

MEMS 智能传感器技术的新进展（续）

赵正平 1,2

（1.中国电子科技集团公司，北京 100846； 2.专用集成电路重点实验室，石家庄 050051）

中图分类号：TP212； TH703 文献标识码：A 文章编号：1671-4776(2019)02-0085-10

New Progress of Smart Sensor Technology Based on MEMS（Continued）

Zhao Zhengping1,2

（1.China Electronics Technology Group Corporation, Beijing 100846, China;

2. Science and Technology of ASIC Laboratory, Shijiazhuang 050051, China）

DOI:10.13250/j.cnki.wndz.2019.02.001EEACC:2575;7230

具有场限环终端的 6 500 V 4H Ⅱ SiC 结势垒

肖特基二极管的研制

李嘉琳 1, 2, 桑玲 1, 2, 郑柳 1, 2, 田丽欣 1, 2, 张文婷 1, 2

(1. 全球能源互联网研究院有限公司 功率半导体研究所, 北京 102209;

2. 先进输电技术国家重点实验室, 北京 102209)

摘要: 阐述了 6 500 V 4H Ⅱ SiC 结势垒肖特基(JBS)二极管的设计、仿真和制备过程, 并对流片结果进行了测试, 分析了测试结果与仿真结果差异的原因。通过仿真对比分析了漂移区厚度、掺杂浓度、有源区 p+区和场限环终端参数对器件电学特性的影响, 数值模拟优化了器件元胞和终端结构的漂移区、有源区和场限环的结构参数。根据模拟结果, 4H Ⅱ SiC 漂移区掺杂浓度为 $1 \times 10^{15} \text{ cm}^{-3}$ 、厚度为 60 μm , 采用经过优化的 70 个场限环终端结构, 通过完整的工艺流程, 完成 6 500 V 4H Ⅱ SiC JBS 的制备。测试结果显示, 室温下当 6 500 V 4H Ⅱ SiC JBS 正向导通电流密度达到 $3 \times 10^5 \text{ A/m}^2$ 时, 正向压降为 4 V, 器件的反向击穿电压约为 8 000 V。

关键词: 4H Ⅱ SiC; 场限环终端; 结势垒肖特基 (JBS) 二极管; 功率器件

中图分类号: TN311 Ⅱ 7; TN304 Ⅱ 24 文献标识码: A 文章编号: 1671-4776(2019)02-0095-06

Development of the 6 500 V 4H Ⅱ SiC Junction Barrier Schottky

Diodes with the Field Limiting Rings Termination

Li Jialin^{1,2}, Sang Ling^{1,2}, Zheng Liu^{1,2}, Tian Lixin^{1,2}, Zhang Wenting^{1,2}

(1. Department of Power Semiconductors, Global Energy Internet Research Institute Ltd., Beijing 102209, China;

2. State Key Laboratory of Advanced Power Transmission Technology, Beijing 102209, China)

Abstract: The design, simulation and fabrication process of the 6 500 V 4H Ⅱ SiC junction barrier Schottky (JBS) diodes were presented. The performances of the fabricated diodes were tested, and the reasons of the difference between the test results and the simulation results were analyzed. The effects of the drift region thickness, doping concentration, active region p+ region and field limiting ring termination parameters on the electrical properties of the devices were contrastively analyzed by the simulation. The structure parameters of the drift region, active region and field limiting ring of the device cell and termination structure were optimized through the numerical simulation. According to the simulation results, the 4H Ⅱ SiC drift region has a doping concentration of $1 \times 10^{15} \text{ cm}^{-3}$ and a thickness of 60 μm . Besides, by using the optimized termination structure with 70 field limiting rings, the 6 500 V 4H Ⅱ SiC JBS was fabricated through the complete process flow. The test results show that the forward voltage drop is 4 V and the reverse breakdown voltage is about 8 000 V when the forward conducting current density of the 6 500 V 4H Ⅱ SiC JBS is $3 \times 10^5 \text{ A/m}^2$ at room temperature.

Key words: 4H Ⅱ SiC; field limiting ring termination; junction barrier Schottky (JBS) diode; power device

DOI:10.13250/j.cnki.wndz.2019.02.002EEACC:2560H; 2560P

n 型异质结背接触太阳能电池前表面的场钝化

高嘉庆, 宋志成, 郭永刚, 屈小勇, 张天杰

(国家电投集团西安太阳能电力有限公司, 西安 710100)

摘要: 利用 Silvaco Ⅱ TCAD 仿真软件建立二维模型, 对 n 型异质结背接触 (HBC) 单晶硅太阳能电池前表面场进行模拟研究。通过在 n 型单晶硅衬底正面分别引入一层较薄的本征非晶硅层和一层 n+非晶硅层对电池前表面进行高质量的场钝化, 分析了 n+非晶硅层的厚度和掺杂浓度以及本征非晶硅层的厚度和带隙宽度对电池电学性能的影响。模拟结果表明: 当 n+非晶硅层厚度小于 6 nm, 掺杂浓度为 $1 \times 10^{19} \text{ cm}^{-3}$, 本征非晶硅层的厚度为 3 nm, 带隙宽度大于 1.5 eV 时, 电池前表面实现了良好的场钝化效果, HBC 太阳能电池获得了 24.5% 的转换效率。

关键词: n 型太阳能电池; 异质结背接触; 前表面场; Silvaco Ⅱ TCAD; 转换效率

中图分类号: TM914.4 文献标识码: A 文章编号: 1671-4776(2019)02-0101-06

Field Passivation of the Front Surface of n Ⅱ Type Heterojunction
and Back Contact Solar Cells

Gao Jiaqing, Song Zhicheng, Guo Yonggang, Qu Xiaoyong, Zhang Tianjie

(SPIC Xi'an Solar Power Co., Ltd., Shaanxi 710100, China)

Abstract: The simulation research of the front surface field (FSF) of n Ⅱ type heterojunction back Ⅱ contact (HBC) monocrystalline silicon solar cells was carried out by using Silvaco Ⅱ TCAD simulation software to establish a two Ⅱ dimensional model. By introducing a thin intrinsic amorphous silicon layer and a n+ amorphous silicon layer on the front of the n Ⅱ type monocrystalline silicon substrate, a high quality field passivation was carried out on the front surface of the cell. The effects of the thickness and doping concentration of the n+ amorphous silicon layer and the thickness and band gap width of the intrinsic amorphous silicon layer on the electrical properties of the cell were analyzed. The simulation results show that when the thickness of the n+ amorphous silicon layer is less than 6 nm, the doping concentration is $1 \times 10^{19} \text{ cm}^{-3}$, the thickness of the intrinsic amorphous silicon layer is 3 nm, and the width of band gap is larger than 1.5 eV , a good field passivation effect is achieved on the front surface of the cell, and the conversion efficiency of the HBC solar cell is 24.5%.

Key words: n Ⅱ type solar cell; heterojunction and back contact; front surface field(FSF); Silvaco Ⅱ TCAD; conversion efficiency

DOI:10.13250/j.cnki.wndz.2019.02.003EEACC:8420

不同尺寸金纳米颗粒的制备及其 SERS 性能

蒋浩, 张霞, 李立松, 李龙, 杨文思

(上海工程技术大学 材料与工程学院, 上海 201600)

摘要: 为了研究不同尺寸的金纳米颗粒作为表面增强喇曼散射 (SERS) 活性基底对表面增强喇曼光谱的影响, 采用氯金酸作为金源, 柠檬酸三钠作为还原剂及保护剂, 通过控制柠檬酸三钠的加入量合成了不同尺寸的金纳米颗粒。通过扫描电子显微镜 (SEM) 和紫外可见分光光度计 (UV-Vis) 等技术对金纳米颗粒进行了性质表征。利用喇曼光谱仪, 以罗丹明 B 作为被检测探针, 研究了三种不同尺寸的金纳米颗粒 (20、50 和 100 nm) 喇曼增强效果。通过喇曼光谱图发现 20 和 50 nm 的金纳米颗粒具有较好的 SERS 效果。随后以 20 nm 的金纳米颗粒为 SERS 活性基底, 对表面增强喇曼光谱检测罗丹明 B 的检测限进行了研究, 可以使罗丹明检测限灵敏度达到 10^{-9} mol/L。

关键词: 金纳米颗粒; 表面增强喇曼散射 (SERS); 罗丹明 B; 检测限; SERS 基底

中图分类号: TB383 文献标识码: A 文章编号: 1671-4776(2019)02-0107-04

Preparation and SERS Properties of Au Nano Particles
with Different Sizes

Jiang Hao, Zhang Xia, Li Lisong, Li Long, Yang Wensi

(College of Materials Engineering, Shanghai University of Engineering Science, Shanghai 201600, China)

Abstract: In order to study the effects of Au nano particles of different sizes as surface enhanced Raman scattering (SERS) active substrates on SERS, the Au nano particles of different sizes were synthesized by using chloroauric acid as Au sources and sodium citrate as reductants and protectants, and by controlling the added amounts of sodium citrate. The properties of the Au nano particles were characterized by the scanning electron microscopy (SEM), ultraviolet visible spectrophotometer (UV-Vis) and so on. With rhodamine B as the test probe, the Raman enhancement effects of the Au nano particles with three different sizes (i.e. 20, 50 and 100 nm) were studied by Raman spectroscopy. Through the Raman spectra, it is found that the Au nano particles of 20 nm and 50 nm exhibit better SERS effects. Then the detection limit of rhodamine B of SERS was studied with 20 nm Au nano particles as the SERS active substrate, and the sensitivity of the detection limit of rhodamine B can reach 10^{-9} mol/L.

Key words: Au nano particle; surface enhanced raman scattering (SERS); rhodamine B; detection limit; SERS substrate

DOI:10.13250/j.cnki.wndz.2019.02.004PACC:6146

Sn 掺杂 ZnO 纳米结构湿度传感器的制备与特性

匡旭良, 叶子, 孙宁, 宋小军, 刘伟景

(上海电力学院 电子与信息工程学院, 上海 200090)

摘要: 首先采用水热法制备了四种不同 Sn 掺杂量的一维 Zn_{1-x}Sn_xO 纳米结构材料, 然后通过介电泳纳米操控技术将制备的四种纳米结构排布到预先设计的 Ti/Au 电极之间, 进而构建四种湿度传感器, 并进行传感特性测试。通过对四种传感结构的测试结果分析发现, 采用原子数分数为 3% 的 Sn 掺杂 ZnO 纳米材料构建的传感器具有较好的传感特性, 相对湿度在 11%~97% 内其最大灵敏度为 7.397%, 响应与恢复时间均为 2 s。结合湿度多层吸附理论深入研究掺杂对湿度传感特性的影响。结果表明, 通过 Sn 掺杂对纳米结构中载流子浓度以及晶格应变的调控, 可以有效改善材料的电导与表面特性, 提升 Zn_{1-x}Sn_xO 纳米湿度传感器的灵敏度、响应与恢复时间和迟滞等传感特性。

关键词: 湿度传感器; ZnO 纳米结构; 水热法; 载流子浓度; 传感特性

中图分类号: TB383; TP212 文献标识码: A 文章编号: 1671-4776(2019)02-0111-08

Preparation and Properties of the Sn Doped ZnO

Nanostructure Humidity Sensor

Kuang Xuliang, Ye Zi, Sun Ning, Song Xiaojun, Liu Weijing

(College of Electromechanical and Information Engineering, Shanghai University of Electric Power, Shanghai 200090, China)

Abstract: Four kinds of one dimensional Zn_{1-x}Sn_xO nano structure materials doped with different amounts of Sn were firstly prepared with the hydrothermal method. Then four nano structures were arranged between the previously designed Ti/Au electrodes by using dielectrophoresis nano manipulation technology. Subsequently, four kinds of humidity sensors were constructed, and the sensing characteristics were tested. By analyzing the test results of the four kinds of sensing structures, it is found that the sensor constructed with the ZnO nano material doped with Sn atom fraction of 3% has excellent sensing properties, such as the maximum sensitivity of 7.397% and response/recovery time of 2 s/2 s for the relative humidity range of 11%~97%. Based on the humidity multi layer adsorption mechanism, the influence of the doping on the humidity sensing properties was studied in depth. The results show that the conductivity and surface properties of the materials can be effectively improved by the regulation of the doping amount of Sn to the carrier concentration and lattice strain of the nano structure. Therefore, the sensitivity, response time, recovery time, hysteresis and other sensing properties of the Zn_{1-x}Sn_xO nano humidity sensors were improved.

Key words: humidity sensor; ZnO nanostructure; hydrothermal method; carrier concentration; sensing property

DOI:10.13250/j.cnki.wndz.2019.02.005EEACC:7230M; 0500

多参量微纳集成传感器

宋金龙, 何常德, 王任鑫, 薛晨阳, 张文栋

(中北大学 仪器科学与动态测试教育部重点实验室, 太原 030051)

摘要: 为了满足采煤机械工作状态在线监测在线分析系统对微纳传感系统小型化和集成化的要求, 设计了一种将压阻式振动传感器与铂电阻温度传感器集成的多参量微纳集成传感器。振动传感器由一个惯性质量块、八个梁和边框组成, 惯性质量块通过八个梁悬挂在边框上。为了减小集成传感器的面积, 铂电阻温度传感器的形状为“蛇”形。对所设计的多参量微纳传感器进行了流片加工和性能测试, 铂电阻温度传感器的灵敏度为 $1 \pm 0.04 \text{ mV}/^\circ\text{C}$, 量程为 $-20 \sim 80 \text{ }^\circ\text{C}$, 振动传感器的灵敏度为 $49 \pm 89 \text{ mV/g}$, 灵敏度幅值线性度为 $-0 \pm 33\%$, 量程为 50g 。实验结果表明, 研制的多参量微纳集成传感器满足对振动和温度信号测量的需求。

关键词: 多参量微纳集成传感器; 在线监测在线分析系统; 小型化和集成化; 压阻式振动传感器; 铂电阻温度传感器

中图分类号: TP212 文献标识码: A 文章编号: 1671-4776(2019)02-0119-07

Multi Parameter Micro/Nano Integrated Sensor

Song Jinlong, He Changde, Wang Renxin, Xue Chenyang, Zhang Wendong

(Key Laboratory of Instrumentation Science & Dynamic Measurement of the Ministry of Education,

North University of China, Taiyuan 030051, China)

Abstract: A multi parameter micro/nano sensor integrating the piezo resistive vibration sensor with the platinum resistance temperature sensor was designed to satisfy the demand of the miniaturization and integration of the micro/nano sensor system for the on line monitoring and analysis system of the working state of the mining machinery. The vibration sensor consists of a proof mass, eight beams and a frame. The proof mass was suspended on the frame through eight beams. For the sake of reducing the area of the integrated sensor, the shape of the platinum resistance temperature sensor was designed as a "snake". The designed multi parameter micro/nano sensor was fabricated, and the performances of the sensor were tested. The sensitivity of the platinum resistance temperature sensor is $1 \pm 0.04 \text{ mV}/^\circ\text{C}$ in the test range of $-20 \sim 80 \text{ }^\circ\text{C}$. The sensitivity, sensitivity amplitude linearity and test range of the vibration sensor are $49 \pm 89 \text{ mV/g}$, $-0 \pm 33\%$ and 50g , respectively. The test results show that the developed multi parameter micro/nano integrated sensor can meet the demand of the vibration and temperature signal test.

Key words: multi parameter micro/nano integrated sensor; on line monitoring and analysis system; miniaturization and integration; piezo resistive vibration sensor; platinum resistance temperature sensor

DOI:10.13250/j.cnki.wndz.2019.02.006EEACC:7230M

微通道内流动沸腾强化换热研究进展

邬智宇¹, 张伟^{1, 2}, 孙远志¹, 姜家宗¹

(1.华北电力大学 能源动力与机械工程学院, 北京 102206;

2.低品位能源多相流与换热北京市重点实验室, 北京 102206)

摘要: 针对微通道流动沸腾换热, 对润湿性和微结构强化微通道换热的最新研究进展进行了综述。总结了近年在金属和硅表面采用的表面处理技术, 包括改变微通道表面润湿性、制作出非均匀润湿性的微通道表面、改变微通道尺寸与形状及制作多孔性涂层。通过把材料科学和强化流动沸腾换热关联起来并进行对比, 找出适合相变换热的微通道表面。指出前人研究过程中出现的问题, 为今后微通道的制作设计提供理论参考的基础, 并对未来强化流动沸腾换热进行展望。

关键词: 微通道; 润湿性; 微结构; 流动沸腾; 强化换热

中图分类号: TH703; TK114 文献标识码: A 文章编号: 1671-4776(2019)02-0126-07

Research Progress on the Flow Boiling Heat Transfer

Enhancement in the Microchannel

Wu Zhiyu¹, Zhang Wei^{1,2}, Sun Yuanzhi¹, Jiang Jiazong¹

(1.School of Energy, Power and Mechanical Engineering, North China Electric Power University, Beijing 102206, China; 2.Beijing Key Laboratory of Low Grade Energy Multiphase Flow and Heat Transfer, Beijing 102206, China)

Abstract: For the flow boiling heat transfer of microchannels, the latest research progresses of the enhancement on heat transfer of microchannels with wettability and micro structure are reviewed. The surface preparation techniques used for the metal and silicon surfaces in recent years are concluded, including the change of the surface wettability of the microchannels, the fabrication of the microchannels surfaces with heterogeneous wettability, the variation of the microchannels with different shapes and sizes and the fabrication of the porous coating. Through the link of the material sciences and flow boiling heat transfer, the suitable microchannel surface for the phase change heat transfer is selected by comparison. The problems of the research of predecessors are pointed out, providing the reference theoretical basis for the fabrication and design of microchannels. Besides, the enhancement of the flow boiling heat transfer in the future is proposed.

Key words: microchannel; wettability; micro structure; flow boiling; heat transfer enhancement

DOI:10.13250/j.cnki.wndz.2019.02.007EEACC:2575

一种针对低浓度应用的高精度微型流式细胞仪

王丽平¹, 洪陵成^{1, 2}, 郭天义²

(1.河海大学 环境学院, 南京 210098; 2. 江苏德林环保技术有限公司, 南京 211101)

摘要: 微型流式细胞仪综合了流式细胞术和微流体的优势, 已成为生物医学、临床应用领域低成本的细胞检测、分析方法。微型流式细胞仪的一个新兴应用是快速检测低浓度的细胞或粒子。基于一种集成了片内光束整形和微流体通道的微加工芯片, 自主设计搭建了一种微型流式细胞仪。利用该微型流式细胞仪进行了实时微珠计数实验, 实验结果表明微珠通量与样品的体积流量、样品浓度之间的线性相关系数均大于 0.99。高线性结果验证了这种微型流式细胞仪的高精度计数功能, 使其成为低浓度应用的理想选择, 如检测食物或水中的病原体。

关键词: 微型流式细胞仪; 微流体; 光学-微流体集成器件; 一维水动力学聚焦; 微珠计数

中图分类号: O35; TH703 **文献标识码:** A **文章编号:** 1671-4776(2019)02-0133-07

A High Accuracy Micro Flow Cytometer for Low Concentration Applications

Wang Liping¹, Hong Lingcheng^{1,2}, Guo Tianyi²

(1.School of Environment, Hohai University, Nanjing 210098, China;

2.Jiangsu Delin Environmental Protection Technologies Co., Ltd., Nanjing 211101, China)

Abstract: The micro flow cytometer, which combines the advantages of the flow cytometry and microfluidic, becomes the low cost detection and analysis method of the biomedicine and clinic application fields. A newly developing application of the micro flow cytometer is the fast detection of the cells or particles with the low concentration. The micro flow cytometer was self designed and built based on a micro fabricated chip that integrated on chip beam shaping and microfluidic channels. The experiment of counting micro beads in real time was carried out with the micro flow cytometer. And the experiment results show that the linearity correlation coefficients of the micro beads flux against the volume flow and concentration of the sample are over 0.99. The high linearity results prove the high accuracy counting function of the micro flow cytometer, thus making it a promising candidate for low concentration applications, such as the detection of pathogens in food or water.

Key words: micro flow cytometer; microfluidic; photonic microfluidic integrated device; 1D hydrodynamic focusing; micro beads counting

DOI:10.13250/j.cnki.wndz.2019.02.008 **PACC:**0340G; 0710C

沉积温度及热处理对 AZO 纳米叠层
薄膜性能的影响

丁铮, 关钧, 端木庆铎

(长春理工大学 理学院, 长春 130022)

摘要: 采用原子层沉积技术 (ALD) 在石英片和 n 型(100)Si 上沉积高阻氧化锌铝 (AZO) 纳米叠层薄膜, 通过扫描电镜 (SEM)、原子力显微镜 (AFM) 和 X 射线衍射仪 (XRD) 和体积表面电阻率测试仪对薄膜的表面形貌、晶体结构及电学性能进行表征分析, 分别研究了不同沉积温度及退火温度对薄膜结构及性质的影响。研究表明 AZO 薄膜存在最优的生长温度窗口为 170~200 °C, 同时发现, 经过退火处理的薄膜电阻率明显增大, 且适当的退火有助于薄膜结构的优化, 经过 400 °C 下退火 4 h 后的薄膜电阻趋于稳定, 可作为微通道板 (MCP) 打拿极高阻导电层材料。

关键词: 微通道板 (MCP); 氧化锌铝(AZO)纳米薄膜; 原子层沉积 (ALD); 热处理; 电学特性

中图分类号: TB383; TN304.26 文献标识码: A 文章编号: 1671-4776(2019)02-0140-05

Effects of the Deposition Temperature and Heat Treatment on
Properties of AZO Nano Laminated Films

Ding Zheng, Guan Jun, Duanmu Qingduo

(School of Science, Changchun University of Science and Technology, Changchun 130022, China)

Abstract: The high μ resistance aluminum zinc oxide (AZO) nano laminated films deposited on the quartz and n μ type (100) Si by atomic layer deposition (ALD) technology. The surface morphology, crystal structure and electrical properties of the films were characterized and analyzed by the scanning electron microscopy (SEM), atomic force microscope (AFM), X μ ray diffraction (XRD) and volumetric surface resistivity tester. The effects of different deposition temperatures and annealing temperatures on the structure and properties of films were researched, respectively. The results show that the optimal growth temperature window of the films is from 170 °C to 200 °C. In the meantime, it is found that the resistivity of the annealed films significantly increases, and the appropriate annealing is helpful to optimize the structure of the thin films. The resistance of the films tends to be stable after annealing at 400 °C for 4 h. The film can be used as the dynode high μ resistance conductive layer material for the microchannel plate (MCP).

Key words: microchannel plate(MCP); aluminum zinc oxide(AZO) nano μ film; atomic layer deposition(ALD); heat treatment; electrical property

DOI:10.13250/j.cnki.wndz.2019.02.009EEACC:2520E; 2550A

隔膜式压电驱动器的制备及其在微泵中的应用

张成功, 李以贵, 王欢

(上海应用技术大学 理学院, 上海 201418)

摘要: 利用块材钛酸锆铅 (PZT) 材料的逆压电效应设计并制备了可用于微泵驱动的压电驱动器, 通过 5 种结构模型的仿真分析确定了压电驱动器的隔膜式结构, 在获取较大中心位移的同时有效提高了结构强度, 增加了驱动器的适用性。工艺上通过键合、减薄、激光烧蚀及硅的湿法刻蚀工艺完成了器件的制备, 施加频率 10 Hz 和 100 Hz 的交变信号测出了中心膜片位移与对应电压的关系, 施加峰峰值为 1 V 的信号测得共振频率为 70 kHz。基于制备的压电驱动器设计并制备了机械式带止回阀的微泵, 经测试泵入、泵出功能正常。当对微泵外加峰峰值为 30 V、频率为 500 Hz 的驱动电压信号时, 每分钟能驱动的液体流量为 55 μ L。该驱动器的驱动效果好, 可进一步结合不同的微阀设计制备性能更加优良的微泵。

关键词: 块材钛酸锆铅 (PZT); 压电驱动器; 微泵; 微加工技术; 微电子机械系统 (MEMS)

中图分类号: TH137; TH703 文献标识码: A 文章编号: 1671-4776(2019)02-0145-06

Preparation of the Spacer Film Piezoelectric Actuator and

Its Application in the Micro μ Pump

Zhang Chenggong, Li Yigui, Wang Huan

(College of Science, Shanghai Institute of Technology, Shanghai 201418, China)

Abstract: A piezoelectric actuator that can be used for micro μ pump driving was designed and fabricated by the inverse piezoelectric effect of the bulk zirconate titanate (PZT) material. The spacer film structure of the piezoelectric actuator was determined by the simulation analysis of five kinds of structural models. While obtaining a large center displacement, the structural strength was effectively improved, and the applicability of the actuator was increased. The actuator was fabricated by bonding, thinning, laser ablation and silicon wet etching process. The alternating signals with the frequency of 10 Hz and 100 Hz were applied to measure the relationship between the displacement of the central diaphragm and the corresponding voltage. Besides, a resonant frequency of 70 kHz was measured by applying a signal with a peak to peak value of 1 V. Based on the prepared piezoelectric actuator, a mechanical micro μ pump with a check valve was designed and fabricated, and the pumping function of the micro μ pump was tested normally. When a driving voltage signal with a peak to peak value of 30 V and a frequency of 500 Hz was applied to the micro μ pump, the flow of the liquid that could be driven per minute was 55 μ L. The actuator has a good driving effect, and can be combined with different micro μ valve designs to prepare a micro μ pump with better performances.

Key words: bulk zirconate titanate (PZT); piezoelectric actuator; micro μ pump; micromachining technology; micro μ electromechanical system (MEMS)

DOI:10.13250/j.cnki.wndz.2019.02.010EEACC:2575

表面活性剂复配对蓝宝石 CMP 后清洗效果的影响

韦嘉辉^{1, 2}, 周海², 高晗², 梁志强³

(1. 江苏大学 机械工程学院, 江苏 镇江 212013; 2. 盐城工学院 机械工程学院, 江苏 盐城 224051; 3. 北京理工大学 机械工程学院, 北京 100081)

摘要: 为了去除蓝宝石化学机械抛光 (CMP) 后表面残留的抛光液, 采用表面活性剂复配清洗法, 选用非离子表面活性剂脂肪醇聚氧乙烯醚 9 (AEO9) 和阴离子表面活性剂脂肪醇聚氧乙烯醚硫酸钠 (AES) 按不同质量比复配, 并与酸碱清洗法进行了对比。对 CMP 后的蓝宝石进行超声辅助清洗实验, 分析了不同复配比对于蓝宝石晶片清洗后表面接触角、表面形貌以及颗粒去除率的影响。结果表明: 表面活性剂复配清洗法的清洗效果优于传统的酸碱清洗法, 最优配比的表面活性剂复配清洗法的颗粒去除率较酸碱清洗法提升了 31% | 17%; 当表面活性剂复配清洗法中 AEO9 与 AES 复配比为 1 : 1 时, 清洗后的蓝宝石表面接触角最小, 为 21° | 6°, 表面形貌最优, 颗粒去除率达到 99% | 65%, 清洗效果最好。

关键词: 蓝宝石; 化学机械抛光 (CMP); 清洗; 表面活性剂复配; 超声波

中图分类号: TN305.2 文献标识码: A 文章编号: 1671-4776(2019)02-0151-06

Influence of the Surfactant Compounding on the Sapphire
Cleaning Effect after the CMP

Wei Jiahui^{1,2}, Zhou Hai², Gao Han², Liang Zhiqiang³

(1. School of Mechanical Engineering, Jiangsu University, Zhenjiang 212013, China;

2. School of Mechanical Engineering, Yancheng Institute of Technology, Yancheng 224051, China;

3. School of Mechanical Engineering, Beijing Institute of Technology, Beijing 100081, China)

Abstract: In order to remove the residual polishing solution on the surface of sapphire after the chemical mechanical polishing (CMP), a nonionic surfactant fatty alcohol polyoxyethylene ether (9) (AEO9) and an anionic surfactant fatty alcohol polyoxyethylene ether sulfate (AES) were used in different mass ratios, and the surfactant compound cleaning method was compared with the acid | base cleaning method. Ultrasonic | assisted cleaning tests were carried out for sapphire after the CMP. The effects of different compounding ratios on the surface contact angle, surface morpho | logy and particle removal rate of sapphire wafers after cleaning were analyzed. The results show that the cleaning effect of the surfactant compound cleaning method is better than that of the traditional acid | base cleaning method. The particle removal rate of the optimal ratio of the surfactant compound cleaning method is 31% | 17% higher than that of the acid | base cleaning me | thod. When the compounding ratio of AEO9 and AES is 1 : 1 for the surfactant compound cleaning method, the contact angle of the sapphire surface after cleaning is the smallest, i | e. 21° | 6°. Besides, the surface morphology is optimal, the particle removal rate is 99% | 65%, and the clea | ning effect is the best.

Key words: sapphire; chemical mechanical polishing (CMP); cleaning; surfactant compounding; ultrasonic wave

DOI:10.13250/j.cnki.wndz.2019.02.011EEACC:2550E

基于正交实验法的 Cu/Ta/TEOS 碱性抛光液的优化

徐奕 1,2, 刘玉岭 1,2, 王辰伟 1,2, 马腾达 1,2

(1. 河北工业大学 电子信息工程学院, 天津 300130;

2. 天津市电子材料与器件重点实验室, 天津 300130)

摘要: 研究了碱性阻挡层抛光液中各组分对 Cu、Ta 和正硅酸乙酯(TEOS)去除速率的影响。通过单因素实验分别考察了磨料、FA/O II 螯合剂、KNO₃ 和 FA/O II 表面活性剂质量分数和 H₂O₂ 体积分数对 Cu、Ta 和 TEOS 去除速率的影响, 再结合正交实验研发了磨料质量分数为 20%、FA/O II 螯合剂质量分数为 2%、H₂O₂ 体积分数为 0 || 1%, KNO₃ 质量分数为 1 || 5%、FA/O II 表面活性剂质量分数为 2%的碱性阻挡层抛光液, 该抛光液的 Cu、Ta 和 TEOS 的去除速率选择比为 1 : 1 || 47 : 1 || 65。对 4 片 12 英寸 (1 英寸=2 || 54 cm) 65 nm 铜互连图形片的 M4 层进行阻挡层抛光, 结果显示, 铜沟槽内剩余铜膜厚度约为 300 nm (目标值), 图形片表面缺陷数目在 10 颗左右, 碟形坑和蚀坑深度分别由 52 || 3 nm 和 40 nm 降至 19 || 9 nm 和 18 || 4 nm, 铜的表面粗糙度由 4 || 4 nm 降至 1 || 9 nm。

关键词: Cu/Ta/TEOS; 去除速率; 碱性阻挡层; 抛光液; 单因素实验; 正交试验

中图分类号: TN305.2 文献标识码: A 文章编号: 1671-4776(2019)02-0157-10

Optimization of the Cu/Ta/TEOS Alkaline Slurry

Based on Orthogonal Experiment

Xu Yi1,2, Liu Yuling1,2, Wang Chenwei1,2, Ma Tengda1,2

(1.School of Electronic and Information Engineering, Hebei University of Technology, Tianjin 300130, China;

2.Tianjin Key Laboratory of Electronic Materials and Devices, Tianjin 300130, China)

Abstract:The effects of the components of alkaline barrier slurry on the removal rates of Cu, Ta and tetraethoxysilane (TEOS) were researched. The effects of the abrasive mass fraction, FA/O II chelating agent mass fraction, H₂O₂ volume fraction, KNO₃ mass fraction and FA/O II surfactant mass fraction on the removal rates of Cu, Ta and TEOS were investigated with the single || factor experiment, respectively. The alkaline slurry with the abrasive mass fraction of 20%, FA/O II chelating agent mass fraction of 2%, H₂O₂ volume fraction of 0 || 1%, KNO₃ mass fraction of 1 || 5%, FA/O II surfactant mass fraction of 2% was developed by combining orthogonal experiment. The selectivity of removal rate ratio of Cu, Ta and TEOS is 1 : 1 || 47 : 1 || 65. The M4 layers of the four 12 inches (1 inch=2 || 54 cm) pattern wafers with 65 nm technology node and copper interconnect were subjected to barrier polishing. The results show that the residual copper film thickness in the copper trench is about 300 nm (target), the number of the pattern surface defects are about 10, the depths of dishing pit and erosion pit decrease from 52 || 3 nm to 19 || 9 nm and from 40 nm to 18 || 4 nm, and the surface roughness of copper reduce from 4 || 4 nm to 1 || 9 nm.

Key words:Cu/Ta/TEOS; removal rate; alkaline barrier; slurry; single || factor experiment; orthogonal experiment

DOI:10.13250/j.cnki.wndz.2019.02.012EEACC:2550E