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微纳技术与精密机械

超高真空精密四刀狭缝的结构原理及有限元分析

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摘要： 针对上海光源X射线干涉光刻(XIL)光束线对狭缝精度的要求，提出了一种应用于超高真空的精密四刀狭缝机构及热缓释方案。给出了四刀狭缝机构的工作原理，其四个缝片独立运动，采用线性驱动装置及精密直线导轨来实现开合。根据XIL光束线的特点，设计了一种合理有效的热缓释方案，对缝片进行了热-结构耦合分析。对狭缝的精度指标进行了测试。结果显示：该四刀狭缝的分辨率优于0.1 μm、运动重复精度优于2 μm、刀口直线度优于2.5 μm、平行度优于0.5 mrad，可以精确实现狭缝在水平和垂直方向-5～250 μm的开度，缝片在热负载下的最大热变形控制在0.034 μm。得到的结果表明，该精密四刀狭缝具有高的精度和稳定性，可满足XIL光束线的使用要求，现已实际使用并制备出了100 nm周期的刻蚀线结构。

关键词： X射线干涉光刻光束线 精密狭缝 四刀结构 重复精度 有限元分析

Principle and finite element analysis on UHV four-knife precision slits

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Abstract: To meet the requirements of X-ray Inteferometric Lithography (XIL) beamline of Shanghai Synchrotron Radiation Facility for slit precision, an Ultra High Vacuum(UHV) four-knife precision slit structure and a cooling scheme were proposed. First, the structural principle of the four-knife precision slit structure was analyzed. The movements of the slits were controlled by linear drive devices independently, and their enclosures were achieved though the precision linear guides. Then, a cooling scheme was designed according to the characteristics of XIL beamline and the thermo-mechanical coupling was analyzed to verify whether the cooling scheme was reasonable. Furthermore, the precision indexes of slits were tested. The results indicate that the movement resolution and repeatability of the slit knife are better than 0.1 μm and 2 μm, respectively, the straightness and parallelism of the knife are better than 2.5 μm and 0.5 mrad, respectively. It can also realize the opening of slits by only -5~250 μm in both horizontal and vertical directions. Moreover, the maximum thermal deformation under the thermal load is controlled under 0.034 μm. These results verify that the four-knife precision slit structure has a very high accuracy and stability, and meets the requirement of XIL beamline. By proposed slit structure and scheme, the etching line structure of 100 nm periodicity has been achieved.

Keywords: X-ray Interferometric Lithography(XIL) beamline precision slits four-slit structure repeatability precision Finite analysis element

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