Feasibility Study of Layer Separation using 2D Patterned Internal Laser Damage in Silicon

Yuan Yao[a)], Andrea Vergara[*] and Shuji Tanaka
Tohoku University, 6-6-01 Aramaki Aza Aoba, Aoba-ku, Sendai, Miyagi 980-0845, Japan
E-mail: vergara@tohoku.ac.jp

a) Temporary leave from Jilin University, 5988 Renmin Street, Changchun, Jilin Province 130024, China

1. INTRODUCTION

Recently, several technologies for separation of thin films from a substrate have been developed, such as IR "LayerRelease" from EVG [1], laser lift-off from Disco [2] and TEL [3]. However, a laser-absorbing thin layer is required for all of them. Our idea is to use stealth laser dicing [4, 5] to generate a damaged layer that can be broken afterwards, by traversing a two-dimensional plane with the laser. Therefore, no special thin layer is required, and the depth of separation can be set freely. To evaluate the feasibility of the proposed technology, we have investigated the laser-damaged layer texture on square planes and the shear force required to break it using a bonding force measurement equipment.

2. EXPERIMENTS

Figure 1 explains the fabrication flow of the test samples starting from a plain silicon wafer. The first step was to use deep reactive ion etching (DRIE) to form the desired square shape. The pattern side sizes were 300 × 300 μm^2. A size larger than 500 μm will cause the breakage of the substrate during the shear force test. Next, a pulsed fiber laser of 1064 nm wavelength [5] was used to induce internal damage beneath the smooth Si surface following a two-dimensional pattern path. The laser scanning pattern is a square grid of laser scanning pitch ranging from 5 to 15μm. Then, the shear force test was conducted, as it is often used to analyze the bonding strength.

Shear force testing after stealth laser ablation can measure the quality of laser processing and be used to explore the optimization of laser scanning pitches and other processing parameters. Figure 2 and figure 3 shows the positive relationship between the shear force, F, the shear stress, τ, and the laser scanning pitch ranging from 5 to 15μm, which is conducted on a square pattern of 300 × 300 μm^2.

Figure 4 is a selection of optical and scanning electron microscope (SEM) pictures of the tested samples; (a) shows the separated layer above the laser damage, which is taken by tape; (b) shows the effect of laser ablation on the morphology on the smooth substrate surface; (c) shows the texture of the laser-damaged area on the substrate after the shear force test; and (d) shows that after the shear force test, the substrate sometimes will be partly broken.

3. SUMMARY

The feasibility of using stealth laser dicing on the two-dimensional patterned path was investigated. The relationship between laser scanning pitch and shear force/stress was measured and the morphology of the 2D laser-damaged area was analyzed. The obtained shear strengths under 100 MPa indicate that 2D stealth laser dicing may be used to develop a film separation technique.

References

[1] "IR LayerRelease™ Technology" EVGroup. www.evgroup.com/technologies/ir-layerrelease-technology /. Accessed 17 June 2024.
[2] "Laser Lift-Off" Disco. https://technology.disco.co.jp/jp/method/laser-lift-off/. Accessed 17 June 2024.
[3] "Tokyo Electron Develops an Extreme Laser Lift Off Technology That Contributes to Innovations in 3D Integration of Advanced Semiconductor Devices" TEL. https://www.tel.co.jp/news/product/2023/20231211_001.html. Accessed 17 June 2024.
[4] M. Kumagai, N. Uchiyama, E. Ohmura, R. Sugiura, K. Atsumi, and K. Fukumitsu, "Advanced Dicing Technology for Semiconductor Wafer—Stealth Dicing," IEEE Trans. Semicond. Manuf. 20, 259 (2007).
[5] Y. Izawa, Y. Tsurumi, S. Tanaka, H. Fukushi, K. Sueda, Y. Nakata, M. Esashi, N. Miyanaga, and M. Fujita, "Debris-Free High-Speed Laser-Assisted Low-Stress Dicing for Multi-Layered MEMS," IEEJ Trans. SM, Vol.129, 63 (2009).

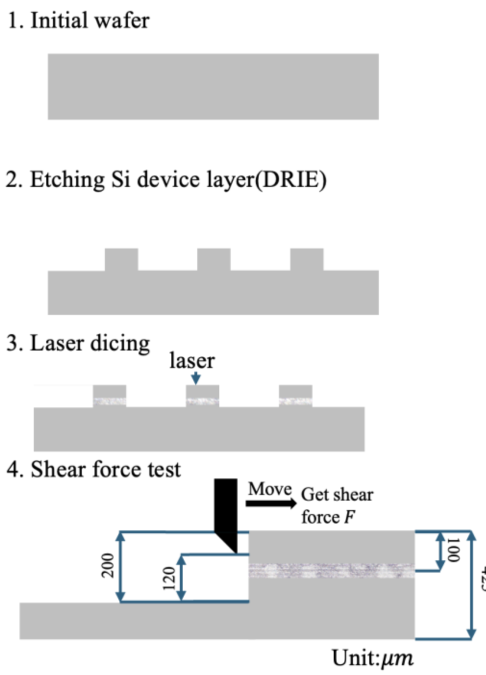

Fig.1 Experimental flow

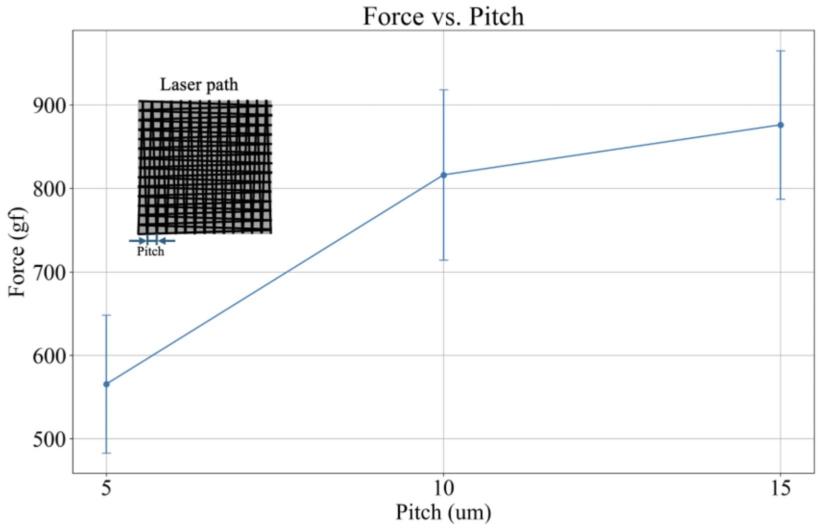

Fig. 2 Shear force (F) for pitches ranging from 5 to 15µm

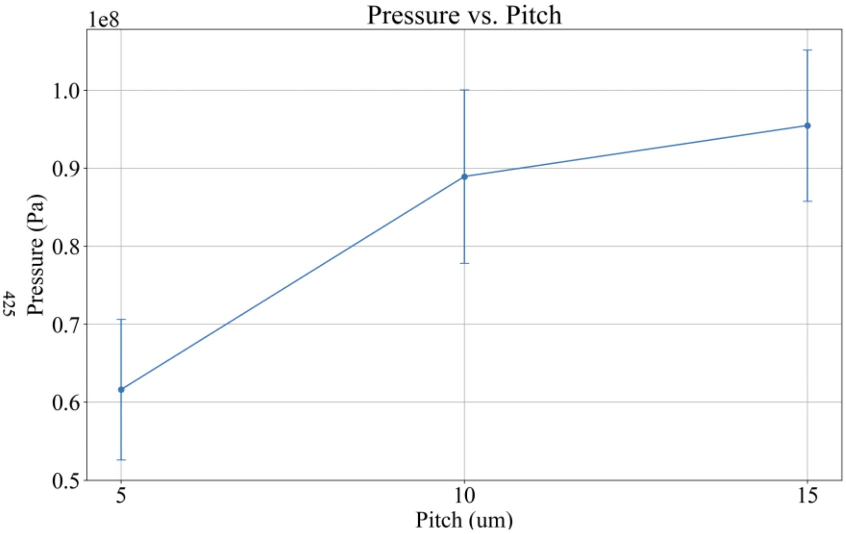

Fig. 3 Shear stress (τ) for pitches ranging from 5 to 15µm

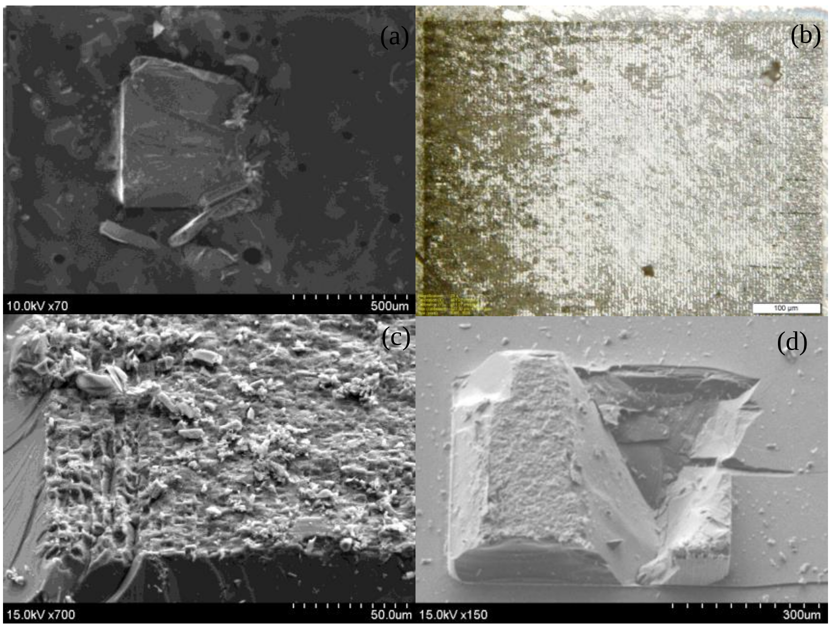

Fig. 4 Pictures of the surface after laser dicing and shear force testing