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光学元件与制造

离子束作用下的光学表面粗糙度演变研究

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摘要：

为了获得超光滑光学表面，介绍了离子束作用下改善表面粗糙度的抛光方法，并通过相关的实验进行了验证。光学材料是典型的硬脆材料，在加工过程中的表面粗糙度要经历复杂的演变过程。离子束加工作为光学镜面加工中的最后一道工序，如果在修正面形的同时，能够有效地改善表面粗糙度，那么离子束加工的性能就可以得到更好的延伸。分析了离子束作用下的粗糙度演变机理，在此基础上提出了倾斜入射抛光和牺牲层抛光技术2种改善表面粗糙度的方法，并使用原子力显微镜进行了测量。实验结果表明：以45°倾斜入射抛光熔石英样件，其粗糙度由初始的0.67nm RMS减小到0.38nm RMS；涂上牺牲层的材料表面粗糙度由0.81nm RMS减小到0.28nm RMS，倾斜入射抛光和牺牲层抛光技术能够有效地改善表面粗糙度。

关键词： 离子束抛光 光学表面粗糙度 倾斜入射抛光 牺牲层抛光技术

Optical surface roughness in ion beam process

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Abstract:

In order to obtain ultra-smooth optical surface in ion beam process, the process methods for reducing surface roughness are introduced and validated by experiments. Optical material is typical hard and brittle material, whose surface roughness evolves complicated variation in process. As the final precision machining, ion beam figuring can correct figure error and improve optical surface roughness. Based on the evolvement mechanism of surface roughness in ion beam process, the methods of obliquely incidence figuring and coating sacrificial layer technology were investigated. The surface roughness was measured by atomic force microscope (AFM). Experimental results indicate that the surface roughness was reduced from 0.67nm RMS to 0.38nm RMS when figuring fused silica sample was processed at oblique incidence angle of 45°. Similarly, the surface roughness was reduced from 0.81nm RMS to 0.28nm RMS after removing sacrificial layer. The methods of obliquely incidence figuring and sacrificial layer figuring technology can effectively improve surface roughness in ion beam figuring.

Keywords: ion beam figuring (IBF) optical surface roughness obliquely incidence figuring sacrificial layer figuring technology

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参考文献：

［1］SAVVIDES N. Surface microroughness of ion-beam etched optical surfaces［J］. Journal of Applied Physics, 2005, 97(5): 053517.1-053517.7.

［2］焦长君. 光学镜面离子束加工材料去除机理与基础工艺研究［D］.长沙: 国防科技大学, 2008.
JIAO Chang-jun. Study on material removal mechanisms and fundamental processes for ion beam figuring optical mirror［D］. Changsha: National University of Defense Technology, 2008. (in Chinese)

［3］JIAO Chang-jun,LI Sheng-yi,XIE Xu-hui.Algo-rithm for ion beam figuring of low-gradient mirrors［J］. Applied Optics, 2009,48(21):4090-4096.

［4］DRUEDING T W, BIFANO T G, FAWCETT S C. Contouring algorithm for ion figuring［J］. Precision Engineering, 1995,17(1):10-21.
［5］ALLEN L N, ROMIG H W. Demonstration of an ion figuring process［J］. SPIE, 1990,1333:22-33.
［6］INABA T, KURASHIMA Y, PAHLOVY S A, et al. Low energy ion beam machining of ULE substrates: evaluation of surface roughness［J］. Microelectronic Engineering, 2009,86(4-6):497-499.
［7］GAILLY P, COLLETTE J P, JAMAR C, et al. Roughness evolution of some X-UV reflective materials induced by low energy ion milling［J］. Nuclear Instruments and Methods in Physics Research Section B, 2004,216:201-212.
［8］FROST F, FECHNER R, ZIBERI B, et al. Large area smoothing of optical surfaces by low-energy ion beams［J］. Thin Solid Films, 2004,459(12):100-105.
［9］周林.光学镜面离子束修形理论与工艺研究［D］.长沙:国防科技大学, 2008.
ZHOU Lin. Study on theory and technology in ion beam figuring for optical surfaces［D］. Changsha: National University of Defense Technology, 2008. (in Chinese)
［10］BRADLEY R M, HARPER J M E. Theory of ripple topography induced by ion bombardment［J］. Journal of Vacuum Science & Technology A, 1988, 6(4):2390-2395.
［11］MAKEEV M A, CUERNO R, BARABASI A L. Morphology of ion-sputtered surfaces［J］. Nuclear Instruments and Methods in Physics Research Section B, 2002,197(3-4):185-227.
［12］DAI Yi-fan, LIAO Wen-in, CHEN Shan-yong, et al. Theoretical analysis and experimental study of material of material removal characteristics in ion beam figuring process［C］. Dalian: The 5th SPIE International Symposium on Advanced Optical Manufacturing and Testing Technologies, 2010.
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