基于隧穿机理的石墨烯纳米带准一维器件设计

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摘要：隧穿场效应晶体管（TFET）在低功耗领域具有很好的应用前景，以优化新型准一维TFET为目的，通过数值仿真研究了以石墨烯纳米带（GNR）为沟道材料的准一维 TFET 以及受器件尺寸和掺杂浓度控制的器件输运特性及开态和关态电流。以能带调控理论结合局域态密度与电流谱密度间的关系为手段对隧穿效应的机理进行了详细的探讨，分析了禁带宽度、栅覆盖范围、沟道长度和源漏掺杂浓度 4 个变量对输运过程的影响，进而确定了其对器件性能影响的变化趋势，并总结了相应原则，得到了有利于提高驱动能力、降低静态功耗以及满足数字电路一般性要求的准一维器件的设计策略。这一研究可为基于准一维材料的 TFET 的设计提供参考，推动基于平面材料的新型器件的发展。

关键词：隧穿场效应晶体管(TFET)；准一维材料；石墨烯纳米带（GNR）；隧穿机理；开关电流比（Ion/Ioff）
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Design of a Graphene Nanoribbon Quasi One Dimensional Device Based on Tunneling Mechanism

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Abstract: The tunnel field effect transistor (TFET) has very good application prospects in low power consumption domains. In order to optimize the new quasi one dimensional TFET, the quasi one dimensional TFET with the graphene nanoribbon (GNR) channel was investigated through the numerical simulation, and the transport properties and on state and off state currents of the TFET controlled by the device size and doping concentration were studied. The mechanism of the tunneling effect was discussed in detail by the combination of the energy band regulation theory with the relation of the density of local states and current spectral density. The influences of four variables i e. the band gap, gate coverage range, channel length and doping concentration of the source and drain regions on the transport process were analyzed. Furthermore, the variation trends of the impact on device performances were determined, and corresponding principles were summarized. The design strategy of the quasi one dimensional device was obtained, which is beneficial to improve the driving capability, reduce the static power consumption and meet general requirements of digital circuits. The research can provide a reference for the design based on the quasi one dimensional TFET and promote the development of new devices based on planar materials.

Key words:tunnel field effect transistor (TFET); quasi one dimensional material; graphene nanoribbon (GNR); tunneling mechanism; on/off current ratio (Ion/Ioff)
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钙钛矿太阳电池用 NiO/石墨烯复合空穴传输材料

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摘要：有机-无机杂化钙钛矿太阳电池(PSC)因其效率高、成本低及制备工艺简单等优点而得到广泛的关注。采用无机材料替代有机空穴传输材料可以进一步降低电池成本，拓宽钙钛矿太阳电池空穴传输材料的选择范围。采用水热合成法制备了 NiO/石墨烯复合材料前驱体，经过高温处理，得到 NiO/石墨烯复合材料，并将其应用于钙钛矿太阳电池空穴传输层。通过 X 射线衍射仪（XRD）、扫描电子显微镜（SEM）和热重分析仪-差式扫描量热仪（TGA DSC）等手段表征了复合材料组分及微观结构。同时，探索了复合材料质量浓度和制膜工艺对空穴传输层性能的影响。研究结果表明，当复合材料的氯苯溶液质量浓度为 1 25 mg/mL 时，采用喷涂工艺制膜得到的空穴传输层具有最优的性能，其相应钙钛矿太阳电池的光电转化效率为 1 44%。NiO/石墨烯复合材料在钙钛矿太阳电池中表现出优于 NiO 和石墨烯的性能，体现了 NiO 和石墨烯在复合材料空穴输运过程中的协同作用。

关键词：钙钛矿太阳电池(PSC)；空穴传输材料；NiO/石墨烯复合材料；喷涂制膜；水热合成法
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NiO/Graphene Composite Hole Transport Materials for Perovskite Solar Cells

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Abstract:The organic inorganic hybrid perovskite solar cell (PSC) attracts wide attention because of its high efficiency, low cost, simple preparation process and other advantages. Substituting the organic hole transport materials with inorganic materials can further reduce the cost and expand the selection range of hole transport materials of the PSCs. NiO/graphene composite precursors were prepared by the hydrothermal synthesis method. Then the NiO/graphene composite materials were obtained by the high temperature treatment, and were applied as the hole transport layer in the perovskite solar cell. The component and microstructure of the composite materials were characterized by using the X ray diffractometer (XRD), scanning electron microscope (SEM), thermal gravimetric analyzer differential scanning calorimeter (TGA DSC) and other methods. Additionally, the influences of the composite material mass concentration and film preparation process on the performance of the hole transport layer were investigated. The research result shows that the performance of the hole transport layer prepared by the spray coating process is optimum with the composite materials chlorobenzene solution mass concentration of 1 25 mg/mL, and the photoelectric conversion efficiency of the corresponding PSC is 1 44%. NiO/graphene composite materials exhibit better performance than single NiO or single graphene in the PSC, reflecting the synergistic effect of NiO and graphene in the hole transport process of the composite materials.

Key words:perovskite solar cell(PSC); hole transport material; NiO/graphene composite material；film preparation by spray coating; hydrothermal synthesis method
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基于微结构的银纳米线透明导电薄膜的光电性能

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摘要：首先，采用光刻技术并结合湿法刻蚀工艺，在玻璃衬底上制备出蜂窝状分布的圆台阵列微结构，从占空比和反射、透射光线分布的角度分析其光学性能。然后，采用水热法制备银纳米线，并对样品进行 X 射线衍射(XRD)物相分析和扫描电子显微镜（SEM）微观形貌表征，得到平均直径为 80 nm、长度为 110 μm、长径比大于 1 000 的超细长银纳米线。最后，通过浓硫酸和双氧水的混合溶液对微结构表面改性，并采用变速旋涂法将银纳米线与微结构完美嵌合，从而制备出基于玻璃衬底上圆台阵列微结构的银纳米线透明导电薄膜，其光电性能优良，测得其可见光透过率为 85 97%、方块电阻平均值为 23 1 Ω/□。

关键词：微结构；银纳米线；透明导电薄膜；湿法刻蚀；变速旋涂法
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Photoelectric Performance of Microstructured Silver Nanowires Transparent Conductive Films

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Abstract: Firstly, a honeycomb circular array microstructure was fabricated on the glass substrate by the combination of the photolithography with wet etching process. The optical properties of the microstructure were analyzed from the aspects of the duty ratio and the distributions of the reflection and transmission lights. Then, the silver nanowires were prepared by the hydrothermal method, and the X ray diffraction (XRD) phase analysis and scanning electron microscope (SEM) micro morphology characterization were carried out for the samples. The ultra long and thin silver nanowires were obtained with the mean diameter of 80 nm, the length of 110 μm and the length diameter ratio over 1 000. Finally, the microstructure surface was modified by the mixed solution of the concentrated sulfuric acid and hydrogen peroxide, and the silver nanowires and the microstructure were perfectly tabled by variable speed spin coating. Thus, a silver nanowire transparent conductive film based on the microstructure of the circular array on the glass substrate was prepared. Its photoelectric performance is excellent. And the test results show that the visible light transmittance is 85 97% and the average square resistance is 23 1 Ω/□.

Key words:microstructure; silver nanowire; transparent conductive film; wet etching; variable speed spin coating
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一种基于氮化硼纳米管的微纳流控芯片

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摘要：由于纳米尺度流道加工过程中存在工艺复杂、效率低等缺点，限制了微纳流控芯片在纳米尺度下流体特性研究领域的应用。针对此问题，提出利用氮化硼纳米管作为纳流道集成到微纳流控芯片中的方法，并对芯片的离子输运性能进行测试。在微纳流控芯片制作过程中，结合 SU-8 厚胶光刻工艺与 PDMS 键合技术，使附着在 Si/SiO2 基底上的氮化硼纳米管连接两个储液槽。实验结果表明，本方法加工出的芯片微流道深度为（15±0 3） μm，纳流道长度为 28 12 μm，直径为 148 nm。此外，浓度高于 100 mmol/L 的 KCl 溶液注入芯片后，在氮化硼纳米管内达到离子平衡至少需要 3 h，离子电导与浓度之间存在 Gionic~c0 43 的非线性关系。

关键词：氮化硼纳米管；微纳流控芯片；SU-8 光刻；PDMS 键合；离子输运
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Micro Nano Fluidic Chip Based on the Boron Nitride Nanotube

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Abstract:Due to the disadvantages of the nanofluid channel process，i e. complication and low efficiency, the application of the micro nano fluidic chip in the research field of nano scale fluid properties is limited. The fabrication method of a micro nano fluidic chip integreated with a boron nitride nanotube as the nanofluid channel was proposed to resolve the issue, and the ion transport properties of the chip were tested. In the fabrication process of the micro nano fluidic chip, by the combination of the SU-8 thick film lithography with PDMS bonding technology, the boron nitride nanotube attached to the Si/SiO2 substrate was connected to two reservoirs. The experiment results show that the depth of the microfluid channel in the chip is （15±0 3） μm, the nanofluid channel is 28 12 μm in the length and 148 nm in the diameter. Besides, it took at least 3 h for the ionization equilibrium in the boron nitride nanotube after injecting KCl solution with the concentration higher than 100 mmol/L into the chip. Moreover, there is a non linear relationship of Gionic~c0 43 between the ion conductivity and concentration of KCl solution.

Key words:boron nitride nanotube; micro nano fluidic chip; SU-8 lithography; PDMS bonding; ion transport
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基于压力分布测试的电容式压力传感器

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摘要：针对 0~0 3 N 压力的大小与分布测试，设计了一款电容式压力传感器。通过 ANSYS 仿真与 Matlab 数据分析，确定传感器单个敏感单元半径为 80 μm，腔高 0 5 μm，膜厚 2 5 μm。阵元内敏感单元呈行列排布。设计工艺加工流程与版图，并进行干法刻蚀、减薄和键合等关键工艺加工。使用阻抗分析仪和压力计搭建测试平台，结果显示加工得到的压力传感器初始电容平均值为 38 03 pF，阵列内电容一致性良好，灵敏度为 9 5 pF/N，线性度良好，连接配套数据处理电路可实现压力分布测试。初步满足在小量程压力条件下测试要求，验证了该传感器结构的可靠性，为制备小量程压力传感器奠定基础。

关键词：微电子机械系统（MEMS）；压力传感器；电感耦合等离子体(ICP)刻蚀；阳极键合；压力测试
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Capacitive Pressure Sensor Based on the Pressure Distribution Test

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Abstract:A capacitive pressure sensor was designed for testing the pressure value and pressure distribution at a range of 0-0 3 N. The ANSYS simulation and Matlab data analysis were carried out for the sensitive units lined up in the array element of the sensor. And the results show that the radius is 80 μm, the cavity height is 0 5 μm and the thickness of the film is 2 5 μm for the single sensitive unit. The processing flow and layout were designed, and the key processes, such as dry etching, thinning and bonding were carried out. The test platform was built by the impedance analyzer and pressure meter. The test results show that the average value of the initial capacitance of the pressure sensor is 38 03 pF, indicating a good consistency of the capacitance in the array. Besides, the sensitivity is 9 5 pF/N, indicating a good linearity. And the pressure distribution test can be achieved by connecting with the ancillary data processing circuit, meeting the preliminary test requirements of the small range pressure. And the reliability of the proposed sensor structure was proved, laying the foundation for the preparation of the small range pressure sensor.

Key words:micro electromechanical system(MEMS)；pressure sensor；inductively coupled plasma（ICP）etching；anodic bonding；pressure test
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基于块材压电陶瓷的悬臂梁式压电微驱动器

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摘要：为了获得高性能、较低成本的压电微驱动器，设计了悬臂梁式压电微驱动器。利用压电性能优良的块材压电陶瓷（PZT）材料和硅（Si）基板通过共晶键合工艺接合，结合硅片切割、PZT 减薄和激光烧蚀及硅的湿法刻蚀工艺完成了微驱动器的制备。对设计的悬臂梁式压电微驱动器的前端位移输出和共振频率进行了理论分析和仿真。工艺上以 0　9 μm 厚的金（Au）层为中间层键合块材 PZT 和预制好沟槽的硅基板，利用物理研磨减薄的方法将块材 PZT 的厚度降至 30 μm 左右，Si 基板背面用湿法刻蚀的方法形成凹槽，随后利用准分子激光器对 PZT 层进行烧蚀加工至预制沟槽。制备的悬臂梁式微压电驱动器的大小为 1 450 μm×300 μm×69　8 μm。搭建测试系统测量确定了 10 Hz 交变频率、0~20 V 电压下的尖端输出位移-电压曲线，并在电压峰峰值为 0　2 V 的条件下测得压电微驱动器的共振频率为 18　43 kHz。悬臂梁式压电微驱动器所用的 PZT 材料压电性能高、均匀性好，器件尺寸小、位移输出大、频率响应快。该方法可用于批量制造微驱动器，以进一步降低成本。

关键词：压电微驱动器；共晶键合；准分子激光加工；微电子机械系统(MEMS)；悬臂梁
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Cantilever　Type Piezoelectric Micro　Actuator
Based on the Bulk PZT

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Abstract:In order to obtain a high　performance low　cost piezoelectric micro　actuator, a cantilever　type piezoelectric micro　actuator was designed. The bulk piezoelectric ceramics (PZT) with good piezoelectric performance and silicon substrate were jointed by the eutectic bonding process. The micro　actuator was fabricated by the combination of wafer dicing, PZT thinning, laser ablation and wet etching process for silicon. The theoretical analysis and simulation of the front　end displacement output and resonant frequency of the designed cantilever　type piezoelectric micro　actuator were made. The gold layer with the thickness of 0　9 μm was used as the intermediate layer, and the bulk PZT and silicon substrate with the prefabricated groove were bonded by the gold layer. Then the thickness of the bulk PZT was reduced to about 30 μm by physical grinding and thinning, and the back of the Si substrate was recessed by wet etching. Afterwards, an excimer laser was used to burn through the PZT layer to the prefabricated groove. The final size of the prepared cantilever　type piezoelectric micro　actuator was 1 450 μm×300 μm×69　8 μm. The tip output displacement　voltage curves at 10 Hz alternating frequency under the voltage of 0-20 V were measured by the built test system. Besides, the resonance frequency of the piezo　electric micro　actuator was 18　43 kHz measured at the peak　to　peak voltage of 0　2 V. The PZT materials used for the cantilever　type piezoelectric micro　actuator have high piezoelectric perfor　mance and good uniformity, and the prepared devices have small size, large displacement output and fast frequency response. The method can be used to manufacture micro　actuators in batches to further reduce costs.

Key words:piezoelectric micro　actuator; eutectic bonding; excimer laser processing; micro electromechanical system (MEMS); cantilever
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一种低横向效应的压阻式加速度传感器设计

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摘要：为了提高传感器的测试精度、抑制传统传感器的横向效应问题，通过改变压阻排布方式设计了一种低横向效应的压阻式加速度传感器。该传感器采用 8 电阻十字梁结构，电阻全部对称排布在应力变化的线性区，使传感器在满足高灵敏度的同时消除了横向效应。通过有限元仿真分析得出该传感器的灵敏度为 0 297 4 μV/g，横向灵敏度为零，对封装后的传感器进行了 Hopkinson 杆冲击测试，横向灵敏度只占工作轴向灵敏度的 1 1%，远小于相同结构尺寸下传统四电阻传感器的 20 7%，而工作轴向灵敏度基本相同。实验表明，该传感器具有较高的工作轴向灵敏度和极低的横向灵敏度。

关键词：压阻式加速度传感器；横向效应；灵敏度；压阻排布；有限元仿真；Hopkinson 杆
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Design of a Piezoresistive Accelerometer Sensor with Low Transverse Effect

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Abstract:In order to improve the testing accuracy of the sensor and suppress the transverse effect of the traditional sensor, a piezoresistive acceleration sensor with low transverse effect was designed by changing the arrangement of the piezoresistor. The sensor uses an eight resistor cross beam structure, the symmetrical placement of the resistors in the variation linear region of the stress makes the sensor satisfy the high sensitivity and eliminate the transversal effect at the same time. The sensitivity and transverse sensitivity of the sensor simulated by the finite element simulation and analysis are 0 297 4 μV/g and 0, respectively. The shock test of Hoplinson rod for the packaged sensor was carried out. And the results show that the transverse sensitivity is 1 1% of the axial sensitivity, much smaller than 20 7% of the traditional four resistor sensor in the same structure size, while they basically have the same working axial sensitivity. The experiment results show that the sensor has high working axial sensitivity and low transverse sensitivity.

Key words:piezoresistive acceleration sensor;transverse effect; sensitivity; arrangement of the piezoresistor; finite element simulation; Hoplinson rod
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用于光镊分选基于电力聚焦的微通道单细胞流

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摘要：以电渗透流原理为理论基础，建立二维十字通道几何模型，推导出电力聚焦流理论模型。在 3 个入口流速一定的前提下，中心聚焦流的宽度与入口处的电压比呈一定关系，成功地预测了聚焦流的宽度。随后以 COMSOL Multiphysics 5 3 为仿真软件，设置层流、电流和粒子追踪 3 个物理场，进行了单细胞流仿真。以此为基础，加工出以聚二甲基硅氧烷(PDMS)材料为主体的芯片，并搭载电力聚焦实验平台，进行了验证。仿真和实验数据都验证了在 3 个入口流速一定的前提下，通过调节电压比可以有效控制中心聚焦流宽度及细胞运动速度，形成基本均匀一致的细胞流，为后续细胞光镊分选奠定了理论和实验基础。

关键词：电渗透流；电力聚焦；微通道；细胞流；聚二甲基硅氧烷（PDMS）
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Micro Channel Single Cell Flow Based on Electric Focusing for Optical Tweezers Sorting

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Abstract:With the principle of the electroosmotic flow as the theoretical basis, a two dimensional cross channel geometry model was established, and a theoretical model of the electric focusing flow was derived. On the premise of the constant flow rate at three inlets, the width of the central focusing flow was proportional to the voltage ratio at the inlets, and the width of the focusing flow was predicted successfully. Then three physical fields i e. the laminar flow, current and particle tracking were set up in COMSOL Multiphysics 5 3 simulation software, and the single cell flow simulation was carried out. On this basis, a chip with the polydimethylsiloxane (PDMS) as the main material was fabricated and moun ted on an electric focusing experimental platform for the verification test. The simulation and experimental data verify that the width of the central focusing flow and the movement speed of the cell can be effectively controlled by adjusting the voltage ratio on the premise of the constant flow rate at three inlets, and a substantially uniform cell flow can form, providing the theoretical and experimental foundation for the subsequent cell optical tweezers sorting.

Key words:electroosmotic flow；electric focusing; micro channel; cell flow; polydimethyl siloxane (PDMS)
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MEMS 陀螺仪零偏温度特性分析及性能优化

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摘要：零偏温度漂移是 MEMS 陀螺仪主要误差源之一，对 MEMS 陀螺仪零偏温度漂移误差源进行了分析。检测电路中延时相位的漂移是引起 MEMS 陀螺仪零偏温度漂移的主要原因。自时钟技术基于锁相环原理，将 MEMS 陀螺仪的驱动频率作为锁相环参考频率。陀螺仪检测电路的系统时钟频率跟随 MEMS 陀螺仪驱动频率而变化，两者始终保持固定的比例关系，最大限度地消除了延时相位变化。使用自时钟技术，将 MEMS 陀螺仪零偏温度漂移减小为原来的 2%。

关键词：微电子机械系统（MEMS）；陀螺仪；零偏温度漂移；延时相位；自时钟；锁相环（PLL）
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Bias Temperature Characteristic Analysis and Performance Optimization of the MEMS Gyroscope

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Abstract:The bias temperature drift is one of the main error origins of the micro electromechanical system (MEMS) gyroscope. The error origins of the bias temperature drift of the MEMS gyroscope were analyzed. The drift of the delay phase in the detection circuit is the main reason of the bias temperature drift of the MEMS gyroscope. The self clock technology is based on the phase locked loop, making the driving frequency of the MEMS gyroscope as the reference frequency of the phase locked loop. The system clock frequency of the gyroscope detection circuit will track with the driving frequency of the MEMS gyroscope with a fixed proportional relation toward each other all the time to eliminate the delay phase drift to the greatest extent. By the self clock technology, the bias temperature drift of the MEMS gyroscope reduces to 2% of the original value.

Key words:micro electromechanical system (MEMS); gyroscope；bias temperature drift；delay phase；self clock；phase locked loop (PLL)
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电纺纳米纤维固相微萃取及农残检测应用

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摘要：利用静电纺丝技术制备了聚苯乙烯/氧化石墨烯（PS/GO）纳米纤维固相微萃取(SPME)涂层，分别研究了 GO 浓度对纳米纤维形貌的影响以及解吸温度、GO 浓度和涂层厚度等参数对萃取性能的影响，比较了 PS/GO 纳米纤维、PS/GO 薄膜及聚二甲基硅氧烷（PDMS）薄膜的萃取性能。将 PS/GO 纳米纤维 SPME 与离子迁移谱（IMS）联用，实现了毒死蜱和辛硫磷农药标准品及其混合样品的检测。当萃取时间为 3 min 时，毒死蜱标准品理论检出限为 0 13 μg/kg，线性范围为 6 25~100 μg/kg，相关系数为 0 999 0，相对标准偏差（RSD）小于 14 0%；辛硫磷标准品理论检出限为 0 33 μg/kg，线性范围为 12 50~100 μg/kg，相关系数为 0 999 8，RDS 偏差小于 9 2%。

关键词：静电纺丝；纳米纤维；固相微萃取（SPME）；离子迁移谱(IMS)；有机磷农药（OPP）
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Electrospun Nanofiber Based Solid Phase Microextraction and Pesticides Determination

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Abstract:The electrospun polystyrene/graphene oxide (PS/GO) nanofiber coating for the solid phase microextraction (SPME) was fabricated with the electrospinning technology. Effects of GO concentration on the nanofiber morphology and effects of parameters, such as the desorption temperature, GO concentration and coating thickness, on the extraction performance were investigated, respectively. Besides, the extraction performances among the PS/GO nanofiber, PS/GO film and polydimethylsiloxane (PDMS) film were compared. Organophosphorous pesticide stan dard samples of chlorpyrifos and phoxime and the mixture sample were detected by the combination of the PS/GO nanofiber SPME with the ion mobility spectrometer (IMS). When the extraction time is 3 min, the theory detection limit of 0 13 μg/kg, the linear range of 6 25-100 μg/kg, the correlation coefficient of 0 999 0 and the relative standard deviation (RSD) below 14 0% were obtained for chlorpyrifos standard samples. While the theory detection limit of 0 33 μg/kg, the linear range of 12 50-100 μg/kg, the correlation coefficient of 0 999 8 and the RSD below 9 2% were obtained for phoxime standard samples.

Key words:electrospinning; nanofiber; solid phase microextraction (SPME); ion mobility spectrometer (IMS); organophosphorous pesticide (OPP)
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表面增强喇曼光谱的 Au@SiO2
核壳纳米粒子制备
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摘要：研究了核壳纳米颗粒的表面增强喇曼光谱（SERS），并制备了不同 SiO2 厚度的 Au@SiO2 核壳纳米粒子进行喇曼光谱分析测试。首先，采用化学还原法制备出酒红色的金溶胶溶液。接着，添加不同量的正硅酸四乙酯（TEOS）制备了以 Au 为核、不同厚度 SiO2 为壳包裹的 Au@SiO2 核壳纳米粒子。然后，采用紫外-可见光（UV Vis）和扫描电子显微镜（SEM）对 Au@SiO2 核壳纳米粒子的结构进行表征。最后，不同 SiO2 厚度的 Au@SiO2 核壳纳米粒子和未进行表面修饰的金溶胶溶液中滴入等量质量浓度为 0 1 mg/L 的罗丹明 B，离心干燥后用喇曼光谱仪测试表面增强喇曼光谱效应。结果表明：罗丹明 B 的检出限可达到 2 1×10-7 mol/L，在扫描范围为 300~1 800 cm-1，激发波长为 532 nm 的条件下，SERS 活性随 TEOS 用量的增加先增大后减小。TEOS 的用量为 120 μL 时，罗丹明 B 的表面喇曼增强效应最佳。
关键词：正硅酸四乙酯（TEOS）；SiO2；核壳纳米粒子；表面增强喇曼光谱(SERS)；罗丹明 B
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Preparation of Au@SiO2 Core Shell Nanoparticles with the
Surface Enhanced Raman Spectroscopy
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Abstract: The surface enhanced Raman spectroscopy (SERS) was researched, and Au@SiO2 core shell nanoparticles with different SiO2 thicknesses were prepared for the analysis and test of Raman spectroscopy. Firstly, the wine red Au nanoparticle solution was prepared by the chemical reduction method. And then, different amounts of ethyl silicate (TEOS) were added to prepare Au@SiO2 core shell nanoparticles with Au as the nucleus and SiO2 of different thicknesses as the shell. Subsequently, the structure of Au@SiO2 core shell nanoparticles was characterized by the ultraviolet visible (UV Vis) spectroscopy and scanning electron microscope (SEM). Finally, adding the same amount of rhodamine B with the mass concentration of 0 1 mg/L into Au@SiO2 core shell nanoparticles with different SiO2 thicknesses and the surface unmodified Au nanoparticle solution, then the mixture was centrifugally dried and the surface enhanced Raman spectro scopy (SERS) effect was tested with the Raman spectrometer. The results show that the detection limit of rhodamine B can reach 2 1×10-7 mol/L within the scan range of 300-1 800 cm-1 and the excitation wavelength of 532 nm, the SERS intensity is enhanced firstly and then becomes weaker with the increase of the amount of TEOS. When the dosage of TEOS is 120 μL, the SERS effect of rhodamine B is optimum.
Key words:tetraethyl orthosilicate（TEOS）; SiO2; core shell nanoparticle; surface enhanced Raman spectroscopy (SERS); rhodamine B
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软体机器人制造工艺研究进展

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摘要：综述了软体机器人的制造工艺研究进展及目前主要的应用领域。其中详细介绍了 3D 打印技术、转印技术、形状沉积工艺、智能复合微结构法及微注塑成型等几种软体机器人制造工艺，探讨了各制造工艺的特点及所面临的挑战，并阐述了软体机器人的应用领域，如工业生产、野外勘探、娱乐电子设备及生物医疗等领域，尤其在生物医疗领域软体机器人具有广阔的发展空间。同时，也提出了软体机器人未来可能的发展前景及发展趋势，为软体机器人领域的进一步研究提供了可参考的理论依据。

关键词：软体机器人；3D 打印技术；转印技术；形状沉积工艺；智能复合微结构法
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Research Progress on the Manufacturing
Technology of the Soft Robot

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Abstract:The research progress of the manufacturing technology and main application fields of the soft robots are summarized. Several manufacturing technologies of the soft robots, such as 3D printing technology, transfer printing technology, shape deposition process, smart composite microstructure method and micro injection molding are introduced in detail. The characteristics and challenges of each manufacturing technology are discussed, and the application fields of the soft robots are presented, such as the industrial production, field exploration, entertainment electronic equipment, biomedicine and other fields, especially in the biomedical soft robots with a broad development space. Meanwhile, the development prospect and trend of the soft robots in the future are also put forward, providing a reference theoretical basis for the further research in the field of the soft robots.

Key words:soft robot; 3D printing technology; transfer printing technology; shape deposition process; smart composite microstructure method
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