

离子注入型半导体 γ 辐射探测器

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关键词: 离子注入 半导体探测器

离子注入探测器在能量分辨率测量上虽然还赶不上面垒型探测器,但在位置灵敏探测上确大有作为,有人还用它做了P-I-N电流型探测器。国外在六十年代后期开始研制工作^[1,2]。国内于七十年代后期也开展了上面两种探测器的研制^[3,4]。八十年代美国ORTEC公司已有商品出售,本文介绍一种在野外较恶劣环境条件下用作剂量测量的(也可用于射线监测的)离子注入 γ 射线探测器^[5]。

一、探测器的制备

材料为N型区熔单晶硅,电阻率为5000—10000 Ωcm ,少数载流子寿命为1000—800 μs ,电阻率不均匀性 $\leq \pm 20\%$,无位错,晶向 $\langle 111 \rangle$ 。制备探测器的工艺流程如下:

Si单晶→切片→割圆→粗磨→细磨→倒角→镜检→清洗→腐蚀→清洗→烘干→粘掩膜→
中检→环托清洗→壳垫圈清洗
装盘→注入→清洗→退火→镜检→去氧化层→粘环托→涂烘胶→蒸发→中测→装壳→中测→
灌封→总测

用内圆切片机将硅单晶切成0.8—0.85mm厚的薄片(对厚度公差、平行度、弯曲度晶向角、有一定要求),然后进行粗、中、细磨,磨料为M28、M14、M5,对三道磨片均有厚度要求,最终厚度为0.65—0.70mm。在大圆片边缘2mm以内用金刚砂刀具割成 $\phi 12$ 的小圆片并一面倒角,用25倍显微镜检查小片的表面质量,合格后进行清洗。方法是酸煮—水洗—有机溶剂超声清洗(全部清洗用聚四氟乙烯托进行)。对烘干、冷却后的硅片立即进行腐蚀,使其成镜面,厚度达0.59—0.64mm(腐蚀条件要严格控制)。

注入离子为 B^+ 和 P^+ ,以形成P-N-N⁺结构。其注入参数和条件如下表。

离子种类	注入能量 (keV)	注入剂量 (个/ cm^2)	束流密度 ($\mu\text{A}/\text{cm}^2$)	真空度 (mmHg)
B^+	36—37	$5-15 \times 10^{13}$	0.1—0.2	$< 2 \times 10^{-5}$
P^+	37.60	$1-5 \times 10^{15}$	0.8—1.6	$< 1 \times 10^{-5}$

经过严格的清洗后,在400 $^{\circ}\text{C}$ 真空条件

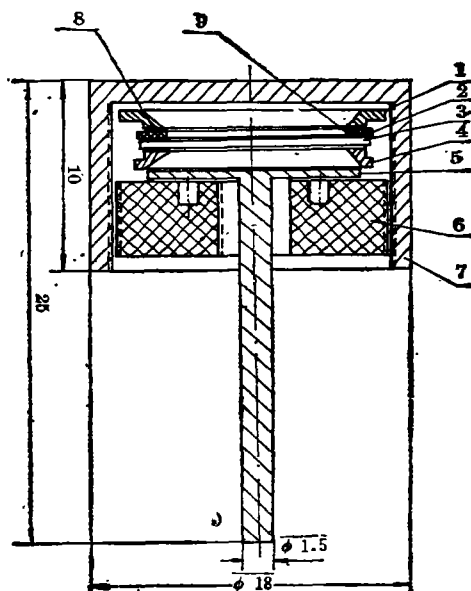


图 探测器结构示意图

1.4. 前、后托 2. 绝缘环 3. 硅片 5. 后电极引线 6. 后盖 7. 外壳 8. 粘胶 9. 搭桥胶

下进行了三十分钟的退火。退火后对样片进行物理参数检查,结果如下:少数载流子残余寿命约 $7.5\mu\text{s}$,结深约 $3400\text{\AA}$,表面薄层电阻率约 $30000\text{--}28000\Omega\text{cm}$ (注 B^+ 面),和 $600\Omega\text{cm}$ (注 P^+ 面)。此外,再用离子探针检查注入的杂质浓度分布情况。

去氧化层前的镜检工序对后道工序的成功率是有益的。片子经过去氧化层和严格清洗之后,先后把已粘有绝缘环的管芯前后托用胶粘在片子的两面,然后再涂上搭桥胶,按一定温度烘烤后前面蒸铝后面蒸金。中测合格后,装壳灌封成管。其结构见图。

二、探测器的性能

当工作电压为 45V 时,室温下的漏电流 $<0.3\mu\text{A}$;当卡本底计数 $<0.3\text{cps}$ 时,噪声阈等效能量约为 50keV ,对 ^{60}Co γ 射线灵敏度 $>2000\text{cps}/(\text{R}\cdot\text{h})$;当阈值提高到 80keV 时,灵敏度大于 $1500\text{cps}/(\text{R}\cdot\text{h})$ 。量程线性从 $10\text{mR}\cdot\text{h}^{-1}\text{--}3\text{R}\cdot\text{h}^{-1}$ 是很好的,如果改善测试仪器,上限还可提高半个数量级。由于采用了 0.15mm 厚的铝壳前窗,故可用 β 源检查探测器好坏。探测器可在 $-40\text{--}+50^\circ\text{C}$ 温度范围内工作,在 $+40^\circ\text{C}$ 相对湿度 $95\pm(2\text{--}3)\%$ 条件下连续存放48小时,性能不变;在 $+50^\circ\text{C}$ 和 -40°C 高低温分别存放2小时后性能不变。经过 50°C 至 -40°C 的热冲击(循环间隔3分钟,每个温度下稳定15分钟,循环三次)后性能无明显变化。能经受加速度 $15g$,频率 $70\text{--}80\text{Hz}$,2000次的冲击和加速度 $4g$,频率 $30\text{--}50$,2小时的振动。

三、结 束 语

在探测器制备过程中,除了注入前后的严格有效的清洗以外,对于硅片表面的质量、整个封装工段的湿度控制是不容忽视的。

在试制过程中,利用P型材料和二次注入工艺以及管芯背面取消绝缘环的结构等情况,也制出了合格的管子。从退火温度实验中,初步得出了 850°C 比 650°C 、 500°C 、 400°C 下退火效果好的结论。在注入层杂质分析中,发现在注入区中仅有微小区域硼含量高些,绝大部分区域硼含量低于 10ppb ;注入表面浓度在同一微小区域也不同。说明注入的不完整性和不均匀性。

降低表面漏电流以减少探测器的噪声是设计和工艺的中心环节,在野外较恶劣环境下应用的射线探测器要求有良好的壳设计和封装工艺。该探测器便于检修,抗恶劣环境性能好。

在研制过程中,曾先后得到中国科学院兰州近代物理所、邮电部508厂、北京师范大学低能核物理研究所、北京测试中心等单位大力协助,在此表示衷心感谢。

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(1985年3月8日收到)

analysis technique is used to study γ -ray energies, relative intensities and half-lives of gas radioisotopes produced by nuclear reaction.

From γ -ray multispectra of ^{23}Ne isotope produced by reaction $^{23}\text{Na}(n,p)^{23}\text{Ne}$, the half-life of 37.3 ± 0.7 s and γ -ray energies of ^{23}Ne were determined. The results are well consistent with the values given in literatures.

Keywords: gas transport system Ge(Li) detector
multispectra analysis technique

A method for calculating two-cylinder lenses and three element einzel lenses with transfer matrices

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The axial potential functions, the axial electric field intensities and the second derivatives of the axial potential functions for two-cylinder lenses and three element einzel lenses are discussed. The transfer matrices for these lenses have been described. The transportation of the intensity of the charged particles in our 2.5 MeV Van de Graaff accelerator has been calculated.

Keywords: two-cylinder lenses three element einzel lenses axial potential function transfer matrix

High resolution HPGe detector and its stability

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After storing the HPGe detector at room temperature for 1056 hours and circulating 15 times from room temperature to liquid nitrogen temperature, the performances of the detector is still excellent. FWHM of 169.1 eV and 408 eV is obtained for ^{55}Fe (5.9 keV) and ^{241}Am (59.5 keV), respectively.

Keywords: HPGe detector energy resolution stability

Ion-implanted semiconductor γ radiation detector used for the purposes of radiation monitoring

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This paper represents a method of preparation of ion-implanted semi-conductor γ

radiation detector used for the purposes of radiation monitoring. The electrical and dosimetric performances of the detector are also introduced. They are specially suitable for the application in rugged field conditions.

Keywords: γ radiation detector semiconductor detector

Dependence of response of plastic track detector CR-39 (DOP) on registration temperature

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The dependence of response of plastic track detector CR-39 (DOP) on registration temperature by means of a new type of cryostat was reported.

Keywords: plastic track detector dependence of response on registration temperature

Data handling machine of thyroid gland function instrument

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A data handling machine of thyroid gland function instrument has been designed and tested. It can calculate absorbing iodine rate and restrain rate of thyroid gland automatically.

Keywords: thyroid gland absorbing iodine rate
restrain rate data handling machine

The on-line separation of Hf and Ta isotopes in the heavy ion reactions by thermochromatographic method

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The on-line separation of Hf and Ta produced by the reactions of $^{163}\text{Dy}(^{12}\text{C}, \text{xn})$ Hf and $^{165}\text{Ho}(^{12}\text{C}, \text{xn})$ Ta, respectively, have been carried out and the separating conditions have been discussed. From the experimental results one can see that it is