

FinFET 纳电子学与量子芯片的新进展

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摘要: 综述了后摩尔时代中两大发展热点: 鳍式场效应晶体管 (FinFET) 纳电子学和基于量子计算新算法的量子芯片的发展历程和近两年的最新进展。在 FinFET 纳电子学领域, 综述并分析了当今 Si 基互补金属氧化物半导体 (CMOS) 集成电路的发展现状, 包括 FinFET 的发展、10 nm 和 7 nm 技术节点的量产、5 nm 和 3 nm 技术节点的环栅场效应晶体管 (GAAFET) 和 2 nm 技术节点的负电容场效应晶体管 (FET) 的前瞻性技术研究以及非 Si 器件 (InGaAs FinFET、WS₂ 和 MoS₂ 两种 2D 材料的 FET) 的探索性研究。指出继续摩尔定律的发展将以 Si 基 FinFET 和 GAAFET 的技术发展为主。在量子芯片领域, 综述并分析了超导、电子自旋、光子、金刚石中的氮空位中心和离子阱等五种量子比特芯片的发展历程, 提高相干时间、固态化及多量子比特扩展等的技术突破, 以及近几年在量子信息应用的新进展。基于 Si 基的纳米制造技术和新的量子计算算法的结合正加速量子计算向工程化的进展。

关键词: 鳍式场效应晶体管 (FinFET); 环栅场效应晶体管 (GAAFET); 负电容场效应晶体管 (FET); InGaAs FinFET; 超导量子芯片; 电子自旋量子芯片; 光子量子芯片; 金刚石中的氮空位中心量子比特; 离子阱量子芯片

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New Advances in FinFET Nanoelectronics and Quantum Chips

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Abstract: Two development hotspots in the Post Moore era are summarized. The development process and recent progress in the past two years for Fin field effect transistor (FinFET) nanoelectronics and quantum chips based on new quantum computing algorithms are reviewed. In FinFET nanoelectronics, the current development status of Si complementary metal oxide semiconductor (CMOS) integrated circuits is reviewed and analyzed, including the development of FinFETs, the volume production of 10 nm and 7 nm technology nodes, the forward looking technology research about 5 nm and 3 nm technology node gate all around field effect transistors (GAAFETs) and 2 nm technology node negative capacitance field effect transistors (FETs), and the exploratory research about non Si devices (InGaAs FinFETs, two kinds of 2D WS₂ and MoS₂ based materials FETs). It is pointed out that the continued development of Moore's law will be mainly Si based FinFET and GAAFET technologies. In the field of quantum chips, the development process of five kinds of quantum bit chips, such as superconducting, electron spin, photon, nitrogen vacancy center in diamond and ion trap, the technical breakthroughs in improving coherence time, solid state and multi quantum bit expansion, and the new progress of the quantum information applications in recent years, are reviewed and analyzed. The combination of the Si based nanofabrication technology and new quantum computing algorithms is accelerating the progress of quantum computing to engineering.

Key words: Fin field effect transistor (FinFET); gate all around field effect transistor (GAAFET); negative capacitance field effect transistor (FET); InGaAs FinFET; superconducting quantum chip; electron spin quantum chip; photon quantum chip; nitrogen vacancy center in diamond quantum bit; ion well quantum chip

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用于增强药物和疫苗经皮给送的微针技术

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摘要: 作为一种微米尺度的类似针状器件, 微针可以克服传统经皮给药 (TDD) 的局限, 在皮肤上无痛、无出血地产生微米量级的孔洞, 提高药物尤其是大分子化合物的经皮递送效果。介绍了 TDD 用微针根据不同给药方法进行的分类和相应的微制造方法。给出了四种微针的给药方案和一般使用方法, 说明了各种微针给药方案的优缺点及一些改进措施。比较全面地阐述了微针在治疗、监测、诊断、美容等方面的应用及研究进展。微针在 TDD 技术的发展过程中起到了重要的促进作用, 其未来的发展将在微加工技术进步的支持下, 通过临床医学实践, 进一步改善人类健康、提高生活品质。

关键词: 微针; 经皮给药 (TDD); 疫苗给送; 微加工; 微电子机械系统 (MEMS)

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Microneedle Technologies for Enhancing Transdermal
Drug and Vaccine Delivery

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Abstract: As micron scale needle like devices, microneedles can produce micron sized holes on the skin painlessly without bleeding and thus overcome the limitations of traditional transdermal drug delivery (TDD) to improve the transdermal delivery of drugs, especially molecular compounds. The classification of microneedles for TDD according to different drug delivery methods and the microfabrication methods of various microneedles are introduced. Subsequently, the drug delivery schemes and general use methods for four types of microneedles are given. The advantages and disadvantages of drug delivery schemes for various microneedles and some improvement measures are described. The applications of microneedles in the aspects of treatment, monitoring, diagnosis, cosmetology and so on, as well as the research progress are more completely described. Microneedles play an important promoting role in the development process of TDD technology. With the progress of micromachining technology, the future development of microneedles will further improve human health and quality of life through clinical medical practice.

Key words: microneedle; transdermal drug delivery (TDD); vaccine delivery; micromachining; micro
electromechanical system (MEMS)

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Frequency Tunable Terahertz Metamaterial Absorbers Based on SrTiO₃

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Abstract: Two types of frequency tunable metamaterial (MM) absorbers in the terahertz (THz) spectrum regime based on the temperature λ sensitive material SrTiO₃ were presented. The resonant frequencies of THz MM absorbers based on SrTiO₃ can change with the external temperature as the complex permittivity of SrTiO₃ is related to the external temperature. One was realized based on the cross λ shaped metallic resonant structure and SrTiO₃ middle dielectric layer. The resonant frequency can be actively tuned across a wide band of frequencies from 1 λ 62 THz to 2 λ 44 THz in the temperature range from 200 K to 400 K. Another one was realized by filling SrTiO₃ material inside the cross ring metallic resonant structure, while the middle dielectric layer still used the common polydimethylsiloxane (PDMS) material. The resonant frequency shift of the absorption peak reaches 470 GHz with the resonant frequency from 1 λ 11 THz to 1 λ 58 THz when the external temperature changes from 200 K to 400 K, thus the frequency tunable MM absorber was achieved. The realization of frequency tunable MM absorbers can further extend the application fields of the MM absorbers to better adapt to various applications, such as THz imaging, THz detection, sensing, stealth and solar cells.

Key words: metamaterial (MM); terahertz (THz); absorber; temperature λ sensitive material; resonant structure

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基于 SrTiO₃ 的频率可调谐太赫兹超材料吸波器

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摘要:基于温度敏感材料钛酸锶(SrTiO₃)提出了两款频率可调谐太赫兹(THz)超材料(MM)吸波器。由于 SrTiO₃ 材料的复值介电常数与外界温度相关,因此基于 SrTiO₃ 材料的太赫兹超材料吸波器的谐振频率可随外界温度变化。一款是基于十字金属谐振结构和 SrTiO₃ 介质层实现的,在 200~400 K 的温度范围内,其谐振频率可在 1 λ 62~2 λ 44 THz 的宽频带范围内实现主动调谐。另一款超材料吸波器通过在十字环金属谐振结构内填充 SrTiO₃ 材料来实现,而中间介电层仍然采用常见的聚二甲基硅氧烷(PDMS)材料。当外部温度从 200 K 变为 400 K 时,谐振频率从 1 λ 11 THz 移至 1 λ 58 THz,频率偏移达到了 470 GHz,实现了频率可调的太赫兹超材料吸波器。可调谐超材料吸波器的实现可进一步扩展超材料吸波器的应用领域,从而更好地适应如太赫兹成像、太赫兹检测、传感和隐身等各种应用。

关键词:超材料(MM); 太赫兹(THz); 吸波器; 温度敏感材料; 谐振结构

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复合陷光织构膜对光面晶体硅电池 光电特性的影响

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摘要: 针对晶体硅表面织构化抵消部分减反射增益的问题, 在光面晶体硅电池表面复合三棱锥陷光织构膜来降低其反射损失, 同时保留其光生伏特效应较高的优点。分析陷光膜的陷光机理, 并通过光线追迹优化陷光膜表面三棱锥结构的几何参数。运用光学仿真与实验对比分析全波长内光面晶体硅电池、绒面晶体硅电池和复合陷光织构膜的光面晶体硅电池光学特性差异, 采用加权计算方法定量评价 3 种晶体硅电池在全波长内的反射损失。实验分析表明, 陷光膜可显著降低光面晶体硅电池反射损失, 最终复合电池实测加权反射率为 6 || 57%, 比光面晶体硅电池和绒面晶体硅电池的加权反射率分别降低 8 || 57%和 1 || 65%; 复合电池的光电转换效率达 20 || 34%, 比光面晶体硅电池和绒面晶体硅电池分别提高 2 || 33%和 1 || 18%。

关键词: 反射损失; 转换效率; 陷光织构膜; 光线追迹; 复合电池

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Effect of Composite Light Trapping Textured Film on Photoelectric
Characteristics of Smooth Crystal Silicon Cell

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Abstract: In order to solve the problem that the surface texture of crystalline silicon offsets part of gain of the anti || reflection, the light trapping textured film of triangular pyramid was composited on the surface of the smooth crystalline silicon cell to reduce its reflection loss and retain advantage of its high photovoltaic effect. The light trapping mechanism of the light trapping film was analyzed and the geometrical parameters of the triangular pyramidal structure on the surface of the light trapping film were optimized by ray tracing. Optical simulation and experiment were used to compare and analyze the difference of the optical properties of the smooth crystalline silicon cell, textured crystal silicon cell and smooth crystalline silicon cell with the composite light trapping textured film in full wavelength, and the weighted calculation method was used to quantitatively evaluate the reflection loss of the three kinds of the crystal silicon cells in full wavelength. Experimental analysis shows that the light trapping film can significantly reduce the reflection loss of the smooth crystalline silicon cells, and the final measured weighted reflectivity of the composite cell is 6 || 57%, which is 8 || 57% and 1 || 65% lower than that of the smooth crystalline silicon cell and textured crystal silicon cell, respectively. The photoelectric conversion efficiency of the composite cell is 20 || 34%, which is 2 || 33% and 1 || 18% higher than that of the smooth crystalline silicon cell and textured crystal silicon cell, respectively.

Key words: reflection loss; conversion efficiency; light trapping textured film; ray tracing; composite cell

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Ag Ⅱ X(X=F, Cl, Br, I)共掺杂锐钛矿

TiO₂ 的可见光吸收

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摘要: TiO₂ 是一种常见的光触媒, 但由于带隙较宽制约了其应用。采用第一性原理研究了 Ag Ⅱ X(X=F, Cl, Br, I)共掺杂对锐钛矿 TiO₂ 的结合能、态密度、吸收系数和带边位置的影响。研究表明: Ag Ⅱ X 共掺杂锐钛矿 TiO₂ 的结合能分别为-6 Ⅱ 43、-5 Ⅱ 54、-4 Ⅱ 36 和-3 Ⅱ 97 eV, 因此 Ag Ⅱ X 都是稳定结构。Ag Ⅱ X 共掺杂对锐钛矿 TiO₂ 的光学性质产生了以下几个方面的影响: 首先, 锐钛矿 TiO₂ 带隙宽度由 3 Ⅱ 15 eV 分别减小到 2 Ⅱ 85、2 Ⅱ 57 和 2 Ⅱ 21 eV, 导致吸收系数产生红移; 其次, 带隙中杂化出新的能级, 有利于可见光的吸收; 最后, Ag Ⅱ X 共掺杂后的锐钛矿 TiO₂ 具有良好的光催化活性。

关键词: 锐钛矿 TiO₂; 第一性原理; 电子结构; 光学性质; 受主能级; 吸收系数; 光催化

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Visible Light Absorption of Ag Ⅱ X(X=F, Cl, Br, I) Co Ⅱ Doped

Anatase TiO₂

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Abstract: TiO₂ is a common kind of photocatalyst, however, its application is restricted by the wide band gap width. By using first principle, the effects of Ag Ⅱ X(X=F, Cl, Br, I) co Ⅱ doping on the binding energy, density of states, absorption coefficient and band edge positions of anatase TiO₂ were studied. The research results show that the binding energies of the Ag Ⅱ X co Ⅱ doping anatase TiO₂ are -6 Ⅱ 43, -5 Ⅱ 54, -4 Ⅱ 36 and -3 Ⅱ 97 eV, respectively. Therefore, all of the Ag Ⅱ X structures are stable. The influences of Ag Ⅱ X co Ⅱ doping on the optical properties of the anatase TiO₂ are as following. Firstly, the band gap width of the anatase TiO₂ decreases from 3 Ⅱ 15 eV to 2 Ⅱ 85, 2 Ⅱ 57 and 2 Ⅱ 21 eV, respectively, resulting in the red shift of the absorption coefficient. Secondly, a new energy level is hybridized in the band gap, which is beneficial for the absorption of visible light. Finally, the Ag Ⅱ X co Ⅱ doping anatase TiO₂ has excellent photocatalytic activity.

Key words: anatase TiO₂; first principle; electronic structure; optical property; acceptor level; absorption coefficient; photocatalytic

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基于烛灰纳米颗粒层的高灵敏度

MEMS 湿度传感器

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摘要: 提出了一种基于烛灰纳米颗粒层的高灵敏度、快速响应的微电子机械系统 (MEMS) 湿度传感器。该湿度传感器的制备工艺简单方便、成本低廉, 仅包括烛灰纳米颗粒层的沉积、烛灰纳米颗粒层表面的氧等离子体亲水化处理 and 金属电极的制备三个步骤。实验表明, 在 30%~90%相对湿度内, 该 MEMS 湿度传感器的灵敏度高达 $4 \parallel 17 \text{ M}\Omega / \% \text{RH}$, 响应和恢复时间分别为 2 s 和 8 s, 同时具有较好的稳定性和重复性。此外, 使用此传感器对呼吸频率进行检测, 实验结果表明此湿度传感器可以精确地跟踪人的呼吸, 因此所研究的湿度传感器在生物医学、环境监测等领域具有潜在应用。

关键词: 微电子机械系统 (MEMS); 湿度传感器; 纳米颗粒; 呼吸监测; 氧等离子体亲水化处理

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Highly Sensitive MEMS Humidity Sensor Based on

Candle \parallel Soot Nanoparticle Layer

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Abstract:Based on candle \parallel soot nanoparticle layers, a micro \parallel electromechanical system (MEMS) humidity sensor with high sensitivity and fast response was presented. The fabrication process of the humidity sensor is quite simple and low cost, only including the deposition of the candle \parallel soot nanoparticle layer, oxygen plasma hydrophilization treatment of the candle \parallel soot nanoparticle layer surface and preparation of metal electrodes. The experiment results show that the MEMS humidity sensor can be used in a relative humidity range from 30% to 90%, its sensitivity can reach $4 \parallel 17 \text{ M}\Omega / \% \text{RH}$, and its response time and recovery time are 2 s and 8 s, respectively. Besides, the humidity sensor has good stability and repeatability. In addition, the sensor was used to detect the respiratory rate. The experimental results show that the humidity sensor can accurately track human breath, and has potential applications in biomedicine, environmental monitoring and other fields.

Key words:micro \parallel electromechanical system(MEMS); humidity sensor; nanoparticle; breath monitoring; oxygen plasma hydrophilization treatment

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基于聚合物材料的转动和摆动传感器技术

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摘要: 现有的一些转速测量所使用的传感器结构复杂、价格昂贵、操作困难, 因此对传感器提出了新的要求。提出了一种基于聚四氟乙烯 (PTFE) 球和金属铜电极的运动传感器, 利用摩擦纳米发电机原理, 使 PTFE 球与铜箔电极相互接触摩擦产生电信号, 分析了 PTFE 球与金属铜电极的摩擦电效应、样机转速与输出电压大小及周期之间的关系、以及样机的快速响应性与平衡性。该传感器可以根据不同转速输出不同周期的电压, 当转速为 0~400 r/min 时, 由其周期算出的频率随转速线性变化。在 0 || 5~0 || 8 s 内即可快速响应转速变化, 实时测量转速。通过采集的电信号来反映电机转速, 并对电机的平衡实现检测。

关键词: 传感器; 柔性聚合物; 转速测量; 摩擦起电; 聚四氟乙烯 (PTFE)

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Rotation and Oscillation Sensor Technology

Based on Polymer Materials

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Abstract:The existing sensors used in rotate speed measurement are complex in structure, expensive in price and difficult to operate, so new requirements are put forward for the sensors. A motion sensor based on polytetrafluoroethylene (PTFE) sphere and metal copper electrode was proposed. Based on the principle of friction nano || generators, electrical signals were produced by the contact and friction between the PTFE sphere and copper foil electrodes. The triboelectricity effect of the PTFE sphere and copper electrode, the relationships of prototype rotate speed, output voltage and period, and the quick response and balance of prototype were analyzed. The sensor can output the voltages with different periods according to different rotate speeds, and when the rotate speed is 0-400 r/min, the frequency calculated by its period changes linearly with the rotate speed. The sensor can quickly respond to the change of the rotate speed in the range of 0 || 5-0 || 8 s and measure the rotate speed in real time. The rotate speed of the motor can be reflected by the collected electrical signals, and the balance of motor can be detected.

Key words:sensor; flexible polymer; rotate speed measurement; frictional electrification; polytetrafluoroethylene (PTFE)

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一种新型微波叶尖间隙传感器

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摘要: 针对恶劣环境下航天发动机、涡轮机等旋转机械对叶尖间隙实时测量的需求, 设计了一种用于涡轮发动机叶尖间隙测量的新型微波传感器。该传感器基于多嵌套式分裂环谐振器(NSRR)结构, 将铂(Pt)金属浆料组成的闭环电路集成于高温共烧陶瓷(HTCC)中, 以此来适应发动机及涡轮机内部的极端测试条件。经过仿真设计, 可知传感器的工作频率为 $2 \sim 44$ GHz, 且在 $2 \sim 5 \sim 5$ mm 仿真间隙范围内最低灵敏度为 $8 \sim 33$ dB/mm。通过传统的HTCC工艺及厚膜技术, 对设计的传感器进行制备和测试, 测试结果验证了仿真结果的正确性, 表明该传感器能为所需应用环境提供准确可靠的数据。

关键词: 微波传感器; 叶尖间隙; 嵌套式分裂环谐振器(NSRR); 氧化铝陶瓷; 谐振频率

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A New Type of Microwave Blade Tip Clearance Sensor

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Abstract: In order to meet the demand of space engine, turbine and other rotating machines for real time measurement of blade tip clearance under harsh environment, a new type of microwave sensor was designed for turbine engine blade tip clearance measurement. The sensor was based on a multi nested split ring resonator (NSRR) structure, a closed loop circuit composed of platinum (Pt) metal paste was integrated into high temperature co fired ceramic (HTCC) to adapt to extreme test conditions inside the engine and turbine. Through simulation design, the working frequency of the sensor is $2 \sim 44$ GHz, and the minimum sensitivity within the simulation gap range of $2 \sim 5 \sim 5$ mm is $8 \sim 33$ dB/mm. Through the traditional HTCC process and thick film technology, the designed sensor was prepared and tested. The test results verify the correctness of simulation results, indicating that the sensor can provide accurate and reliable data for the required application environment.

Key words: microwave sensor; blade tip clearance; nested split ring resonator(NSRR); alumina ceramic; resonant frequency

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量子调控型 NV 色心系综磁强计灵敏度优化

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摘要: 氮空位 (NV) 色心是金刚石中固有的缺陷, 具有纳米量级的空间分辨率和微特斯拉量级的磁灵敏度, 可以实现高灵敏度与高空间分辨率的微弱磁检测。利用 NV 系综磁敏感单元, 可以将固态电子自旋信号实时检测技术应用于 NV 磁强计。准确进行 AC 磁测量是研究的关键。利用 NV 色心电子自旋进行量子调控, 通过光探测磁共振 (ODMR) 测试确定共振频率, 二能级 Rabi 振荡测试确定 Rabi 频率以及退相干时间测试确定横向弛豫时间。由于自旋回波存在相位积累, 导致荧光布局数发生改变。最后利用量子相位随荧光布局数的关系计算出最大 AC 磁场灵敏度约为 0.18 pT/Hz 。

关键词: 金刚石; NV 色心; AC 磁测量; 光探测磁共振 (ODMR) 测试; Rabi 振荡; 退相干时间

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Sensitivity Optimization of Quantum Controlled NV Color

Center Series Synthetic Magnetometer

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Abstract: Nitrogen vacancy (NV) color center is an inherent defect in diamond, has nano scale spatial resolution and micro Tesla magnitude magnetic sensitivity, and can realize weak magnetic detection with high sensitivity and high spatial resolution. The NV series synthetic magnetic sensing unit can be used to apply real time detection technology of solid state electron spin signals to NV magnetometers. Accurate AC magnetic measurement is the key to this study. The NV color center electron spin was used for quantum regulation. The resonance frequency was determined by optical detection magnetic resonance (ODMR) test. The Rabi frequency was determined by the two level Rabi oscillation test, and the transverse relaxation time was determined by the decoherence time test. Due to the phase accumulation of the spin echo, the number of the fluorescent layouts changes. Finally, the maximum AC magnetic field sensitivity is calculated to be about 0.18 pT/Hz by using the relationship of the quantum phase with the number of the fluorescent layouts.

Key words: diamond; NV color center; AC magnetic measurement; optical detection magnetic resonance (ODMR) test; Rabi oscillation; decoherence time

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355 nm 全固态紫外激光加工玻璃通孔工艺

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摘要: 玻璃通孔结构广泛应用于光通信、微电子机械系统 (MEMS) 封装、芯片三维垂直集成等领域。采用单一变量法详细研究了 355 nm 全固态紫外激光进行玻璃通孔加工时, 各激光参数对通孔直径、锥度及表面质量的影响。研究表明, 随着激光功率密度的增大, 孔边缘易出现较严重的裂损现象, 孔径随之增大; 激光重复频率的增大将增加通孔边缘及侧壁的熔融物数量, 且通孔锥度也会增加; 适当降低激光扫描速度可减小通孔边缘重凝区宽度, 然而扫描速度太低时, 由于热累积效应打孔质量下降; 适当的负离焦有利于获得垂直度高、质量良好的玻璃通孔。研究结果对使用激光加工高质量玻璃通孔的参数选取具有一定的参考价值。

关键词: 紫外激光; 玻璃通孔; 激光加工; 3D 垂直封装; 单一变量法

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Glass Through Holes by 355 nm All Solid State

Ultraviolet Laser Processing

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Abstract: The glass through hole structure is widely used in the fields of optical communication, micro electro-mechanical system (MEMS) packaging and three dimensional vertical integration of chips. The single variable method was used to investigate the effects of various laser parameters on the diameter, taper and surface quality of the through hole when the glass through holes were processed with a 355 nm all solid state UV laser. The research results show that with the increase of the laser power density, the severe cracking is easy to appear at the edge of the hole and the hole diameter increases. The increase of the laser repetition frequency will increase the amount of melt at the edges and sidewalls of the through holes, and the through hole taper will increase. Properly reducing the laser scanning speed can decrease the width of the resolidification zone at the edge of the through hole. However, in case the scanning speed is too slow, the quality of the hole deteriorates due to the heat accumulation effect. Proper negative defocusing is beneficial for obtaining the glass through holes with high verticality and good quality. The research results have certain reference value for the parameter selection of laser processing for glass through holes with high quality.

Key words: ultraviolet laser; glass through hole; laser processing; 3D vertical package; single variable method

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多量子阱红外探测器耦合光栅的新型制备工艺

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摘要: 基于微米球刻蚀技术设计了一种制备多量子阱红外探测器(QWIP)表面二维光栅的新型工艺, 通过改变微米球的直径可以为不同探测波长的 QWIP 制备表面二维光栅, 有效降低了制备成本和技术难度。采用 GaAs 衬底作为实验片制作光栅、聚苯乙烯 (PS) 材质小球作为表面掩膜, 对小球的单层排布、PS 小球刻蚀和光栅的刻蚀等工艺进行了深入的实验研究, 并得出了最优的工艺参数。制备出了具有良好均匀性和一致性的二维光栅结构。通过傅里叶光谱仪测得表面光栅的耦合波长为 6~9 μm 。最后研究了不同工艺条件对耦合结果的影响, 证实当光栅直径为 PS 球直径的 0.74 倍时获得的耦合效果最优。

关键词: 二维光栅; 微米球刻蚀; 量子阱; 反应离子刻蚀(RIE); 多量子阱红外探测器(QWIP)

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Novel Preparation Process for Multi-Quantum Well

Infrared Photodetector Coupled Grating

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Abstract:A novel process for preparing a two-dimensional grating on the surface of a multi-quantum well infrared photodetector (QWIP) was designed based on microsphere etching technology. The surface two-dimensional grating can be prepared for the QWIPs with different detection wavelengths by changing the diameters of the microspheres, which effectively reduces the preparation cost and technical difficulty. A GaAs substrate was used as an experimental wafer for fabricating grating, and a surface mask was made of small spheres of polystyrene (PS) material. The single layer arrangement of the small spheres, the PS small sphere etching and the etching of the grating were further studied by the experiment, and the optimal process parameters were obtained. A two-dimensional grating structure with good uniformity and consistency was prepared. The measuring result of Fourier spectrometer shows that the coupling wavelength of the surface grating is 6-9 μm . Finally, the influences of different process conditions on the coupling results were researched. It is confirmed that the obtained coupling effect is optimal when the grating diameter is 0.74 times the diameter of the PS small sphere.

Key words:two-dimensional grating; microsphere etching; quantum well; reactive ion etching (RIE); multi-quantum well infrared photodetector (QWIP)

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等离子体工艺对 PDMS 褶皱断纹的影响

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摘要: 一维聚二甲基硅氧烷 (PDMS) 褶皱可用于纳米颗粒自组装模板, 具有制备工艺简单、成本低、适合大面积制备的优点, 因而引起人们的广泛关注。然而, 采用机械拉伸释放法形成褶皱的过程中会出现大量的断纹, 进而影响褶皱模板的周期性。从断纹形成机理出发, 将 PDMS 样品制备、机械拉伸及电机释放过程的工艺条件保持不变, 通过调整等离子体产生的工艺参数来改善断纹。实验结果表明: 气压和功率是影响褶皱断纹的主要因素, 减小气压和减小功率可以使同周期褶皱断纹分别减少 46% 和 26%。研究结果为制备不同周期的高质量 PDMS 褶皱模板提供实际参考, 有利于其在自组装模板中的应用。

关键词: 纳米颗粒; 聚二甲基硅氧烷 (PDMS); 褶皱; 自组装; 等离子体; 断纹

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Influence of Plasma Process on Cracks of PDMS Wrinkles

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Abstract: One dimensional polydimethylsiloxane (PDMS) wrinkle can be used for self assembly template of nanoparticles, and has attracted wide attention because its advantages of simple preparation process, low cost and suitable for large area preparation. However, a large number of cracks will appear in the process of wrinkle formed by mechanical stretch release method, and will affect the periodicity of the wrinkled template. Based on the formation mechanism of cracks, the cracks were improved by adjusting the technological parameters of plasma generation while the process conditions of the PDMS sample preparation, mechanical stretching and motor release remain unchanged. The experimental results show that pressure and power are the major factors to affect the cracks of the wrinkle. The decreasing pressure and power can reduce the wrinkle cracks in the same period by 46% and 26%, respectively. The research results provide a practical reference for the preparation of high quality PDMS wrinkled templates with different periods, being beneficial to its application in self assembly templates.

Key words: nanoparticle; polydimethylsiloxane (PDMS); wrinkle; self assembly; plasma; crack

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微波功率器件中 AuGe 合金焊接界面特征

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摘要: 在微观尺度上, 焊点的可靠性取决于焊料同焊盘之间界面反应生成的界面金属间化合物 (IMC) 的结构。通过金锗合金焊点的界面反应及微观结构随环境的变化表征了焊点的可靠性, 研究了 AuGe 合金焊料与不同金层厚度的 Ni/Au 焊盘共晶焊接后其界面特征, 同时总结了 AuGe 合金焊料在 Cu 和 Ni 等常见焊盘上的焊接润湿性及其焊接界面特征。切片分析结果显示, 在共晶焊接后, 厚金样品焊接界面冷却时焊料层析出富 Au 相形成不规则焊接结合层, Au 层厚度减薄 50%~60%; 薄金样品的 Au 层全部消失, 并在界面处形成很薄的一层富 Ni 的 NiGe 化合物。实验结果显示, 厚 Au 层样品未出现 Ni 向焊接层扩散的现象和 NiGe 化合物的生成, 厚 Au 层起到了阻挡层作用; 薄金样品时, Ni 通过互扩散缓慢与 Ge 形成 NiGe 化合物, 在长期使用中焊接层会通过元素扩散等形式演变, 使整个焊接层转变为含氧化层、富 P 层、NiGe 层和 AuCuGe 合金层等多层结构的 IMC, 降低了焊点强度, 严重影响焊接层可靠性。这说明 IMC 在焊接过程中主要以界面化学反应方式形成, 服役过程中主要以元素扩散方式演变。

关键词: 金锗合金; 金属间化合物 (IMC); 共晶; 界面反应; 元素扩散

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Soldering Interface Characteristics of AuGe Alloy in

Microwave Power Devices

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Abstract: On a microscopic scale, the reliability of a solder joint depends on the structure of the interfacial intermetallic compound (IMC) formed by the interfacial reaction between the solder and the pad. The reliability of solder joints was characterized by the interfacial reaction of AuGe alloy solder joints and the change of microstructure with environment. After eutectic soldering, the interface characteristics of the AuGe alloy solders and Ni/Au pads with different gold thicknesses were studied. The solder wettability and soldering interface characteristics of the AuGe alloy solder on common pads such as Cu and Ni were summarized. The results of slicing analysis show that after the eutectic soldering, the solder layer precipitates out Au-rich phase to form an irregular solder joint layer when the soldering interface of the thick Au samples are cooled, and the thickness of the Au layer is reduced by 50%-60%, all the Au layers of the thin gold sample disappear, and a very thin layer of Ni-rich NiGe compound is formed at the interface. The experimental results show that the diffusion of Ni to the solder layer and the formation of NiGe compound do not appear in the thick Au layer sample. The thick gold layer acts as a barrier layer. In the thin Au sample, NiGe compound is formed by Ge and Ni through slow interdiffusion. In long term use, the solder layer can evolve through elemental diffusion and other forms, transforming the entire solder layer into an IMC containing a multilayer structure such as an oxide layer, a P-rich layer, a NiGe layer and an AuCuGe alloy layer, which reduces the solder joint strength and seriously affects the reliability of solder layer, indicating that the IMC is mainly formed by interfacial chemical reaction during the soldering process and mainly evolves in the form of elemental diffusion during the service.

Key words: AuGe alloy; intermetallic compound (IMC); eutectic; interface reaction; element diffusion

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