

硅基片上的中波红外铝线栅偏振器设计

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摘要: 设计了一种 Si 基片上的 Al 线栅偏振器, 在 Al 线栅和 Si 基片间引入一层低折射率 SiO₂ 介质层, 适用于 3~5 μm 的中波红外波段。采用有限时域差分(FDTD)方法, 对 SiO₂ 介质层和金属线栅材料(Al, Au, Ag, Cu 和 Rh)分别进行了优化。SiO₂ 介质层的引入削弱了 Al 线栅和 Si 基片之间界面上激发的表面等离子体激元, 横磁(TM)偏振光的透过率提高, 横电(TE)偏振光的反射增强, 消光比上升。对 Al, Au, Ag, Cu 和 Rh 五种金属线栅材料分析表明, Al 是最合适的材料。当 SiO₂ 介质层厚度为 300 nm、线栅周期为 400 nm 和占空比为 0.5 时, Al 线栅偏振器在 4 μm 波长处的 TM 偏振光的透过率达到 94.8%, 消光比为 28.3 dB, 在 3~5 μm 波段具有良好的偏振性能。

关键词: 线栅偏振器; 硅(Si)基片; 介质层; 铝(Al)线栅; 消光比

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Design of a Mid Infrared Al Wire Grid Polarizer on Si Substrates

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Abstract: An Al wire grid polarizer for the mid infrared band of 3-5 μm was designed with a SiO₂ dielectric layer with low refractive index inserted between Al wire grid and Si substrate. The SiO₂ dielectric layer and metal wire grid materials (Al, Au, Ag, Cu and Rh) were optimized by the finite difference time domain (FDTD) method. The surface plasmon polaritons at the interface between Al wire grid and Si substrate are weakened by the introduction of the SiO₂ dielectric layer, leading to the improvement in the transmittance of transverse magnetic (TM) polarized light and the increases of the reflection of transverse electric (TE) polarized light and extinction ratio. The analyses of different metal wire grid materials (Al, Au, Ag, Cu and Rh) show that Al is the most appropriate material. When the thickness of the SiO₂ dielectric layer is 300 nm, the period of the wire grid is 400 nm and the duty cycle is 0.5, the TM polarized light transmittance and extinction ratio of the Al wire grid polarizer are 94.8% and 28.3 dB at the wavelength of 4 μm, respectively. The Al wire grid polarizer has excellent polarization performance in the wavelength range of 3-5 μm.

Key words: wire grid polarizer; Si substrate; dielectric layer; Al wire grid; extinction ratio

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具有窄带透明窗口的金属纳米颗粒流体吸收器

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摘要: 为了解决金纳米颗粒在构建金属流体时存在的紫外-蓝光波段吸收较弱的问题, 提出可采用由种子生长法制备的金核银壳纳米棒, 该结构可将金纳米棒的局域表面等离子共振 (LSPR) 移向紫外-蓝光波段, 在有效增强这一波段光吸收的同时, 不会影响透明窗口的透射率。实验结果表明, 这种由不同尺寸的金纳米棒和金核银壳纳米棒所构成的胶体溶液, 能够使紫外-蓝光波段透射率降低到 1% 以下, 在 300~1100 nm 光谱范围内实现了较好的宽带吸收, 同时在中心波长 730 nm 附近获得了一个透明窗口, 其带宽约为 150 nm, 透射率大于 40%。这种由贵金属纳米颗粒胶体溶液所构成的具有窄带透明窗口的流体吸收器的制备方法相对简单, 有望用于太阳能电池、传感等领域。

关键词: 金属纳米颗粒; 表面光学; 局域表面等离子共振 (LSPR); 金属流体; 透明窗口
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Metal Nanoparticle Fluid Absorber with Narrow Band
Transparent Window

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Abstract: In order to solve the problem of weak absorption of gold nanoparticles in the ultraviolet blue band during the construction of metal fluid, the Au core Ag shell nanorods prepared by the seed mediated growth method were used to adjust the localized surface plasmon resonances (LSPR) of gold nanorod to the ultraviolet blue spectral range. The corresponding absorption can be effectively enhanced without affecting the transmissivity of the transparent window at the same time. The experimental results indicate that by using the colloidal solutions composed of gold nanorods and Au core Ag shell nanorods with different sizes, the transmissivity in the ultraviolet blue spectral range can be reduced to less than 1%, and the good broadband absorption is achieved at the spectral range of 300-1100 nm. A transparent window is obtained at the center wavelength of around 730 nm, the bandwidth is about 150 nm and the transmissivity is larger than 40%. The preparation method of the fluid absorber with narrow band transparent window made up of noble metal nanoparticles colloid solution is relatively simple, and is expected to be used in the fields of solar cells and sensing.

Key words: metallic nanoparticle; surface optics; localized surface plasmon resonance (LSPR); metal fluid; transparent window

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TiO₂ 纳米管阵列的电化学自掺杂及电容特性

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摘要: 阳极氧化钛箔合成高度有序的 TiO₂ 纳米管阵列。通过电化学自掺杂的方法对原始 TiO₂ 纳米管阵列电极进行改性, 研究了不同掺杂条件对 TiO₂ 纳米管阵列电极电化学性能的影响, 探索了电化学自掺杂的最佳实验参数。实验结果表明: 电化学未掺杂的原始 TiO₂ 纳米管阵列电极表现出的最大比电容仅为 1 55 mF · cm⁻², 在 25 °C 下 0 5 mol/L 的 Na₂SO₄ 溶液中, 施加 5 V 电压掺杂 30 s 后, TiO₂ 纳米管阵列电极导电性显著增强, 比电容可达到 22 17 mF · cm⁻², 是原始 TiO₂ 纳米管阵列电极比电容的 14 3 倍, 电化学自掺杂显著提高了 TiO₂ 纳米管的导电性及电容性能。同时, 电化学自掺杂不会损坏或改变 TiO₂ 纳米管的形貌和晶体结构。

关键词: TiO₂ 纳米管; 阳极氧化; 电化学自掺杂; 电化学性能; 晶体结构

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Electrochemical Self Doping and Capacitance Characteristics of

TiO₂ Nanotube Arrays

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Abstract: Highly ordered TiO₂ nanotube arrays were synthesized by the anodization of Ti foils. The pristine TiO₂ nanotube array electrodes were modified by electrochemical self doping method. The effects of different doping conditions on the electrochemical performances of TiO₂ nanotube array electrodes were studied. The optimum experimental parameters of electrochemical self doping were explored. The experimental results show that the pristine TiO₂ nanotube array electrodes exhibit the maximum specific capacitance of 1 55 mF · cm⁻². After applying 5 V self doping voltage for 30 s in 0 5 mol/L Na₂SO₄ solution at 25 °C, the conductivity of TiO₂ nanotube array electrodes significantly improves, exhibiting an outstanding specific capacitance of 22 17 mF · cm⁻², which is 14 3 times that of the pristine TiO₂ nanotube array electrodes. The electrochemical self doping significantly improves the conductivity and capacitive properties of TiO₂ nanotubes. At the same time, the morphology and crystal structure of the TiO₂ nanotubes are not damaged or changed during the electrochemical self doping process.

Key words: TiO₂ nanotube; anodization; electrochemical self doping; electrochemical performance; crystal structure

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柠檬酸镁掺杂的葡萄糖基电极材料的 制备及电化学性能

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摘要: 以葡萄糖为前驱体、柠檬酸镁为模板, 先预碳化再结合 KOH 活化制备高性能多孔碳电极材料。通过扫描电子显微镜 (SEM) 研究掺杂柠檬酸镁前后样品的形貌结构, 发现通过柠檬酸镁模板法制备的活性炭孔径分布更为均匀。通过氮气吸脱附测试发现, 以柠檬酸镁为模板, 活性炭的比表面积由 $135.6 \text{ m}^2/\text{g}$ 提高到 $326.13 \text{ m}^2/\text{g}$ 。电化学测试结果表明, 以柠檬酸镁为模板, 电极材料的双电层电容特性得到明显提高。在电流密度为 0.5 A/g 时, AC/Mg 的比电容 139.88 F/g 远大于 AC 的比电容 31 F/g ; 在 10 A/g 的电流密度下, AC 比电容保持率为 72.5% , AC/Mg 比电容保持率增加到 87% , 电极材料的电阻从 1589Ω 下降到 1021Ω , 具有更好的导电性, 在进行了 5000 圈循环测试后, AC/Mg 比电容保持率仍为 96% 。

关键词: 葡萄糖; 柠檬酸镁; KOH 活化; 电极材料; 活性炭

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Preparation of the Glucose Based Electrode Material Doping with
Magnesium Citrate and Its Electrochemical Properties

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Abstract: The high performance porous carbon electrode materials were prepared by the pre carbonization and KOH activation with glucose as the precursor and magnesium citrate as the template. The morphology structures of the samples before and after doping magnesium citrate were researched by the scanning electron microscope (SEM). It is found that the pore size distribution of the activated carbon prepared by magnesium citrate template method is more uniform. Through the nitrogen absorption-desorption test, it is found that the specific surface area of the active carbon increases from $135.6 \text{ m}^2/\text{g}$ to $326.13 \text{ m}^2/\text{g}$ with magnesium citrate as the template. The electrochemical test results show that the double layer capacitance characteristic of the electrode material is obviously improved with magnesium citrate as the template. When the current density is 0.5 A/g , the specific capacitance of AC/Mg is 139.88 F/g , which is much greater than the AC specific capacitance of 31 F/g . When the current density is 10 A/g , the specific capacitance retention rate of AC is 72.5% and that of AC/Mg increases to 87% . The resistance of the electrode material decreases from 1589Ω to 1021Ω , showing the better conductivity. After the 5000 cycles test, the specific capacitance retention rate of AC/Mg is still 96% .

Key words: glucose; magnesium citrate; KOH activation; electrode material; activated carbon

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基于 PDMS 的柔性可穿戴微带天线

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摘要: 提出了一种新型柔性微带天线, 具有结构简单、质量轻、易共形和可穿戴的功能, 且易于与衣物集成。该天线是以柔性材料聚二甲基硅氧烷(PDMS)为介质基底, 以金属镍为辐射贴片, 将镍覆于介质基底两侧, 设计了 E 形辐射贴片和矩形金属地, 并基于微机电系统(MEMS)加工工艺进行加工制造, 经测试取得了良好的效果。仿真结果表明, 该天线的谐振频率为 13.5 GHz, 带宽为 2.0 GHz。在平放和弯曲的状态下分别进行了测试, 测得的谐振频率为 12.8 GHz, 带宽为 1.2 GHz, 谐振频率的测试结果变化范围较小, 测试结果良好, 说明该柔性天线可实现弯曲的性能且谐振频率和带宽比较稳定。该天线的仿真和测试结果都体现出良好的阻抗匹配性和稳定的辐射方向性, 为天线与电子设备的集成化提供了参考。

关键词: 可穿戴微带天线; 柔性天线; 聚二甲基硅氧烷(PDMS); 微机电系统(MEMS); 镍

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Flexible Wearable Microstrip Antenna Based on PDMS

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Abstract: A novel flexible microstrip antenna was proposed. The unique advantages of the antenna are simple structure, light weight, easy to be conformable and wearable, and easy to integrate with clothing. The antenna was based on a flexible material of polydimethylsiloxane (PDMS) as the dielectric substrate and with the metal nickel as a radiation patch. Nickel was covered on both sides of the dielectric substrate. The E type radiation patch and rectangular metal ground were designed. And the antenna was fabricated based on the micro electromechanical system (MEMS) processing technology and was obtained good results through testing. The simulation results show that the resonant frequency and bandwidth of the antenna are 13.5 GHz and 2.0 GHz, respectively. The performances of the antenna in the flat and bent states were measured, respectively. The measured resonant frequency is 12.8 GHz and the bandwidth is 1.2 GHz. The measured results of the resonant frequency have a small variation range and the measured results are good, which shows that the flexible antenna can achieve the bending performance, and the resonant frequency and the bandwidth are relatively stable. The simulation and measured results of the antenna show good impedance matching performance and stable radiation directivity, providing a reference for the integration of antennas and electronic equipment.

Key words: wearable microstrip antenna; flexible antenna; polydimethylsiloxane (PDMS); micro electromechanical system (MEMS); nickel

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基于 MEMS 的原位液体 TEM 芯片的设计与制作

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摘要: 传统透射电子显微镜 (TEM) 观察液态样品特征时, 通常将其先速冻成固态, 而原位 TEM 可以动态地观察液态样品的变化, 避免了一些额外因素的影响。设计了一款基于微机电系统 (MEMS) 技术的非流动原位液体 TEM 芯片, 用于对液态样品结构动态变化的实时观测。采用低压化学气相沉积 (LPCVD) 法制备 50 nm 厚的低应力氮化硅薄膜作为芯片的电子束透射窗的材料, 并在窗口层上面制作金属网格来加固其承载能力, 采用 MEMS 技术完成了芯片的制造。实验结果表明, TEM 芯片在相应的 TEM 样品杆的辅助下, 成功实现了对铜纳米粒子生长过程中形态变化的实时观测。

关键词: 原位透射电子显微镜 (TEM); 微机电系统 (MEMS); 低应力氮化硅; 液体 TEM 芯片; 铜纳米粒子

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Design and Fabrication of an In Situ Liquid Cell

TEM Chip Based on MEMS

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Abstract: The liquid samples are usually frozen into solid state for observing their characteristics by the traditional transmission electron microscopy (TEM). The in situ TEM can directly observe the change of liquid samples to avoid the effects of some additional factors. In order to observe the real time structure dynamic changes of liquid samples, an in situ non flow liquid cell TEM chip based on micro electromechanical system (MEMS) was designed. The low stress silicon nitride membrane with a thickness of 50 nm was prepared by the low pressure chemical vapor deposition (LPCVD) method, which was used as a material for the electron beam transmission window of the chip, and the metal grid was made on the window layer to strengthen its bearing capacity. The chip was fabricated by MEMS technology. The experiment results show that during the growth of copper nanoparticles, the real time observation of morphology changes is successfully realized by the TEM chip assisted with the corresponding TEM sample rod.

Key words: in situ transmission electron microscopy (TEM); micro electromechanical system (MEMS); low stress silicon nitride; liquid TEM chip; copper nanoparticle

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基于掺铒光纤谐振腔的谐振式光学陀螺

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摘要: 谐振式光学陀螺 (ROG) 是以谐振腔为基础的角速度传感器件, 因此其受到光学谐振腔性能的制约。当光学谐振腔中不存在增益补偿机制时, 由于谐振腔制备材料的固有属性, 光在光学谐振腔中的损耗仍然是阻碍谐振式光学陀螺性能提升的关键因素之一。为了提升谐振式光学陀螺的性能, 提出利用掺铒光纤的增益补偿作用减小光在谐振腔中的损耗, 并对其相应的陀螺系统进行了验证。在光学谐振腔直径为 10 cm、腔长为 4.5 m、掺铒光纤长度为 14 cm、泵浦功率为 40.6 mW 的条件下, 光学谐振腔的品质因数达到了 8.3×10^8 , 同时得到谐振式光学陀螺的零偏稳定性为 $0.24^\circ/\text{s}$, 理论的极限灵敏度提升到了 $0.0126^\circ/\text{h}$ 。

关键词: 掺铒光纤; 光学谐振腔; 谐振式光学陀螺 (ROG); 零偏稳定性; 极限灵敏度

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Resonant Optical Gyroscope Based on Erbium Doped
Fiber Resonant Cavity

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Abstract: The resonant optical gyroscope (ROG) is an angular velocity sensing device based on the resonant cavity, which is restricted by the performance of the optical resonant cavity. Due to the inherent properties of fabricated materials for the resonant cavity, the loss of light in the optical resonant cavity is still one of key factors hindering the performance improvement of the ROG when there is no gain compensation mechanism in the optical resonant cavity. To improve the performance of the ROG, it was proposed that the loss of light in the resonant cavity was decreased by erbium doped fiber with the gain compensation mechanism, and the gyroscope system based on the erbium doped fiber was verified. The quality factor of the optical resonant cavity is 8.3×10^8 under the conditions of the optical resonant cavity diameter of 10 cm, cavity length of 4.5 m, erbium doped fiber length of 14 cm and pump power of 40.6 mW. Meanwhile, the zero bias stability of $0.24^\circ/\text{s}$ is obtained for the ROG, and the theoretical limited sensitivity can be improved to $0.0126^\circ/\text{h}$.

Key words: erbium doped fiber; optical resonant cavity; resonant optical gyroscope (ROG); zero bias stability; limited sensitivity

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MEMS 陀螺仪振动特性分析及性能优化

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摘要: 谐振式 MEMS 陀螺仪在随机振动中会发生性能退化, 主要表现为噪声增大、零偏变化及标度因数降低。研究了陀螺仪的振动模态, 发现当正交耦合和电容不对称时, 检测模态及检测同相模态极易被激发。被激发的两种信号会占用有限的 C/V 检测信道, 引起信道饱和, 造成标度因数变小, 同时还会引起振中噪声变大和零位变化。从加工工艺和 MEMS 设计两方面提出提高陀螺仪振动性能的方法。优化后陀螺仪振中噪声降为优化前的 1/10, 振中零位差降为原来的 1/5, 标度因数降低的现象完全消失。

关键词: 微电子机械系统 (MEMS); 陀螺仪; 振动; 正交耦合; 标度因数; 噪声

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Vibration Characteristic Analysis and Performance

Optimization of MEMS Gyroscope

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Abstract: The performance of the resonance MEMS gyroscope will degenerate in random vibration. The main representations are noise increasing, bias changing and scale factor decreasing. The vibration modes of the gyroscope were investigated. The sense mode and sense in phase mode are easily excited under the condition of orthogonal coupling and asymmetry capacitance. The two signals will occupy the finite C/V sense channel to make the channel saturation, scale factor smaller, noise increasing and bias changing during the vibration. The methods to improve the vibration performance of the gyroscope were proposed from two aspects of the manufacture process and MEMS design. After optimization, the noise and bias changing during the vibration of the gyroscope reduce to 1/10 and 1/5 before the optimization, respectively, and the phenomenon of scale factor decreasing completely disappears.

Key words: micro electromechanical system (MEMS); gyroscope; vibration; orthogonal coupling; scale factor; noise

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用于固态纳米孔制备的单层 WS₂ 薄膜转移技术

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摘要: 由于单层 WS₂ 薄膜转移技术的限制, 使基于 WS₂ 的固态纳米孔精确构筑成为了技术难题, 限制了 WS₂ 等新型二维材料在固态纳米孔 DNA 测序领域的应用。在可控生长 WS₂ 单层薄膜的基础上, 以在 SiO₂/Si 衬底上生长的单层 WS₂ 薄膜为研究对象, 通过改进传统的聚甲基丙烯酸甲酯(PMMA)辅助湿法转移技术, 成功地将单层 WS₂ 薄膜精确转移至纳米/微米级 Si₃N₄ 窗口上。本方法具有可重复性好和操作简便等特点, 特别适合小尺寸薄膜的精确转移, 可推广至其他二维材料的应用, 进而推动基于二维材料的固态纳米孔 DNA 测序技术的发展。

关键词: 二硫化钨 (WS₂); 固态纳米孔; 转移技术; 氮化硅 (Si₃N₄); DNA 测序

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WS₂ Monolayer Transfer Technique for Fabrication of

Solid State Nanopores

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Abstract: Due to the limit of transfer technique for WS₂ monolayer, the precise fabrication of WS₂ solid state nanopores has been hindered, which can be a barrier for the application of WS₂ and other two dimensional materials in DNA sequencing. Based on the controllable growth of WS₂ monolayer, the WS₂ monolayer grown on SiO₂/Si substrate was precisely transferred onto a nano/micro sized Si₃N₄ window by the modified polymethyl methacrylate (PMMA) assisted wetting transfer technique. The method has good repeatability and easy operating, and quite suitable for the accurate transfer of small sized membranes, which can promote the application of other two dimensional materials, thus facilitate the development of solid state nanopore DNA sequencing based on two dimensional materials.

Key words: WS₂; solid state nanopore; transfer technique; Si₃N₄; DNA sequencing

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电镀镍磷层及其在薄膜剥离中的应用

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摘要: 利用柔性压电薄膜为能量采集器供电在微电子机械系统(MEMS)领域应用越来越广泛, 通过电镀应力层剥离制备薄膜是近年来广受关注的一种方法。通过在氯化镍电镀液中加入不同质量浓度的磷离子和控制不同的电流密度, 在铜片上电镀得到不同的镍磷镀层。对镀层进行共聚焦显微镜观测、台阶仪测量厚度、镍磷层内应力计算、X射线衍射(XRD)和X射线能谱仪(EDS)分析, 结果表明: 电流密度恒定为10 mA/cm², 磷离子质量浓度由0~0.04 g/L的变化过程中, 镍磷层内应力由112 MPa增加到322 MPa, 而磷离子质量浓度高于0.04 g/L后, 内应力减小, 镀层含磷原子数分数逐渐升高; 磷离子质量浓度恒定为0.04 g/L, 电流密度由5 mA/cm²增加到20 mA/cm²时, 镍磷层内应力从181 MPa增加到343 MPa, 而电流密度高于20 mA/cm²后, 内应力逐渐减小, 镀层含磷原子数分数逐渐降低。之后通过控制电镀条件利用电镀镍磷层应力从硅基底成功剥离制备硅薄膜。

关键词: 微电子机械系统(MEMS); 柔性压电薄膜; 电镀; 剥离; 硅(Si)

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Electroplated Nickel Phosphorus Layer and Its Application in Film Stripping

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Abstract: Using flexible piezoelectric films to power energy collectors is more and more widely applied in the field of micro electromechanical systems (MEMS). The method for stripping and preparing a thin film by electroplating stress layer has drawn extensive attention in recent years. The electroplated nickel phosphorus layers on the copper plates were gotten by adding different mass concentrations of phosphorus ions to the nickel chloride electroplating solution and controlling different current densities. The observation of the confocal microscopy, thickness measurement by the step profiler, calculation of the internal stress of the Ni-P layer, analyses of X-ray diffraction (XRD) and X-ray energy dispersive spectroscopy (EDS) were used to obtain the parameters of electroplated coatings. The results show that when the current density is constant at 10 mA/cm² and the mass concentration of the phosphorus ion varies from 0 to 0.04 g/L, the internal stress of the Ni-P layer increases from 112 MPa to 322 MPa. While the mass concentration of the phosphorus ion is higher than 0.04 g/L, the internal stress decreases and the atomic number fraction of phosphorus in the electroplated coating gradually increases. When the mass concentration of phosphorus ion is constant at 0.04 g/L and the current density increases from 5 mA/cm² to 20 mA/cm², the internal stress of the Ni-P layer increases from 181 MPa to 343 MPa. While the current density is higher than 20 mA/cm², the internal stress gradually decreases and the atomic number fraction of phosphorus in the Ni-P layer gradually reduces. Then the silicon films were successfully stripped from the silicon substrate using the stress of the electroplated Ni-P layer by controlling electroplating conditions.

Key words: micro electromechanical system(MEMS); flexible piezoelectric film; electroplating; stripping; silicon(Si)

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纳米银导电墨水的制备及烧结

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摘要: 通过液相化学还原法制备了纳米银颗粒, 纯化后通过 X 射线衍射 (XRD) 和能量色散谱 (EDS) 分析证明得到了结构完整、较为纯净的纳米银颗粒。将其制备为纳米银导电墨水, 墨水的粒度分布窄、平均粒径约为 25 nm、分散性好, 表面张力为 32.13 dyn/cm ($1 \text{ dyn/cm} = 0.001 \text{ N/m}$)、黏度为 $4.66 \text{ mPa} \cdot \text{s}$, 符合喷墨打印对于墨水的要求。将墨水喷印在聚酰亚胺 (PI) 基材上, 分别在 125, 150, 175, 200 和 225 °C 下烧结 30 min, 然后测量导电路径的电阻率, 发现 150 °C 下烧结电阻率为 $5.72 \times 10^{-4} \Omega \cdot \text{cm}$, 已满足电子电路印刷需求, 随着烧结温度的提升, 电阻率也不断下降, 225 °C 下烧结, 电阻率达 $1.53 \times 10^{-5} \Omega \cdot \text{cm}$; 同时对其烧结过程进行了分析, 探究了导电路径中不导电组分的挥发及纳米银的熔融程度对电阻率的影响。

关键词: 喷墨打印; 纳米银; 导电墨水; 烧结; 电阻率

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Preparation and Sintering of Nano Silver Conductive Ink

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Abstract: The silver nanoparticles were prepared by the liquid phase chemical reduction method. The X ray diffraction (XRD) and energy dispersive spectroscopy (EDS) analyses prove that the structurally complete and pure silver nanoparticles are obtained after purification. The nano silver conductive ink prepared by the silver nanoparticles has a narrow particle size distribution with an average particle size of about 25 nm and good dispersion. Its surface tension is 32.13 dyn/cm ($1 \text{ dyn/cm} = 0.001 \text{ N/m}$) and viscosity is $4.66 \text{ mPa} \cdot \text{s}$. The properties of the ink meet the requirements of inkjet printing. The ink was patterned on polyimide (PI) substrate by ink jet printing and sintered for 30 min at 125, 150, 175, 200 and 225 °C, respectively. Then the resistivity of the conductive circuit was measured. The resistivity is $5.72 \times 10^{-4} \Omega \cdot \text{cm}$ at the sintering temperature of 150 °C, which meets the demand of electronic circuit printing. The resistivity constantly decreases with the increase of the sintering temperature. The resistivity reaches $1.53 \times 10^{-5} \Omega \cdot \text{cm}$ at the sintering temperature of 225 °C. The sintering process was analyzed, and the effects of the volatilization of non conductive components and the melting degree of nano silver on the resistivity in the conductive circuit were discussed.

Key words: inkjet printing; nano silver; conductive ink; sintering; resistivity

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TMAH 湿法腐蚀工艺制备微台面结构

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摘要: 针对目前四甲基氢氧化铵 (TMAH) 湿法腐蚀工艺制备微台面结构工艺可控性差、需要添加添加剂、溶液使用周期短及工艺维护繁琐、无法实现大尺寸晶圆工程化应用等问题, 研究了无添加剂时, 微台面的腐蚀形貌与 TMAH 溶液质量分数和循环速率之间的关系, 提升了大尺寸晶圆凸角腐蚀尺寸的均匀性及表面质量, 6 英寸 (1 英寸=2.54 cm) 硅晶圆内, 凸角腐蚀尺寸不均匀性小于 5%, 台面高度不均匀性小于 3%, 且腔体底部平整光亮, 腐蚀速率较快, 实现了工程化应用。当 TMAH 溶液 pH 值为 12.2~12.6 时, 微台面结构制备工艺稳定可控、维护简单, 实现了高质量微台面结构的可批量化生产。

关键词: 四甲基氢氧化铵 (TMAH); 湿法腐蚀; 微台面结构; 凸角; 黑点; 循环速率; 不均匀性

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Preparation of Micro Mesa Structure Using
TMAH Wet Etching Process

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Abstract: For the problems of the poor process controllability of micro mesa structure prepared by tetramethylammonium hydroxide (TMAH) wet etching process, needing additives, short period of use for solution and tedious process maintenance, it is unable to realize the engineering application of large size wafers. The relationships among the corrosion morphology of micro mesa structure, the mass fraction and cycle rate of TMAH solution without additives were studied. The uniformity of corrosion size of convex corner and the surface quality for large size wafers are improved. On the 6 inches (1 inch=2.54 cm) silicon wafer, the non uniformity of corrosion size of convex corner and the non uniformity of mesa height are less than 5% and 3%, respectively. The bottom surface of the cavity is flat, and the corrosion rate is rapid, realizing the engineering application. When the pH value of the TMAH solution is 12.2-12.6, the preparation process of the micro mesa structure is stable and controllable with simple maintenance, and the mass production of high quality micro mesa structures can be realized.

Key words: tetramethylammonium hydroxide (TMAH); wet etching; micro mesa structure; convex corner; black dot; cycle rate; non uniformity

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