Influence of a Dielectric Surface on Laser Drilling Micro-holes in Single Crystal Germanium at 1070nm wavelength using Millisecond Pulse Widths

R. McClelland[1], A.D. Johnson[2] and J. O. Maclean[1]

1- School of Physics and Astronomy, University of Nottingham, University Park, Nottingham, NG7 2RD
2- IQE Solar, IQE plc, Pascal Close, St Mellons, Cardiff, CF3 0LW.

Corresponding Author: jessica.maclean@nottingham.ac.uk

Laser pulses are used for machining metals and hard-to-machine materials such as superalloys. They are also utilised for fabricating via holes in semiconductor materials, for use in atom chips for cold atom quantum sensors [1], the thru vias of solar cells [2] and, more generally, as an alternative to semiconductor manufacturing techniques such as plasma etching, which requires complex gas-handling equipment and corrosive, high purity gases. In this paper, millisecond-long, single pulses in an air environment are shown to be successful for drilling germanium, in addition to other semiconductor substrates [3, 4]. This shows that a new regime of laser pulse parameters can be used, not only to machine micro/nano-structures on the semiconductor surface [5] but to create circular thru holes with diameters of hundreds of microns, generated by the melt-ejection material removal mechanism rather than ablation by vaporisation.

A 1070 nm wavelength Ytterbium fibre laser was used to drill micro-holes into single-crystal, 170 µm thick germanium wafer with epitaxial dielectric grown on the rear surface, using (1-10) ms pulses and powers of (300-1500) W. Hole shape, size, and the extent of micro-cracking were characterised by optical microscopy. Results for drilling onto the germanium surface and the dielectric surface were compared. For the majority of pulse powers and drilling from either side, longer pulses gave a higher exit/entrance ratio. It was found that laser micro-drilling onto the dielectric produced thru holes at lower pulse energies and gave a larger exit/entrance ratio of the hole diameter. Drilling onto the dielectric side gave the most cylindrical hole shapes, i.e. the exit/entrance ratio was closer to 1. The sphericity (ratio of the diameters in perpendicular directions) showed a clear trend as a function of pulse power for the entrance holes, but was less predictable and had a larger standard deviation for the exit holes. The dimensions of the holes were successfully controlled by varying the power and duration of the pulse and achieved dimensions in the range (90-520) µm.

[1] Jessica O. Maclean, J.R. Hodson, C. Tangkijcharoenchai, S. Al-Ojaili, S. Rodsavas, S. Coomber and K.T. Voisey (2018) Laser drilling of microholes in single crystal silicon using continuous wave (CW) 1070 nm fiber lasers with millisecond pulse widths, Lasers in Engineering, vol. 39, pp. 53-65.

[2] Booth, H. (2010) *Laser Processing in Industrial Solar Module Manufacturing.* JLMN-Journal of Laser Micro/Nanoengineering, **5**: p. 183-191.

[3] Jessica O. Maclean, C. Tangkijcharoenchai, Stuart Coomber and Katy T. Voisey (2018) Laser drilling of micro-holes in single crystal silicon, indium phosphide and indium antimonide using a continuous wave (CW) 1070 nm fibre laser with millisecond pulse widths. Procedia CIRP pp. 407-412 DOI information: 10.1016/j.procir.2018.08.158

[4] Jessica O. Maclean, Jonathan R. Hodson and Katy T. Voisey (2015) Laser Drilling of Via Micro-holes in Single-crystal Semiconductor Substrates using a 1070 nm Fibre Laser with Millisecond Pulse Widths, Proc. of Society of Photo-Optical Instrumentation Engineers (SPIE) Vol. 9657 965704-1-6 doi: 10.1117/12.2175898

[5] Manikam Sivakumar and Jun Wang (2016) Controlled fabrication of micro/nano structures on Germanium using ultrashort laser pulses under ambient conditions Advanced Materials Research *ISSN: 1662-8985,*Vol. 1136 pp. 440-445 doi:10.4028/www.scientific.net/AMR.1136.440.