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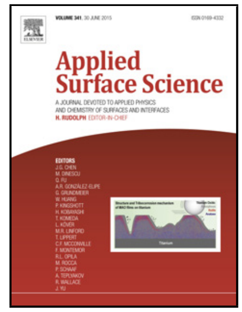

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Debris-Free Rear-Side Picosecond Laser Ablation of Thin Germanium Wafers in Water with Ethanol

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In this paper, we perform picosecond laser cutting of 150µm thin germanium wafers from the rear side. By investigating the cutting efficiency (the ability to allow a one-line cut-through) and quality (characterized by groove morphologies on both sides), the pros and cons of this technique under different conditions are clarified. Specifically, with laser fluence fixed, repetition rate and scanning speed are varied to show quality and efficiency control by means of laser parameter modulation. It is found that in our cases low-repetition rate ablation in liquid gives rise to a better cut quality on the front side than high-repetition rate ablation since it avoids dispersed nanoparticles redeposition resulting from a bubble collapse and less power input, unlike the case of 100kHz which leads to large nanorings near the grooves resulting from a strong interaction of bubbles and the case of 50kHz which leads to random cutting due to the interaction of the former pulse induced cavitation bubble and the subsequent laser pulse. Furthermore, ethanol is mixed with pure distilled water to assess the liquid's impact on the cutting efficiency and cutting quality. The results show that increasing the ethanol fraction decreases the ablation efficiency but simultaneously, greatly improve the cutting quality. The improvement of cut quality as ethanol ratio increases may be attributed to less laser beam interference by a lower density of bubbles which adhere near the cut kerf during ablation. A higher density of bubbles generated from ethanol vaporization during laser ablation in liquid will cause stronger bubble shielding effect towards the laser beam propagation and therefore result in less laser energy available for the cut, which is the main reason for the decrease of cut efficiency in water-ethanol mixtures. Our findings give an insight into under which condition the rear-side laser cutting of thin solar cells should be performed: high repetition, pure distilled water and high laser power are favorable for high-speed rough cutting but the cut kerf suffers from strong side effects of ripples, nanoredeposition occurrence, while low laser power at low repetition rate (10kHz), mixed solution (1wt% ethanol in water) and moderate scanning speed (100µm/s) are preferable for ultrafine high-quality debris-free cutting. The feasibility of high-quality cut is a good indication of using rear laser ablation in liquid to cut thinner wafers. More importantly, this technique spares any post cleaning steps to reduce the risk to the contamination or crack of the thin wafers.