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剪切增稠抛光磨料液的制备及其抛光特性

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Preparation of shear thickening polishing abrasive slurries and their polishing properties

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摘要 为了实现对工件的剪切增稠抛光(STP),采用机械混合与超声波分散法制备了一种Al_2O_3基STP磨料液,并研究了它们的抛光特性。利用应力控制流变仪考察其流变性能,通过扫描电镜和光学轮廓仪研究了单晶硅加工后表面显微组织的变化,并测量其表面粗糙度。结果表明:STP磨料液具有剪切变稀和可逆的剪切增稠特性,达到临界剪切速率后,会形成Al_2O_3"粒子簇";当剪切速率增大至1000 s^{-1},储能模量,耗能模量和耗散因子都增至最大值,此时主要表现为类似固体的弹性行为,有利于形成类似"柔性固着磨具"。在STP加工单晶硅过程中,采用塑性去除的材料去除方式。随着抛光时间的延长,硅片去除速率先增大后减小;表面粗糙度不断减小并趋于稳定。实验显示,磨粒浓度不宜过高,否则会因剪切增稠效应造成黏度过大,导致流动性差而影响抛光质量。当Al_2O_3质量分数为23%时,抛光25 min后,硅片表面粗糙度R_a由422.62 nm降至2.46 nm,去除速率达0.88 μm/min,表明其能实现单晶硅片的高效精密抛光。

关键词 : 剪切增稠抛光(STP), 剪切增稠, Al_2O_3, STP磨料液, 单晶硅

Abstract : To realize Shear Thickening Polishing (STP) for workpieces, a kind of Al_2O_3-STP slurries were prepared by mechanical mixing and ultrasonic dispersion methods and their polishing properties were investigated. The rheological properties of dispersion of STP slurries were studied by using a stress controlled rheometer. The morphologies of a Si wafer before and after STPs were also researched by a Scanning Electron Microscopy(SEM) and an optical profilometer, and their surface roughnesses were measured. Experimental results indicate that the STP slurry sytem has shear thinning and reversible shear thickening behaviors. The Al_2O_3 "cluster" would be formed as the critical shear rate is reached. When the shear rate increases to 1000 s^{-1}, the storage modulus, loss modulus and the dissipation factor are increased to a maximum value, respectively. At this time, the slurry shows the main properties of the elastic behavior like solid, which are conducive to the formation of "flexible fixed abrasive tool". In STP process, the material of Si wafer is removed by ductile mode. As extension of polishing time, the material removal rate increases quickly, but grows at a slow rate in the later period. The surface roughness decreases and tends to a stable during the STP process. Moreorer, it suggests that the abrasive concentration should not be too high, otherwise polishing quality would be affected. When the mass fraction of Al_2O_3 is 23%, the surface roughness R_a reduces from 422.62 nm to 2.46 nm and removal rate is up to 0.88 μm/min after polishing by 25 min, which indicate that it achieves high efficiency precision polishing of Si wafers.

Key words : Shear Thickening Polishing (STP) shear thickening Al_2O_3 STP slurry Si wafer

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