

Femtosecond Versus Nanosecond Laser Machining: Comparison of Induced Stresses and Structural Changes in Silicon Wafers

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Abstract

Laser micromachining has proven to be a very successful tool for precision machining and microfabrication with applications in microelectronics, MEMS, medical device, aerospace, biomedical, and defense applications. Femtosecond(FS) laser micromachining is usually thought to be of minimal heat-affected zone(HAZ) local to the micromachined feature. The assumption of reduced HAZ is attributed to the absence of direct coupling of the laser energy into the thermal modes of the material during irradiation. However, a substantial HAZ is thought to exist when machining with laser shaving pulse durations in the nanosecond(NS) regime. In this paper, we compare the results of micromachining a single crystal silicon wafer using a 150-femtosecond and a 30-nanosecond lasers. Induced stress and amorphization of the silicon single crystal were monitored using micro-Raman spectroscopy as a function of the fluence and pulse duration of the incident laser. The onset of average induced stress occurs at lower fluence when machining with the femtosecond pulse laser. Induced stresses were found to maximize at fluence of 44 Jcm and 8 Jcm for nanosecond and femtosecond pulsed lasers, respectively. In both laser pulse regimes, a maximum induced stress is observed at which point the induced stress begins to decrease as the fluence is increased. The maximum induced stress was comparable at 2.0 GPa and 1.5 GPa for the two lasers. For the nanosecond pulse laser, the induced amorphization reached a plateau of approximately 20% for fluence exceeding 22 Jcm. For the femtosecond pulse laser, however, induced amorphization was approximately 17% independent of the laser fluence within the experimental range. These two values can be considered nominally the same within experimental error. For femtosecond laser machining, some effect of the laser polarization on the amount of induced stress and amorphization was also observed.

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