Investigation on Residual Stress and Subsurface Damage on 2-step Machining of Single Crystal Sapphire

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Single crystal sapphire is the material of choice in many applications ranging from optics and electronics to biomedical devices due to its superior performance under harsh environments. However, due to pronounced hardness and brittleness exhibited by sapphire, machining sapphire is a challenge. Ultra-precision machining is the preferred manufacturing process to make sapphire parts having complex geometries due to added flexibility of tool geometries and tool motions compared to abrasive processes. As the machining process entails multiple passes of the tool over a particular region of the workpiece, residual stresses and subsurface damage build up in the workpiece with each machining pass, which can lead to premature crack initiation and propagation that can hinder the functionality of the machined component. In this study, the effect of crystalline anisotropy on the formation of residual stress and subsurface damage in ultra-precision machined sapphire is investigated using Raman Spectroscopy and cutting forces are measured during machining. These measurements are then correlated to predict the activation of specific slip and fracture systems for the different cutting directions. Based on the analysis, machining strategies that minimize subsurface damage and reduce the need for post processing steps are suggested.

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Fig. 1 (a) Residual stress map across region of secondary cutting on R-plane of sapphire and (b) Variation in residual stress magnitude with depth of cut during secondary cutting on R-plane of sapphire