Ultrashort pulse laser-induced processes for electronics and advanced chip integration

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The global market for semiconductors is expected to reach $1 trillion by 2030, up from $600 billion in 2021 [1]. Increased demand for advanced chips by artificial intelligence, vehicle electrification, and autonomous driving applications is combined with huge investments into new fabs in various countries (EU Chip Act, etc.). As Moore's law does not work anymore, increasing the performance of chips with reducing area on a wafer is possible through advances in packaging technologies.

The interaction of ultra-short laser pulses with a dielectric material is unique, with multiple non-linear effects involved. Most of them could provide benefits in manufacturing chips and electronics, and they will be more expressed with a shift to glass substrates. Millions of holes should be drilled in interposers made of silicon, glass or polymers, filled and connected with tiny metal lines for a high-speed interconnection among CPU, memory, and input/output ports to make a system on a package.

Direct ablation and femtosecond-laser-induced selective chemical etching are applied for the through glass via (TGV) formation. Challenges remain in the efficiency, quality and smaller diameters. Ultra-short pulse lasers were found to be valuable for highly selective activation of dielectric surfaces, metal seeding in an activation bath followed by electroless copper plating [2]. Narrow metal lines below 2 µm in width could be made on many plastics, glasses, ceramics and even silicon without additives in the substrate material.

The benefits of combining a few ultra-short pulse laser technologies are evident not only in moulded interconnect device (MID) manufacturing but also in the heterogeneous integration of semiconductor devices and probably, in a value chain of photonic integrated circuits. Global problems and achievements in our laboratories are discussed.

[1] O. Burkacky, M. Mancini, M. Patel, G. Poltronieri, T. Roundtree, Exploring new regions: The greenfield opportunity in semiconductors, McKinsey & Company, January 29, 2024.
[2] K. Ratautas, A. Jagminienė, I. Stankevičienė, M. Sadauskas, E. Norkus, G. Račiukaitis, Evaluation and optimisation of the SSAIL method for laser-assisted selective electroless copper deposition on dielectrics, Results in Physics, vol 16, art. 102943 (2020).