Laser Machining of Free-Standing Silicon Nitride Membranes

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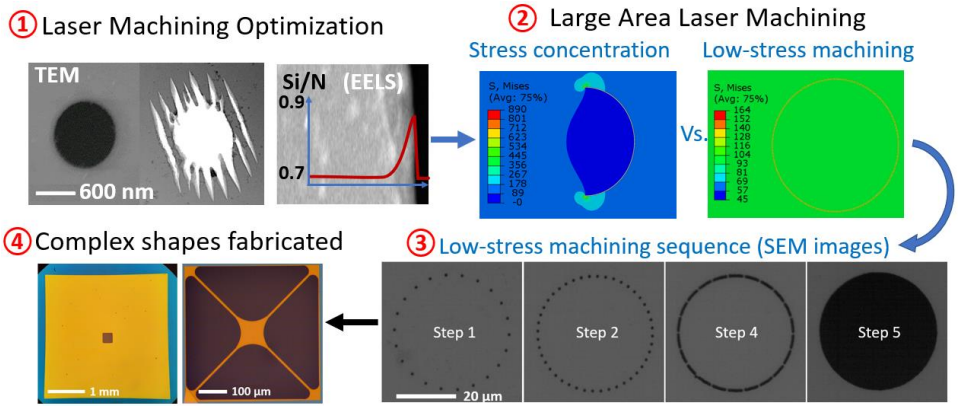
Freestanding Silicon Nitride (SiN) devices on silicon have enabled various important scientific advances in quantum resonators [1], biosensors [2], radiation detectors [3], and plasmonic devices [4]. Traditionally, the fabrication process of these devices involves expensive microfabrication photomasks that limit access to fast prototyping [5]. In this study, a maskless ultrafast pulsed laser process is demonstrated for creating micro/nano scale features directly in free-standing SiN membranes. Process parameters to avoid membrane failure are identified.

The effects of laser pulse energy and number of pulses on the morphological and chemical changes in the ablated membranes were revealed by Scanning Electron Microscopy and Transmission Electron Microscopy with Electron Energy Loss Spectroscopy. The formation of high spatial frequency laser induced periodic surface structures (HSFL) at high number of pulses was observed. Near the laser ablated area, the chemical composition (Si/N ratio) of the membrane was altered due to laser induced decomposition of the SiN membrane. The fracture toughness of the tested SiN membrane was extracted from the residual stress in the membrane and the lengths of laser fabricated lines (that act like cracks) at fracture. A "low stress" laser machining method is proposed where the laser drilling sequences is optimized to decreases stress concentration, a result confirmed by Finite Element Simulations. Using this "low stress" method, complex patterns were fabricated at millimeter scale in a fast and economical manner, with high successful rate, enabling the rapid development of new membrane designs.



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