutting-edge materials for electronic and optical devices. Table 3 lists the major device applications of each material.

With blade dicing, these hard and brittle materials must be processed at a slow speed in order to minimize chipping. It is expected that high speed with high quality can be achieved by replacing blade dicing with the SD processing.

Fig. 3 shows photographs of each material processed with the SDEs in Table 2, and their processing parameters.

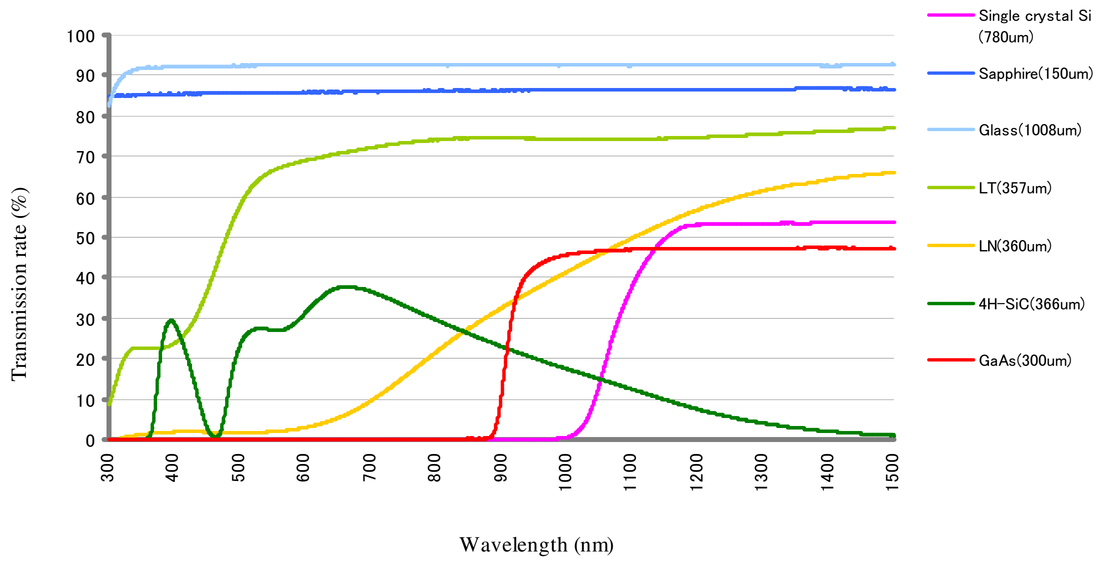


Fig.2 Beam transmission spectrum of each material

Measurement instrument: Spectrophotometer

Manufactured by JASCO Corporation

Model no.V-670

Both sides of all materials used are mirror-finished surfaces.

Transmission rates include losses due to optical reflection on the front and back surfaces of the materials.

Measured by DISCO using the measurement instrument shown at the left side.

Table 3 Major device applications of each materials

Material	Major device applications
GaAs	Hetero-bipolar transistors (HBTs) High-density backplane-mounted (HBMT) connectors Red and infrared ligt emitting diodes (LEDs) Semiconductor lasers
SiC	Power semiconductor devices Shot key barrier diodes Metal-oxide-semiconductor field-effec transistors (MOSFETs) Insulated-gate bipolar transistors (IGBTs) Blue light-emitting diodes (LEDs)
LiTaO3 LiNbO3	Surface acoustic wave (SAW) devices
Glass	Optical filters Substrates for high-frequency devices Medical applications
GaN	High-frequency devices Power semiconductors Blue light-emitting diodes (LEDs)
InP	High-electron-mobility transistors (HEMTs) Hetero-bipolar transistors (HBTs) Semiconductor lasers

4. Intellectual property rights of stealth dicing

Hamamatsu Photonics K.K. owns most of the patents relevant to the basic principle and processes of SD technology. A list of their patents can be reviewed on their official website at https://www.hamamatsu.com/jp/en/technology/innovation/sd/index.html.

Semiconductor and LED manufacturers who use SDEs not licensed by Hamamatsu Photonics and their products probably infringe these SD patents.

We have been granted a comprehensive license for the SD technology from Hamamatsu Photonics and supply our equipment to device manufacturers. By doing so, our users can manufacture and sell devices without infringing the rights of Hamamatsu Photonics (Fig. 4).

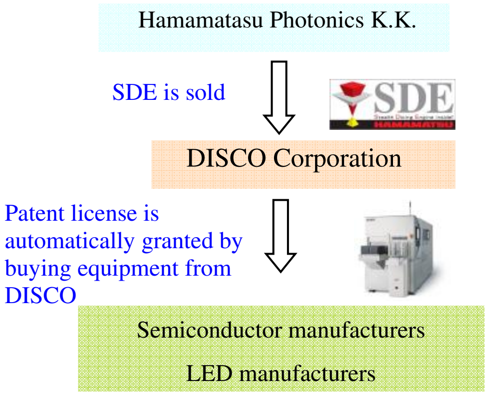


Fig.4 Patent licensing structure of the SD

5. Conclusion

SD is an innovative technology to realize further thinning of Si devices and to process materials that are difficult to process with conventional blade dicing at high speed with high quality. It is also an environmentally-friendly process that does not require deionized water, and it reduces wastewater treatment because it is a completely dry process that does not require cleaning operations during dicing.

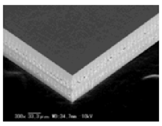
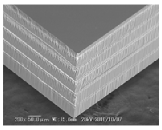
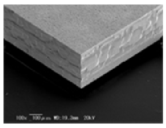
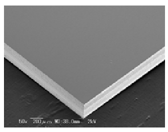
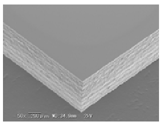
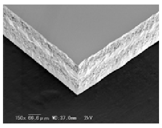
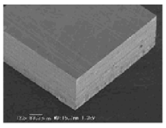
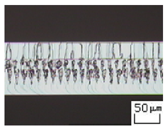
GaAs	SiC	LiTaO3	LiNbO3
 t100 um 240 mm/s×2 pass	 t250 um 350 mm/s×5 pass	 t300 um 360 mm/s×3 pass	 t300 um 360 mm/s×2 pass
Quartz glass	Borosilicate glass	GaN	InP
 t700 um 600 mm/s×8 pass	 t200 um 700 mm/s×3 pass	 t50 um 270 mm/s×6 pass	 t100 um 240 mm/s×2 pass

Fig.3 Microscope images and processing parameters of each material

This technology has been applied mainly in the field of Si materials, such as radio frequency integrated circuits (RFICs) and microelectromechanical systems (MEMS) for wireless communication, in addition to flash memories, and in the field of sapphire materials for LEDs. These markets are rapidly expanding. Both fields are now entering into the phase where further enhancement of productivity and lower costs are strongly demanded. In order to meet these demands, we are now accelerating the development of SDE.

We have also emphasized technical development for materials other than Si. We strive to ensure that our innovation will lead to higher productivity and quality than those of the existing technology, and accelerate the introduction of our new engines to the market. We have already sold our SDEs for new materials, such as glasses, lithium tantalate ($LiTaO_3$), and lithium niobate ($LiNbO_3$). The scope of applications will expand to cover even more types of materials.

References

[1] D. Kawaguchi, Hamamatsu Photonics K.K., "Application of the internal resorption type laser dicing technology for chemically tempered glass," *NEW GLASS*, Vol. 27, No. 106 (2012).

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