

## Rayleigh 波与 Love 波双模式声波产生器件的建模及特性

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摘要: 针对 Rayleigh 波和 Love 波两种声波不能在同一声波器件中产生的不足, 提出了一种 Rayleigh 波与 Love 波双模式声波产生器件结构和三维建模方案。该三维建模方案用有限元分析法逼近压电基片、叉指换能器及波导层等实际器件结构和尺寸。通过一个压电基片材料为  $128^\circ$  YX LiNbO<sub>3</sub>, 波导层材料为 ZnO, 叉指换能器材料为 Al 电极的双模式声波产生器件三维模型实验, 验证了该双模式声波产生器件的可行性。实验结果表明, 在 49~51 MHz 的频率内, 该双模式声波产生器件有一个 Rayleigh 波模态解和一个 Love 波模态解, 其频率分别为 49.5 MHz 和 49.7 MHz。在 49.5 MHz 处的 Rayleigh 波只存在 Y 和 Z 方向质点位移的周期性变化, X 方向的质点位移为 0, 且 Y 方向位移与 Z 方向位移相位相差  $90^\circ$ 。在 49.7 MHz 处的 Love 波沿 X 方向传播, 且只存在 Y 方向的质点位移, 没有其他方向的质点位移, 此时 X 方向为该 Love 波的纯模方向。

关键词: 双模式; Rayleigh 波; Love 波; 三维建模; 质点位移

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Modeling and Properties of a Rayleigh Wave and Love Wave Dual Mode Acoustic Wave Generation Device

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Abstract: A Rayleigh wave and Love wave dual mode acoustic wave generation device structure and three dimensional modeling scheme were proposed in order to solve the deficiency that Rayleigh wave and Love wave can not be generated in one acoustic wave device. The finite element analysis method was used in the three dimensional modeling scheme to approximate the real device structures and sizes, such as the piezoelectric substrate, inter digital transducer and waveguide layer. By means of a three dimensional model experiment of the dual mode acoustic wave generation device with  $128^\circ$  YX LiNbO<sub>3</sub> piezoelectric substrate, ZnO thin film waveguide layer and Al electrode inter digital transducer, the feasibility of the dual mode acoustic wave generation device was verified. The experimental results show that in the frequency range of 49-51 MHz, the dual mode acoustic wave generation device has a Rayleigh wave mode solution and a Love wave mode solution with the frequency of 49.5 MHz and 49.7 MHz, respectively. The Rayleigh wave at 49.5 MHz only has a periodic change of the particle displacement in the Y and Z directions, and the particle displacement in the X direction is 0. Meanwhile, the phase difference between the Y direction displacement and the Z direction displacement is  $90^\circ$ . The Love wave at 49.7 MHz propagates along the X direction and only has the particle displacement in the Y direction, and there is no particle displacement in other directions. At the frequency, the X direction is the pure mode direction of the Love wave.

Key words: dual mode; Rayleigh wave; Love wave; three dimensional modeling; particle displacement

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## 新型阻挡层材料钌的研究进展

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摘要: 随着集成电路特征尺寸不断缩小到 14 nm 及以下, 钌凭借其低的电阻率、对铜高的依附性而被考虑替代传统阻挡层材料 Ta/TaN。但是, 钌作为阻挡层材料依然存在很多问题, 如低去除速率、容易引起铜的界面腐蚀、铜钌去除的不均匀性。针对以上问题, 主要从三个方面介绍了近几年的研究进展。首先, 介绍了氧化剂及络合剂对钌去除速率的影响; 然后, 总结了针对铜钌界面腐蚀问题的研究进展; 最后, 阐述了国内外解决铜钌去除速率选择性问题的研究进展。此外, 提出未来新型阻挡层钌的抛光液的研究应综合解决上述问题, 而非单一解决, 才能真正应用于生产领域。

关键词: 钌 (Ru); 化学机械抛光(CMP); 去除速率; 电偶腐蚀; 去除速率选择性

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Research Progress of Ruthenium as a New Barrier Material

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Abstract:As the integrated circuit feature size continuously shrinks to 14 nm and below, ruthenium (Ru) is considered to replace the traditional barrier material Ta/TaN due to its low resistivity and high dependence on copper. However, there are many problems with Ru as a barrier material, such as low removal rate, easily causing the interface corrosion of copper (Cu), and non uniformity of Cu/Ru removal. In view of the above issues, the research progress in recent years is mainly introduced from three aspects. Firstly, the effects of oxidizing agents and complexing agents on the removal rate of Ru are introduced. Then, the research progress of the interface corrosion of Cu/Ru is summarized. Finally, the research progress of the removal rate selectivity of Cu/Ru at home and abroad is described. In addition, it is proposed that the research on the new type slurry of barrier Ru in the future should focus on the comprehensive solution to the above problems, rather than a single solution, and Ru as a barrier material can be truly applied to the production field.

Key words:ruthenium(Ru); chemical mechanical polishing (CMP); removal rate; galvanic corrosion; removal rate selectivity

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## $\beta$ -Ga<sub>2</sub>O<sub>3</sub> 材料在半导体技术领域的应用现状

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摘要: 单斜晶系氧化镓 ( $\beta$ -Ga<sub>2</sub>O<sub>3</sub>)超宽带半导体材料具有优良的电学、光学特性以及较高的物理化学稳定性, 在大功率器件、紫外探测器以及气体传感器等技术领域具有巨大的应用前景, 近年来已成为国际研究的热点。概述了 $\beta$ -Ga<sub>2</sub>O<sub>3</sub> 半导体材料的特性优势。综述了 $\beta$ -Ga<sub>2</sub>O<sub>3</sub> 在功率半导体器件、紫外探测器、气体传感器、衬底材料以及 GaN 器件栅介质领域的研发和应用现状。最后, 分析了 $\beta$ -Ga<sub>2</sub>O<sub>3</sub> 材料在半导体技术领域的应用前景, 指出大功率半导体器件领域和日盲深紫外探测器领域将是未来发展的重要方向。

关键词: Ga<sub>2</sub>O<sub>3</sub>;  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> 功率器件;  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> 紫外探测器;  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> 气体传感器; Ga<sub>2</sub>O<sub>3</sub> 衬底

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Application Status of  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> Materials in  
Semiconductor Technology Fields

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Abstract: As an ultra wide bandgap semiconductor material, monoclinic gallium oxide ( $\beta$ -Ga<sub>2</sub>O<sub>3</sub>) has a huge application potential in the fields of high power devices, UV detectors and gas sensors due to its excellent electrical and optical properties and high physicochemical stability, and becomes an international research hotspot in the last few years. The material characteristic advantages of  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> are summarized. The research and application status of  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> materials in semiconductor technology fields such as the power semiconductor devices, UV detectors, gas sensors, substrate materials and gate dielectric materials for GaN devices are reviewed. Finally, the application prospects of  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> materials in above mentioned semiconductor technology fields are analyzed, and it is pointed out that the fields of high power devices and solar blind UV detectors would be the important development direction in the future.

Key words: Ga<sub>2</sub>O<sub>3</sub>;  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> power device;  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> UV photodetector;  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> gas sensor; Ga<sub>2</sub>O<sub>3</sub> substrate

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## 标矢量一体化水听器的设计

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**摘要:** MEMS 仿生矢量水听器具有体积小、刚性安装和单支定位等优点, 但是在单支水听器定位时, 常存在双边指向性造成左右舷模糊的问题。为了解决单支矢量水听器定位的问题, 设计了一种通过集成一个标量通道实现单边指向性的标矢量一体化水听器。首先, 详细介绍了标矢量一体化水听器的制备过程。然后, 通过 ANSYS 17 0 软件对标矢量敏感结构的模态进行了仿真分析, 确定了标矢量敏感单元共同的可测带宽为 20~1 000 Hz。经过耐压实验, 该标矢量一体化水听器可经受 5 MPa 的静水压力。从指向性测试可以看出标量端具有较为完整的全向指向性, 矢量端具有良好的 8 字形双边指向性, 验证了本设计的可行性。通过外场实验得出, 标量信息采集端与标准水听器信噪比皆在 40 dB 左右, 证明标量信息采集端具有良好的声音接收能力。

**关键词:** 矢量水听器; 标量水听器; 指向性; 封装; 承压测试

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Design of a Scalar and Vector Integrated Hydrophone

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**Abstract:** The MEMS bionic vector hydrophone has advantages of small volume, rigid installation, positioning by a single hydrophone and so on. However, when a single hydrophone is used to position, usually there is a problem of left right starboard ambiguity due to the dipole directivity. In order to solve the problem of a single vector hydrophone positioning, a scalar and vector integrated hydrophone was designed to realize the single side directivity by integrating a scalar channel. Firstly, the fabrication process of the scalar and vector integrated hydrophone was introduced in detail. Then, through ANSYS 17 0 software, the modal simulation analysis of the scalar and vector sensitive units was made, and the 20-1 000 Hz common measurable bandwidth of the scalar and vector sensitive units was determined. The compression test result shows that the scalar and vector integrated hydrophone can withstand the static water pressure of 5 MPa. It can be seen from the directivity test that the scalar end has a relatively complete omnidirectional directivity, and the vector end has a good "8 shape" dipole directivity, proving the feasibility of the design. Through external field experiments, it is concluded that the signal to noise ratio of the scalar information acquisition terminal and standard hydrophone are both around 40 dB, proving a good acoustic signal reception ability of the scalar information acquisition terminal.

**Key words:** vector hydrophone; scalar hydrophone; directivity; encapsulation; compression test

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基于系综 NV 色心的温度传感器关键技术

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摘要: 金刚石中的氮空位中心 (NV 色心) 具有独特的自旋特性, 且其电子自旋受周围环境如温度的影响, 从而可以通过探测 NV 色心的电子自旋态实现对温度的精密测量。在精密测量中, NV 色心的哈密顿量起重要作用, 而哈密顿量受周围环境温度的影响, 所以研究了 291~390 K 温度下系综 NV 色心的光探测磁共振 (ODMR) 信号与温度的关系。随着温度的升高, 零场劈裂 D 值逐渐减小, 并且获得 370~390 K 时零场劈裂 D 值与温度间存在斜率为-61 65 kHz/K 的线性关系, 并对 ODMR 信号进行微波调制, 这对以后实现高精度的温度场测量具有很好的应用前景, 也为研究金刚石材料的温度特性提供了很好的技术支持。

关键词: 金刚石; 氮空位 (NV) 色心; 零场劈裂 D 值; 光探测磁共振 (ODMR) 信号; 温度探测; 纳米传感

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Key Technology of Temperature Sensors Based on  
NV Center Ensembles

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Abstract:The nitrogen vacancy center (NV color center) in the diamond has unique spin characteristics and its electron spin is affected by the surrounding environment, such as the temperature, thus the temperature can be accurately measured by detecting the electron spin state of the NV color center. The Hamiltonian of the NV color center plays an important role in the accurate measurement and is strongly dependent on the surrounding temperature, therefore the relationship between the optical detected magnetic resonance (ODMR) signal of the ensemble NV color centers and the temperature in the range of 291-390 K is investigated. The results show that as the temperature increases, the zero field splitting D value gradually decreases. The linear dependence of the temperature and zero field splitting D value with the slope of -61 65 kHz/K was obtained at 370-390 K. In addition, the microwave modulation of the ODMR signal was carried out. It has a good application prospect for achieving high precision measurement of the temperature field in the future, and provides a good technology support for studying the temperature characteristics of diamond materials.

Key words:diamond; nitrogen vacancy(NV) color center; zero field splitting parameter D value; optical detected magnetic resonance (ODMR) signal; temperature detection; nano sensing

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## 谐振式光学陀螺数字锁频精度优化设计

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摘要: 环境温度等外界因素引起的互易性噪声极易改变谐振式光学陀螺中光波导谐振腔特性, 对陀螺系统测试产生极大影响。利用高精度的激光频率锁定技术对陀螺系统中的互异性噪声进行有效抑制, 提高了陀螺性能。根据谐振式光学陀螺系统工作原理, 分析建立激光器锁频闭环回路模型, 通过程控运算放大电路改变控制增益, 优化激光器电流调谐的控制精度, 实现了闭环回路锁频精度的提升与系统中的互异性噪声的抑制。通过搭建的谐振式光学陀螺系统平台测试得到, 锁频精度可提高近一个数量级, 最终成功将频率锁定精度提升至  $6 \times 10^{-3} \text{ }^\circ/\text{h}$ , 陀螺长期零偏稳定性达到  $31 \times 10^{-26} \text{ }^\circ/\text{h}$ 。

关键词: 谐振式光学陀螺; 光波导谐振腔; 激光频率锁定; 数字频率锁定; 互异性噪声

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Optimization Design of the Digital Frequency Locking Accuracy of the Resonant Optical Gyro

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Abstract: The optical waveguide resonant cavity characteristics of the resonant optical gyro are easily changed by the reciprocity noise caused by the external factors, such as the environment temperature, therefore greatly affecting the measurement of the gyro system. The performances of the gyro were improved by the effective suppression of the reciprocity noise in the gyro system with high precision laser frequency locking technology. According to the working principle of the resonant optical gyro system, the laser frequency locking closed loop model was analyzed and established. The improvement of the closed loop frequency locking accuracy and the suppression of the reciprocity noise in the system were achieved by changing the control gain of the process controlled operational amplifier circuit and optimizing the control precision of the laser current modulation. The frequency locking accuracy can be increased by an order of magnitude through the measurement with the built resonant optical gyro system platform. The results show that finally the frequency locking accuracy is successfully improved to  $6 \times 10^{-3} \text{ }^\circ/\text{h}$ , and the long term zero bias stability of the gyro reaches  $31 \times 10^{-26} \text{ }^\circ/\text{h}$ .

Key words: resonant optical gyro; optical waveguide resonant cavity; laser frequency locking; digital frequency locking; reciprocity noise

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## MEMS 陀螺仪高阶带通 $\Sigma \Delta$ 闭环检测系统设计

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摘要: 为了解决 MEMS 陀螺仪开环检测带宽窄、量程低、线性度差等问题, 设计了机电结合带通  $\Sigma \Delta$  闭环检测系统。首先设计 4 阶带通纯电学  $\Sigma \Delta$  调制器, 结合 MEMS 陀螺的机械结构, 提出机电结合闭环检测系统结构及参数获取方法。该环路采用脉冲密度反馈方式, 考虑输入热噪声、正交误差等非理想因素, 建立闭环检测系统的非理想模型。仿真结果表明: 对比开环检测, 该闭环反馈力平衡了哥氏力, 抑制了哥氏振动, 陀螺的响应位移降低了 4 个数量级, 响应速度提升了 0.6 s; 当陀螺量程为  $300^\circ/\text{s}$ 、带宽 200 Hz 时, 信噪比(SNR) 达到了 113.2 dB。基于现场可编程门阵列(FPGA)开发了 MEMS 陀螺测控系统电路并进行实际测试, 结果表明闭环检测标度因数非线性、测量范围和带宽分别提高了 4 倍、1.5 倍和 1.5 倍, 系统性能得到了有效提升。

关键词: MEMS 陀螺; 带通; 脉冲密度;  $\Sigma \Delta$  调制器; 信噪比(SNR); 正交误差

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Design of a High Order Bandpass  $\Sigma \Delta$  Closed Loop Detection System for MEMS Gyroscopes

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Abstract: In order to solve the problems such as narrow bandwidth, low range and poor linearity in MEMS gyroscope open loop detection, an electromechanical bandpass  $\Sigma \Delta$  closed loop detection system was designed. A fourth order bandpass electrical  $\Sigma \Delta$  modulator was designed firstly. A method of determining the structure and parameters of the electromechanical closed loop detection system was proposed by combing the mechanical structure of the MEMS gyroscope. A pulse density feedback was used in the loop. Considering the non ideal factors such as input thermal noise, quadrature error and so on, the non ideal model of the closed loop detection system was established. The simulation results show that compared with the open loop detection, the closed loop feedback force is effective in balancing Coriolis force and inhibiting Coriolis vibration. The response displacement of the MEMS gyroscope is decreased by 4 orders of magnitude, and the response speed is increased by 0.6 s. When the range of the gyroscope is  $300^\circ/\text{s}$  and the bandwidth is 200 Hz, the signal to noise ratio (SNR) can reach 113.2 dB. The circuit of the MEMS gyroscope measurement and control system was developed based on field programmable gate array (FPGA). The test results show that the non linearity of closed loop detection scale, measuring range and bandwidth are increased by 4 times, 1.5 times and 1.5 times, and the system performance is improved effectively.

Key words: MEMS gyroscope; bandpass; pulse density; sigma delta modulator; signal to noise ratio (SNR); quadrature error

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基于同轴式组合微喷嘴的虾卵细胞微胶囊封存

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摘要: 为探究同轴式组合微喷嘴的喷射方向性以及制备虾卵细胞微胶囊时的封存效率, 搭建了以电磁铁为驱动器的微流体数字化脉冲驱动控制喷射平台, 并通过 COMSOL Multiphysics 5

3 建立二维仿真模型, 对同轴式组合微喷嘴及单微喷嘴内的微粒运动状态进行了对比仿真。仿真结果表明同轴式组合微喷嘴中的内喷嘴对喷射的粒子流有明显的限制作用, 并在以铬粉为主体材料的粉体喷射实验中得到验证。在此基础上, 探究了驱动电压及微喷嘴尺寸对水相微液滴直径和虾卵细胞封存效率的影响规律, 以及亲疏水性对同轴式组合微喷嘴喷射效果的影响。结果显示所获得的水相微液滴的直径正比于微喷嘴出口尺寸和系统驱动电压, 通过改变微喷嘴出口尺寸和系统驱动电压的大小, 获得了直径为 500~1 500  $\mu\text{m}$  的水相微液滴; 使用经过疏水化处理后的同轴式组合微喷嘴制备的虾卵细胞微胶囊, 其粒径均匀, 单细胞封存率可达 84%。

关键词: 微流体数字化脉冲驱动控制; 微喷嘴; COMSOL Multiphysics 仿真; 虾卵细胞; 疏水化处理

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Encapsulation of Shrimp Oocyte Microcapsules Based on

Coaxial Combined Micro Nozzles

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Abstract: A micro fluidics digital pulse driving and control jet platform with the electromagnet as the actuator was built in order to investigate the jet directivity of the coaxial combined micro nozzle and the encapsulating efficiency of preparing shrimp oocyte microcapsules. Then, based on COMSOL Multiphysics 5 3 simulation model, the two dimensional simulation model was built. By using the model, the comparison simulations of the motion state of particles in the coaxial combined micro nozzle and single micro nozzle were carried out. And the results show that the inner nozzle of the coaxial combined micro nozzle has a significant limiting effect on the jetted flow of particles, which is verified in the powder jet experiment using chromium powder as the main material. On this basis, the effect rules of the driving voltage and the size of the micro nozzle on the aqueous phase micro droplet diameter and the encapsulating rate of the shrimp oocytes were investigated. Besides, the influence of the hydrophilic hydrophobic property on the jet effects of coaxial combined micro nozzles was researched. The results show that the diameter of the obtained aqueous phase micro droplets is proportional to the outlet size of the micro nozzle and the driving voltage of the system. By adjusting the outlet size of the micro nozzle and the magnitude of the system driving voltage, the aqueous phase micro droplets with the diameter of 500-1 500  $\mu\text{m}$  were obtained. The microcapsules of shrimp oocytes prepared by coaxial combined micro nozzles with hydrophobic processing are uniform in the particle diameter, and the single cell encapsulating rate reaches 84%.

Key words: digital pulse driving and control of micro fluids; micro nozzle; COMSOL Multiphysics simulation; shrimp oocyte; hydrophobic processing

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原子力显微镜电场辅助纳米沉积加工

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摘要: 主要研究了基于原子力显微镜(AFM)的场蒸发沉积加工方法, 分析了影响沉积加工的因素。通过选择适当的针尖和样品间的距离、加工电压和探针运动速度等参数, 实现了纳米点、纳米线及纳米字符等纳米结构的加工。纳米点加工中, 加工参数保持不变, 纳米点的高度变化不大, 平均高度约为 1~5 nm。纳米线加工中, 通过改变加工电压和探针运动速度, 加工得到了不同高度的纳米线, 其高度最小约为 1~5 nm, 最高可达 65 nm。总体上, 沉积加工重复性、可控性较好。然而, 沉积加工的起始位置容易产生高度过大的点, 并且在纳米线与纳米字符的加工中, 加工结果呈现规律性的偏移。分析表明, 以上问题主要与探针形貌以及大气环境有关。此外, 加工电压过高时也容易导致高度不均匀。

关键词: 原子力显微镜(AFM); 纳米焊接; 纳米加工; 场蒸发沉积; 纳米器件

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Nano Deposition Fabrication Assisted by the Electric Field with the Atomic Force Microscope

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Abstract:The electric filed deposition fabrication with the atomic force microscope(AFM) was researched, and the factors affecting the deposition fabrication were analyzed. The fabrications of a few nanostructures, such as nanodots, nanolines and nanoletters, were realized by selecting proper parameters, i.e. the tip-sample distance, fabricating voltage and motion velocity of the probe, etc. The heights of the nanodots vary slightly due to constant fabrication parameters during the fabrication of the nanodots. The mean value of the nanodot heights is about 1~5 nm. The nanolines have different heights due to the alteration of the fabricating voltage and motion velocity of the probe during the fabrication of the nanolines. The maximum height is up to 65 nm, meanwhile the minimum height is about 1~5 nm. As a whole, the deposition fabrications present a good repeatability and controllability. However, the overhigh nanodots were more likely produced at the starting position of the deposition fabrication. Moreover, the deposition fabrication results drifted regularly during the fabrication of the nanolines and the nanoletters. The analysis results show that the above problems are mainly related with the probe morphology and atmospheric environment. Besides, the overhigh fabricating voltage is more likely to induce nonuniform heights.

Key words:atomic force microscope(AFM); nano welding; nano fabrication; electric field deposition; nano device

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碳化硅表面亚微米减反射结构及其制作工艺

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摘要: 创新性地提出一种经济高效的碳化硅表面亚微米减反射结构制作工艺, 即“黑碳化硅技术”。该方法无需光刻, 采用非完全后烘的光刻胶微掩膜反应离子刻蚀(RIE)工艺, 克服了碳化硅材料由于高硬度和高化学稳定性而无法采用传统硅材料湿法工艺的困难。利用该技术, 已在4英寸(1英寸=2.54 cm) 4H-SiC单晶片表面成功制作出网格状亚微米阵列结构, 其深度为200~300 nm。测试结果表明, 该结构可以在390~800 nm的波长范围内使SiC表面平均反射率至少降低20%。可以应用于SiC材料制作的中间带太阳能电池及紫外探测器件, 提升器件的量子效率; 或作为高功率GaN LED的生长衬底, 增强LED的光出射效率。

关键词: 黑碳化硅技术; 中间带太阳能电池; 网格状刻蚀; 亚微米结构; 表面减反射

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Antireflective Sub-Micron Structures on the Surface of Silicon Carbide and Its Fabrication Technology

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Abstract: An innovative and cost-effective fabrication technology of the antireflective sub-micron structures on the surface of SiC was presented, namely "black silicon carbide technology". Overcoming the difficulty of unable to use the traditional silicon materials wet etching technology due to high hardness and high chemical stability of SiC, this method used the insufficient post-baked resist as the micro-mask during reactive ion etching (RIE) process and without the photolithography. The mesh-shaped sub-micron array structures were successfully fabricated on the surface of a 4-inches (1 inch=2.54 cm) 4H-SiC wafer by the technology. The depth of sub-micron structures reaches 200-300 nm. The test result shows that the average reflectivity of SiC in the wavelength range of 390-800 nm is significantly decreased by more than 20% after introducing the mesh patterning sub-micron structures. This sub-micron structures can improve the quantum efficiency of intermediate band solar cells and UV detectors made by SiC materials, or as the growth substrate of high power GaN LEDs, the sub-micron structures can enhance the light extraction efficiency of LEDs.

Key words: black silicon carbide technology; intermediate band solar cell; mesh patterning etch; sub-micron structure; surface antireflection

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KPFM 测试参数对表面电势测量的影响

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摘要: 开尔文探针力显微镜 (KPFM) 是一种可以对材料表面电势进行纳米级成像的工具, 是研究纳米材料表面特性的一种重要手段。高定向热解石墨 (HOPG) 具有表面光滑、导电性好的特点, 在原子力显微镜 (AFM) 的 KPFM 模式下, 向 HOPG 表面施加不同电压, 测量 HOPG 的表面电势, 以结果作为参照, 采用控制变量法分别对比了滤波器阶数、灵敏度和驱动值三种参数对表面电势测量的影响。实验结果表明: 滤波器阶数、灵敏度和驱动值均对表面电势的测量有不同程度的影响, 不同程度增加滤波器阶数、灵敏度和驱动值都可以起到提升信噪比的作用, 其中灵敏度的提升对信号的影响最为显著。

关键词: 开尔文探针力显微镜(KPFM); 高定向热解石墨(HOPG); 滤波器阶数; 灵敏度; 驱动值

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Influence of KPFM Measurement Parameters on the Surface Potential Measurement

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Abstract:The Kelvin probe force microscopy (KPFM) is a nanometer scale imaging tool of the surface potential on the materials, and is an important method to research the surface characteristics of nanomaterials. The highly oriented pyrolytic graphite (HOPG) has the characteristics of the smooth surface and good conductivity. In the KPFM mode of the atomic force microscope (AFM), the surface potential of the HOPG was measured by applying different voltages to the HOPG surface. With the results as the reference, the influences of three parameters, i.e. the filter order, sensitivity and driving value on the measurement of the surface potential were compared by using the control variable method. The experiment results show that the filter order, sensitivity and driving value affect the measurement of the surface potential differently. And the signal to noise ratio can be improved by increasing the filter order, sensitivity and driving value in varying degrees, among which the enhancement of the sensitivity has the most significant effect on the signal.

Key words:Kelvin probe force microscope (KPFM); highly oriented pyrolytic graphite (HOPG); filter order; sensitivity; driving value

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热电制冷技术的研究进展

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摘要: 热电制冷 (TEC) 已成为制冷领域的一个重要发展方向, 但是由于其转换效率过低且材料成本较高, 目前难以得到广泛应用。对热电制冷技术进行了简要介绍, 并综述了热电制冷技术的研究进展, 包括热电材料、结构优化和散热方式。讨论并分析了有机热电材料和无机热电材料的热电性能、不同结构设计所导致的性能系数、不同散热方式对制冷效率的影响。最后, 对热电制冷技术的优化进行了简单总结, 只有不断提高热电材料的优值系数, 并选择合适的结构设计和散热方式, 才能使热电制冷技术在各个领域拥有更大的发展空间。

关键词: 半导体制冷; 珀尔贴效应; 热电材料; 结构优化; 散热

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Research Progress of the Thermoelectric

Refrigeration Technology

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Abstract: The thermoelectric cooling (TEC) has become an important development direction in the field of refrigeration, while it is difficult to be widely applied mainly because of its low conversion efficiency and high material cost. The thermoelectric refrigeration technology is briefly introduced, and the research progresses of the thermoelectric refrigeration technology are reviewed, including thermoelectric materials, structure optimization and heat dissipating methods. The effects of the thermoelectric properties of organic thermoelectric materials and inorganic thermoelectric materials, the performance coefficient caused by different structural designs, and different heat dissipation methods on the cooling efficiency are discussed and analyzed. Finally, the optimization of the thermoelectric refrigeration technology is simply summarized. Only by constantly improving the figure of merit of thermoelectric materials and selecting appropriate structural design and heat dissipation method, the thermoelectric refrigeration technology can gain a broader development space in various fields.

Key words: semiconductor refrigeration; Peltier effect; thermoelectric material; structure optimization; heat dissipating

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