High-Speed Ultrashort Pulse Laser Dicing of 4H-SiC via Polygon Scanner

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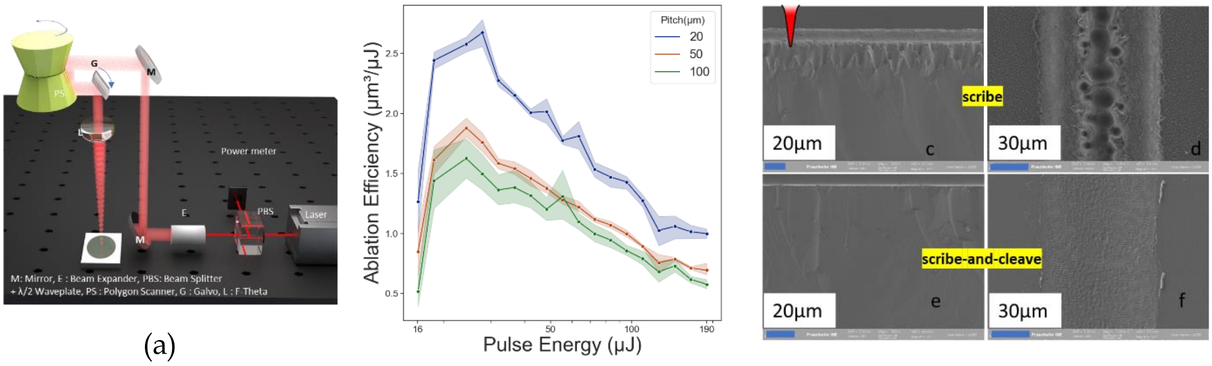
4H-silicon carbide (4H-SiC) based power electronics are pivotal for the transition to e-mobility, efficient energy distribution and storage [1]. Their superior properties compared to silicon, including a wider bandgap, higher thermal conductivity, and mechanical robustness, have driven widespread adoption but also present challenges in the semiconductor production chain. Consequently, laser micromachining has become indispensable in the SiC- device production. The combination of ultrashort pulsed lasers with high average power and pulse repetition rates (PRR), coupled with fast beam polygon mirrors (speed > 1 km/s), has been shown to improve the throughput by a factor of 7 [2]. One concomitant effect of such processes is thermal incubation, which can detrimentally affect the precision of the laser process and the end device. However, for hard-to-machine materials like 4H SiC (E_g= 3.2eV and thermal conductivity $280\mathrm{Wm^{-1}K^{-1}}$), increasing the thermal budget may reduce the threshold and enhance throughput—a novel approach not explored in prior studies. In this paper, we demonstrate polygon scanner-driven laser dicing of 4H-SiC (Fig. 1a). The experiments were performed on the Si-face of an EPI-ready n-type 4H-SiC substrate (thickness=350 μm), utilizing a commercial ultrafast laser system (AMPHOS 2000, λ=1030nm, τ=0.9-15 ps, maximum average power = 200 W) and a polygon scanner (Hochschule Mittweida). The effective laser beam waist and the modification threshold were determined via Liu fit to be ≅ $20\mu\mathrm{m}\ 1/e^2$ and $1.82\mathrm{J/cm^2}$ respectively [3]. Lines were scribed along the <1120> direction with constant τ (3 ps) and PRR (1 MHz) while laser pulse energy, number of scans (n), and pulse to pulse pitch were varied based on the modification threshold. We report an increase in dicing throughput by an order of magnitude in comparison to mechanical dicing and standard ablative laser dicing [4]. We present a qualitative and quantitative analysis of the microstructures, revealing the interplay of temporal and spatial distance via number of scans and scanning speed (pitch) which is crucial in minimizing the kerf loss.



(a)

Fig 1: (a) Setup Schematic (b) Ablation efficiency decline towards higher pulse energy could be attributed to redeposition and plasma shielding effects which is evident by the surface morphology of the microstructures. (c) Cross-sectional SEM image of a sample diced with laser scribe process (170 μJ/n=1000). (d) Top view shows regular ripple structure around the periphery with molten bulges in the microstructure (scribe). (e-f) Cross-sectional and top-view SEM images of the diced sample, using the hybrid scribe-and-cleave process, showing minimal kerf and burr (170uJ/n=50).

[1] Shi et al., doi: 10.1049/pel2.12524
[2] Hoppe et al., doi: 10.1002/ente.202300445
[3] Liu, J. M., doi: 10.1364/OL.7.000196
[4] Dohnke et al., doi: 10.4028/www.scientific.net/msf.821-823.520