Fast fabrication of microlens array on single crystal Si by in-situ laser and elliptical vibration hybrid diamond cutting

Shanyi Ma[1], Yingjie Sun[1], Yujiang Lu[1], Bolong Chen[1], Cheng Hu[1], Liang Liu[1], Haoqi Luo[1], Jianguo Zhang[1] and Jianfeng Xu[1,#]

1 State Key Laboratory of Intelligent Manufacturing Equipment and Technology, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, P.R. China
Corresponding Author / Email: jfxu@hust.edu.cn

KEYWORDS: In-situ laser and elliptical vibration hybrid diamond cutting, Single crystal Si, Microlens array, Machining efficiency, Ductile remove

Microlens arrays on single crystal silicon (Si) are promising for enhancing the integration and lightweighting of advanced optoelectronic systems. However, there are still challenges of low surface quality and low machining efficiency in single crystal Si microlens array diamond cutting due to the hard and brittle properties. In-situ laser assisted diamond cutting has proven to be an effective method in the ultra-precision machining of hard and brittle materials by softening the material, improving the material ductility and suppressing the tool wear through the irradiation of in-situ laser. Besides, the elliptical vibration texturing process enables fast generation of microstructures through coupling the high-frequency vibration trajectories and the tool geometry. In this study, a method of fabricating single crystal Si microlens arrays combining in-situ laser softening and elliptical vibration texturing process is proposed for improving the material ductile machinability and processing efficiency. Firstly, a microlens arrays machined surface model was established considering the tool geometry, elliptical vibration trajectory and machining parameters. The relationship between the target profile and tool geometry, elliptical vibration trajectory, machining parameters was revealed. Then, the critical depth of cut under in-situ laser assistance for each orientation of single crystal Si was analyzed based on the helix scratching method. The maximum allowable sag of microlens without cracks in each orientation during the in-situ laser assisted diamond cutting process was calculated. Finally, the diamond cutting experiments of single crystal Si microlens arrays were carried out by an in-situ laser-vibration hybrid assisted diamond cutting system, and the microlens array was successfully fabricated on the single crystal Si in ductile mode with high efficiency. This work provides a valuable method for the fast generation of microstructure array on hard and brittle materials.