课程编号 1800450034

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**深 圳 大 学 实 验 报 告**

**课程名称：­ 大学物理实验（二）**

**实验名称： 霍尔效应及其应用**

**学 院： 电子与信息工程学院**

**指导教师： 郭志男**

**报告人： 王俊彬 组号： 7**

**学号 2020282017 实验地点 致原楼214**

**实验时间： 2021 年 12 月 21 日**

**提交时间： 2021 年 12 月 21 日**

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| 1. 实验目的 2. 了解产生霍尔效应的物理过程。 3. 学习用霍尔元件测量长直螺线管的轴向磁场分布。 4. 学习“对称测量法”消除负效应的影响，测量试样的VH—IS 和VH—IＭ曲线。 5. 确定试样的导电类型、载流子浓度以及迁移率 |
| 1. 实验原理 2. 霍尔效应原理     如图所示，一块长为l、宽为b、厚度为d的半导体薄片置于磁场中，磁感应强度B垂直于半导体薄片，在半导体薄片的横向上加载工作电流Is,在薄片的纵向两侧会出现一个电压,这种现象叫霍尔效应，称为霍尔电压。  实验表明：在磁场不太强时，与工作电流Is、磁感应强度的大小B成正比，与薄片厚度d成反比，即  式中叫霍尔系数。  雷尔效应可用洛仑兹力来解释。设半导体薄片内载流子的定向漂移速率为v,那么载流子所受洛仑兹力为  因v和B垂直，所以,在洛仑兹力的作用下，电子向一侧漂移，结果在两侧分别聚集了正负电荷，在之间建立了静电场，形成电势差。静电场会阻碍电子的继续漂移，当静电场力和洛仑兹力达到平衡时，电子不再侧向漂移，电势差达到恒定状态，此时  设载流子浓度为n,则电流Is和载流子定向漂移速率v的关系为  将（4）代入（3）得  对比式（1）和（5）可知霍尔系数为  式(6)表明，霍尔系数和载流子浓度有关。半导体的载流子浓度比金属导体的载流子浓度小得多，因而半导体的霍尔系数比导体大得多，半导体的霍尔效应较为显著，而导体几乎观察不到该效应。通过测量材料的霍尔系数可以确定材料的载流子浓度，因此霍尔效应是研究载流子浓度的一个重要方法。  由式（5）还可看出，半导体薄片的厚度d越小，霍尔效应越显著，所以霍尔器件通常做得很薄。式（5）中叫霍尔器件的灵敏度，用表示：  式(5)可以写成  若已知KH(一般由仪器生产厂家给出）,通过测量霍尔电压UH和工作电流Is可以求出磁感应强度的大小，这就是霍尔片测磁场的原理。  半导体的载流子有正有负，A、A'之间的电势差（即霍尔电压）UH与载流子的正负有关。当载流子是正（空穴导电——P型半导体）时，载流子定向漂移的速度方向与电流方向相同，洛仑兹力使它向上偏转，结果是端电势高于A端，如图3-1-2(a)所示；当载流子是负（电子导电——N型半导体）时，载流子定向漂移的速度方向与电流方向相反，洛仑兹力使电子向上偏转，结果是A端电势高于A'端，如图3-1-2(b)所示。所以根据霍尔系数的正负可以判断半导体的导电类型。  2.霍尔器件的重要参数  （1）霍尔系数：  （2）霍尔器件的灵敏度：  （3）迁移率、电导率：  在低电场下载流子平均漂移速度和场强E成正比，即，比例系数μ称为迁移率。  场强E与电流密度J成正比，即，比例系数ρ称为电阻率，电阻率的倒数称为电导率，即。又因为电流密度大小，可得电导率和迁移率之间的关系为，进而得到  测出电导率，即可求出迁移率。  （二）长直螺线管的磁场分布  如图3-1-3所示，一密绕螺线管，管内是真空，管长l，半径为R，单位长度匝数为n，当通以电流I时，则在管内外产生磁场，根据毕奥萨伐尔定律，可求得密绕螺线管内部轴线上磁感应强度大小为  其中是真空磁导率。  当时，螺线管成为长直螺线管，在远离端点的螺线管内部，近似地认为式(10)，，则在远离端点的螺线管内部的轴线上可视为均匀磁场，而在长直螺线管的端点处。  （三）对称测量法与附加电动势  1.附加电动势  将载流半导体薄片置于磁场中，除了会产生尔效应外，还会有其他的副效应产生。实际测量霍尔片两侧的电压时，得到的不只是，还包括副效  应产生的附加电动势(如图3-1-4所示)。副效应主要有以下4种:  (1)厄廷豪森( Etinghausen)效应引起的电势差由于电子实际上并非以同一速度沿y轴负向运动，速度大的电子回转半径大，能较快地到达接点3的侧面，从而导致3侧  面较4侧面集中了较多能量高的电子，结果3、4侧面出现温差，产生温差电动势。可以证明,容易理解的正负与I和B的方向有关。  (2)能斯特( Nernst)效应引起的电势差。焊点1、2间的接触电阻可能不同,通电发热程度不同,故1、2两点间的温度可能不同,于是引起热扩散电流。与霍耳效应类似,该热扩散电流也会在3、4点间形成电势差。若只考虑接触电阻的差异,则的方向仅与B的方向有关。  (3)里纪-勒杜克( Righi- Leduc)效应产生的电势差上述热扩散电流的载流子由于速度不同,根据厄廷豪森效应同样的理由,又会在3、4点间形成温差电动势 。的正负仅与B的方向有关,而与I的方向无关。  (4)不等电位效应引起的电势差Uo。由于造上的困难及材料的不均匀性,3、4两点  实际上不可能在同一条等势线上,因而只要有电流,即使没有磁场B，3、4两点间也会出  现电势差Uo。Uo的正负只与电流I的方向有关,而与B的方向无关。  2.对称测量法消除附加电动势。  上述副效应产生的附加电动势叠加在霍尔电压上,在测量中形成系统误差。由于副效应与磁感应强度B和电流I的方向有关,测量时采用“对称测量法”,即通过改变电流I和磁感应强度B的方向基本可以消除附加电动势。 |
| 三、实验仪器：  TH—H霍尔效应实验测试仪    TH—H霍尔效应实验组合仪    实验连接图： |
| **四、实验内容：**  (一)霍尔器件输出特性的测量  （1）实验仪双刀开关倒向“*VH*”，测试仪功能选择置于“*VH*”，然后调节*IM*=0.5A，测绘*VH*—*IS*曲线．  （2）保持*IS*的值不变（ *IS**=*3.00mA），测绘曲线*VH*—*IＭ*  (3)由上述测量数据确定材料的霍尔系数RH和霍尔器件的灵敏度KH。  (二)利用霍尔器件测量长直螺线管的磁场分布  首先在*IS*与*IM*均为0A时对*VH*进行置零操作，再令IM=0.500A， IS=3.00mA，将霍尔片从螺线管右端移到左端，每10mm记录一组数据。作螺线管轴线上磁场分布曲线。  由UH=KHISB可知,已知霍尔器件的灵敏度KH (KH的值由仪器生产厂家给出,在仪器上有标识),只要测出UH,就可以测出磁感应强度的大小B. |

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| 五、数据记录：  组号： 7 ；姓名 王俊彬  1.测量试样的和曲线  表1 不变时关系的数据记录表   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | 组数 |  |  |  |  |  |  | | +B,+Is | -B,+Is | -B,-Is | +B,-Is | | 1 | 1.00 | -1.59 | 1.64 | -1.63 | 1.60 | 1.6150 | | 2 | 1.50 | -2.38 | 2.45 | -2.44 | 2.39 | 2.4150 | | 3 | 2.00 | -3.18 | 3.27 | -3.26 | 3.19 | 3.2250 | | 4 | 2.50 | -3.97 | 4.08 | -4.07 | 3.98 | 4.0250 | | 5 | 3.00 | -4.77 | 4.89 | -4.89 | 4.78 | 4.8325 | | 6 | 3.50 | -5.56 | 5.70 | -5.70 | 5.57 | 5.6325 | | 7 | 4.00 | -6.37 | 6.53 | -6.51 | 6.38 | 6.4475 | | 8 | 4.50 | -7.17 | 7.35 | -7.33 | 7.17 | 7.2550 |   注： ，励磁参数。  表2 不变时关系的数据记录表   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | 组数 |  |  |  |  |  |  | | +B,+Is | -B,+Is | -B,-Is | +B,-Is | | 1 | 0.300 | -4.78 | 4.90 | -4.89 | 4.78 | 4.8375 | | 2 | 0.400 | -6.41 | 6.53 | -6.52 | 6.40 | 6.4650 | | 3 | 0.500 | -8.01 | 8.15 | -8.14 | 8.03 | 8.0825 | | 4 | 0.600 | -9.64 | 9.76 | -9.76 | 9.63 | 9.6975 | | 5 | 0.700 | -11.26 | 11.40 | -11.39 | 11.27 | 11.3300 | | 6 | 0.800 | -12.87 | 13.00 | -13.00 | 12.87 | 12.9350 |   注： , 励磁参数。  2. 测量螺线管轴线上的磁场分布。  注：，，。  表3 螺线管轴线上不同位置的磁场分布的数据记录表   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | 组数 |  |  |  |  |  |  |  | | +B,+Is | -B,+Is | -B,-Is | +B,-Is | | 1 | 0 | -0.03 | -0.47 | 0.46 | 0.02 | 0.2200 | 0.4264 | | 2 | 0.5 | 0.04 | -0.54 | 0.52 | -0.05 | 0.2875 | 0.5572 | | 3 | 1.0 | 0.14 | -0.64 | 0.62 | -0.15 | 0.3875 | 0.7510 | | 4 | 1.5 | 0.27 | -0.77 | 0.76 | -0.29 | 0.5225 | 1.0126 | | 5 | 2.0 | 0.46 | -0.95 | 0.94 | -0.47 | 0.7050 | 1.3663 | | 6 | 2.5 | 0.67 | -1.17 | 1.15 | -0.69 | 0.9200 | 1.7829 | | 7 | 3.0 | 0.90 | -1.39 | 1.38 | -0.92 | 1.1475 | 2.2238 | | 8 | 3.5 | 1.08 | -1.58 | 1.56 | -1.11 | 1.3325 | 2.5824 | | 9 | 4.0 | 1.23 | -1.73 | 1.71 | -1.24 | 1.4775 | 2.8634 | | 10 | 4.5 | 1.33 | -1.83 | 1.81 | -1.35 | 1.5800 | 3.0620 | | 11 | 5.0 | 1.40 | -1.90 | 1.88 | -1.42 | 1.6500 | 3.1977 | | 12 | 5.5 | 1.45 | -1.95 | 1.94 | -1.47 | 1.7025 | 3.2994 | | 13 | 6.0 | 1.49 | -1.98 | 1.97 | -1.50 | 1.7350 | 3.3624 | | 14 | 6.5 | 1.51 | -2.01 | 2.00 | -1.53 | 1.7625 | 3.4157 | | 15 | 7.0 | 1.54 | -2.03 | 2.02 | -1.55 | 1.7850 | 3.4593 | | 16 | 7.5 | 1.55 | -2.05 | 2.03 | -1.56 | 1.7975 | 3.4835 | | 17 | 8.0 | 1.56 | -2.06 | 2.05 | -1.57 | 1.8100 | 3.5078 | | 18 | 8.5 | 1.57 | -2.07 | 2.05 | -1.58 | 1.8175 | 3.5223 | | 19 | 9.0 | 1.58 | -2.08 | 2.06 | -1.59 | 1.8275 | 3.5417 | | 20 | 9.5 | 1.58 | -2.08 | 2.07 | -1.60 | 1.8325 | 3.5514 | | 21 | 10.0 | 1.58 | -2.09 | 2.07 | -1.60 | 1.8350 | 3.5562 | | 22 | 10.5 | 1.58 | -2.09 | 2.07 | -1.60 | 1.8350 | 3.5562 | | 23 | 11.0 | 1.58 | -2.09 | 2.08 | -1.60 | 1.8375 | 3.5610 | | 24 | 11.5 | 1.58 | -2.09 | 2.08 | -1.60 | 1.8375 | 3.5610 | | 25 | 12.0 | 1.59 | -2.09 | 2.08 | -1.60 | 1.8400 | 3.5659 | | 26 | 12.5 | 1.58 | -2.09 | 2.08 | -1.60 | 1.8375 | 3.5610 | | 27 | 13.0 | 1.58 | -2.09 | 2.08 | -1.60 | 1.8375 | 3.5610 | | 28 | 13.5 | 1.58 | -2.09 | 2.08 | -1.59 | 1.8350 | 3.5562 | | 29 | 14.0 | 1.57 | -2.09 | 2.07 | -1.59 | 1.8300 | 3.5465 | | 30 | 14.5 | 1.57 | -2.08 | 2.07 | -1.59 | 1.8275 | 3.5417 | | 31 | 15.0 | 1.56 | -2.08 | 2.06 | -1.58 | 1.8200 | 3.5271 | | 32 | 15.5 | 1.55 | -2.07 | 2.05 | -1.57 | 1.8100 | 3.5078 | | 33 | 16.0 | 1.54 | -2.05 | 2.04 | -1.55 | 1.7950 | 3.4787 | | 34 | 16.5 | 1.52 | -2.04 | 2.02 | -1.54 | 1.7800 | 3.4496 | | 35 | 17.0 | 1.50 | -2.01 | 2.00 | -1.52 | 1.7575 | 3.4060 | | 36 | 17.5 | 1.47 | -1.99 | 1.97 | -1.48 | 1.7275 | 3.3479 | | 37 | 18.0 | 1.43 | -1.95 | 1.93 | -1.44 | 1.6875 | 3.2703 | | 38 | 18.5 | 1.38 | -1.89 | 1.88 | -1.39 | 1.6350 | 3.1686 | | 39 | 19.0 | 1.29 | -1.81 | 1.80 | -1.31 | 1.5525 | 3.0087 | | 40 | 19.5 | 1.18 | -1.70 | 1.68 | -1.19 | 1.4375 | 2.7859 | | 41 | 20.0 | 1.03 | -1.54 | 1.53 | -1.04 | 1.2850 | 2.4903 | | 42 | 20.5 | 0.83 | -1.35 | 1.33 | -0.85 | 1.0900 | 2.1124 | | 43 | 21.0 | 0.62 | -1.13 | 1.12 | -0.63 | 0.8750 | 1.6957 | | 44 | 21.5 | 0.41 | -0.93 | 0.91 | -0.42 | 0.6675 | 1.2936 | | 45 | 22.0 | 0.23 | -0.76 | 0.74 | -0.25 | 0.4950 | 0.9593 | | 46 | 22.5 | 0.11 | -0.63 | 0.61 | -0.12 | 0.3675 | 0.7122 | | 47 | 23.0 | 0.01 | -0.54 | 0.52 | -0.03 | 0.2750 | 0.5329 | |
| 六、数据处理：  1. 计算霍尔电压。霍尔电压已经计算好并写入表1、表2、表3。  2.根据表1做曲线。  3.根据表2做曲线。  4.计算材料霍尔系数。  5.螺线管轴线上磁场分布曲线如图：  先利用（单位：T），补充表3数据，然后绘图。 |
| 七、结果陈述：  1. 由图1图2可得，误差允许范围内可认为，。  2.材料的霍尔系数为。  3.由图3可见，该分布曲线形状如“高原”，中间部分变化幅度不大，两边变化幅度大，中间部分的磁场强度是比较大的。 |
| 八、实验总结与思考题：  1.实验总结  （1）实验前，要检查Is和Im是否调到0，且开启设备后，要记得调零。  （2）测量试样的和曲线时，调整双刀开关时要小心电火花，而且要卡到位，否则会接触不良。  （3）使用完仪器后，也要把Is和Im调到0，再关闭电源。  （4）处理数据时，灵活运用电脑软件绘图。计算时也要注意单位换算。  2.思考题  （1）如果磁感应强度B不垂直于霍尔片，对测量结果有何影响？如何由实验判断B与霍尔片是否垂直？  答：不垂直于霍尔片的话，实际的磁感应强度B会比测量值偏小。如果理论值和实际值差别很大，就可以认为B与霍尔片不垂直。  （2）霍尔效应有哪些应用，试举例，并简单阐述原理。  答：霍尔效应可以用来测磁场，因为，已知霍尔灵敏度的话，通过实验可以测出磁场，当然测出的磁场是垂直于霍尔元件的方向的分量。 |

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| 指导教师批阅意见： |
| 成绩评定：     |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **预习**  （20分） | **操作及记录**  （40分） | 数据处理  20分 | 结果陈述实验总结10分 | 思考题  10分 | **报告整体**  **印 象** | **总分** | |  |  |  |  |  |  |  | |