镨钕金属化学分析方法

碳、铁、钼、铝、硅和镨含量的测定

火花放电原子发射光谱法

实验报告

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标样准备

共收到起草单位的20块实验用样品，其中19块用于曲线绘制。

如表1所示；

表1 用于绘制工作曲线的样品

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 名称 | C | Fe | Mo | Al  | Si  | Pr |
| 9# | 0.011  | 0.090  | / | 0.021  | 0.018  | 16.890  |
| 27 | 0.064  | 0.323 | 0.016  | 0.022  | 0.049  | 18.721  |
| 538 | 0.038  | 0.467  | 0.010  | 0.037  | 0.043  | 19.082  |
| 3-55 | 0.107  | 0.180  | / | 0.007  | 0.020  | 19.430  |
| 2-1 | 0.159  | 1.083  | / | 0.008  | 0.029  | 19.712  |
| 4-187 | 0.010  | 0.017  | / | 0.004  | / | 20.715  |
| 11-201 | 0.037  | 0.214  | / | 0.041  | 0.105  | 22.882  |
| 20-193 | 0.012  | 0.034  | / | 0.008  | 0.011  | 23.127  |
| 503 | 0.016  | 0.204  | 0.006  | 0.067  | 0.075  | 23.485  |
| 22-114 | 0.023  | 0.049  | / | 0.006  | 0.009  | 23.690  |
| PNMo-8 | 0.021  | 0.146  | 0.061  | 0.015  | 0.018  | 23.725  |
| PNMo-7 | 0.038  | 0.414  | 0.054  | 0.013  | 0.033  | 23.917  |
| PNMo-9 | 0.023  | 0.288  | 0.064  | 0.030  | 0.032  | 24.114  |
| 9-201 | 0.080  | 0.168  | / | 0.006  | 0.011  | 24.682  |
| 19# | 0.034  | 0.325  | / | 0.177  | 0.138  | 25.725  |
| NCS203036 | 0.090 | 1.480 | 0.0078 | 0.0087 | 0.045 | 30.82 |
| 9-200 | 0.473  | 1.261  | 0.0009  | 0.026  | 0.036  | 33.203  |
| NCS203035 | 0.046 | 0.56 | 0.032 | 0.019 | 0.023 | 20.85 |
| 539 | 0.086  | 0.275  | 0.026  | 0.060  | （0.080） | 18.798  |
| **曲线范围** | **0.010-0.473** | **0.017-1.480** | **0.0009-0.064** | **0.004-0.177** | **0.009-0.138** | **16.890-33.203** |
| **产品标准** | **<=0.05** | **<=0.3** | **<=0.1** | **<=0.1** | **<=0.05** | **18.0-32.0** |

1. 仪器设备
2. 钢研纳克HSRE 1000型稀土金属快速分析仪
3. 仪器主要工作条件：实验采用一次积分，充气、预燃、积分各阶段具体参数见表2。静止流量0.07L/min，分析流量9L/min。实验过程中选用的分析线对见表3. 分析线对选择主要考虑谱线干扰、曲线线性和测试结果精密度几个因素，选择干扰较少，拟合曲线相关系数接近于1且测试结果相对标准偏差较小的分析线对。。

表2实验条件选择

|  |  |  |  |
| --- | --- | --- | --- |
| 实验阶段 | 时间/s | 频率/Hz | 电压/V |
| 吹扫 | 15 | / | / |
| 预燃 | 10 | 500 | 380 |
| 燃烧 | 8 | 500 | 190 |

表3 实验选用的分析线对

|  |  |  |
| --- | --- | --- |
| 元素 | 分析谱线/nm | Nd参比谱线/nm |
| C | 193.09 | 193.2 |
| Fe | 239.4 | 242.8 |
| Mo | 281.6 | 275.8 |
| Al | 396.1 | 395.4 |
| Si | 288.1 | 289.2 |
| Pr | 405.6 | 406.0 |

1. 绘制工作曲线

用BD4800砂带机和40目砂带制样，将样品一个面打磨至表面平整且有方向一致的清晰纹路。磨好的表面不要用手触摸或用其他物品擦拭，直接放在激发台上激发。在选定的实验条件下激发表2所列样品，每个样品激发4个点，以各元素分析线强度与参比线强度比值（相对强度）为横坐标，以各元素含量与Nd基体含量比值（相对含量）为纵坐标，绘制各元素校准曲线。由于火花发射光谱法为持久曲线法，为便于后期使用绘制的曲线分析样品，为每个元素选取接近于曲线上限和曲线下限附近的样品作为强度校正样品。本方法选取9-200、PNMo-8、503、9#等4块样品作为各元素的标准化样品（高低标），其参考含量见表4。

表4 各元素标准化样品（高低标参考含量）

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 名称 | C | Fe | Mo | Al  | Si  | Pr |
| 9# | 0.011  | 0.090  | / | 0.021  | 0.018  | 16.890  |
| 503 | 0.016  | 0.204  | 0.006  | 0.067  | 0.075  | 23.485  |
| PNMo-8 | 0.021  | 0.146  | 0.061  | 0.015  | 0.018  | 23.725  |
| 9-200 | 0.473  | 1.261  | 0.0009  | 0.026  | 0.036  | 33.203  |

1. 制样方法条件实验

分别考察了砂带机磨样和铣床制样两种制样方式对测试结果精密度的影响。

1. 砂带机磨样

采用BD4800型砂带机制样，将样品一个面打磨至表面平整且有方向一致的清晰纹路。磨好的表面不要用手触摸或用其他物品擦拭，直接放在激发台上激发。选取均匀度较好的PNMo-8和PNMo-7两块样品，每个样品分别用40目、60目、80目砂带打磨样品，然后用绘制好的曲线对同一样品激发11次（两次激发之间刷电极和更换样品激发位置）。为减少偶然因素影响，每块样品用不同粒度砂纸打磨后各保留2组数据（每组10个激发点），取各元素两组数据相对标准偏差（RSD）的平均值作为衡量标准。2块样品测试数据原始值列于附录1（附表1.1-1.12）中。统计不同砂纸粒度下，RSD平均值最小值出现最多次的砂带粒度作为后续实验所用，表5、6为测试结果统计值，表中用灰色底纹标注了各元素RSD最小的数据。从表5、6可以看出，40目、60目、80目砂带制样时RSD相差不大，可见砂带粒度在40-80目之间，测试结果无显著差异，因此推荐采用40-80目砂带制样。

表5砂带制样测得的PNMo-8样品结果统计值

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 砂带粒度 | 统计结果 | C | Fe | Mo | Al | Si | Pr |
| 含量参考值 | 0.021 | 0.146 | 0.061 | 0.015 | 0.018 | 23.725 |
| 40# | 第一次RSD% | 6.077 | 1.497 | 4.449 | 2.451 | 1.747 | 0.095 |
| 第二次RSD% | 3.171 | 1.699 | 2.451 | 1.767 | 0 | 0.108 |
| **RSD%平均值** | 4.624 | 1.598 | 3.45 | 2.109 | 0.8735 | 0.1015 |
| 60# | 第一次RSD% | 1.673 | 2.971 | 6.312 | 3.8 | 0 | 0.114 |
| 第二次RSD% | 2.849 | 2.246 | 2.603 | 5.184 | 0 | 0.212 |
| **RSD%平均值** | 2.261 | 2.6085 | 4.4575 | 4.492 | 0 | 0.163 |
| 80# | 第一次RSD% | 4.108 | 2.618 | 22.326 | 3.688 | 0 | 0.339 |
| 第二次RSD% | 6.857 | 2.53 | 4.559 | 3.688 | 2.64 | 0.372 |
| **RSD%平均值** | 5.4825 | 2.574 | 13.4425 | 3.688 | 1.32 | 0.3555 |

表6砂带制样测得的PNMo-7样品结果统计值

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 砂带粒度 | 统计结果 | C | Fe | Mo | Al | Si | Pr |
| 含量参考值 | 0.038 | 0.414 | 0.054 | 0.013 | 0.033 | 23.917 |
| 40# | 第一次RSD% | 2.328 | 2.173 | 4.417 | 9.353 | 0 | 0.244 |
| 第二次RSD% | 1.852 | 2.025 | 3.453 | 7.154 | 2.481 | 0.225 |
| **RSD%平均值** | 2.09 | 2.099 | 3.935 | 8.2535 | 1.2405 | 0.2345 |
| 60# | 第一次RSD% | 2.613 | 2.544 | 2.846 | 7.465 | 1.768 | 0.274 |
| 第二次RSD% | 1.859 | 1.798 | 7.449 | 8.754 | 0.991 | 0.168 |
| **RSD%平均值** | 2.236 | 2.171 | 5.1475 | 8.1095 | 1.3795 | 0.221 |
| 80# | 第一次RSD% | 1.572 | 1.77 | 5.088 | 4.444 | 1.495 | 0.3 |
| 第二次RSD% | 1.964 | 1.51 | 2.143 | 2.946 | 0.985 | 0.151 |
| **RSD%平均值** | 1.768 | 1.64 | 3.6155 | 3.695 | 1.24 | 0.2255 |

1. 铣床制样

采用小型铣床制样，将样品一个面加工至表面平整且有方向一致的清晰纹路。制好的表面不要用手触摸或用其他物品擦拭，直接放在激发台上激发。选取均匀度较好的PNMo-8和PNMo-7两个样品，固定铣刀进给速度为60mm/min，对比转速分别为168r/min、232r/min、330r/min时样品测试结果精密度差异（因铣床型号差异，无法设置与起草单位同样转速参数），2块样品测试数据原始值列于附录1（附表1.13-1.24）中。统计不同转速下，RSD平均值最小值出现最多次的铣刀转速作为后续实验所用，表7、8为测试结果统计值，表中用灰色底纹标注了各元素RSD最小的数据。从表7、8可以看出，铣床转速168、232、330时RSD最低的元素分别有3个、4个和5个，可见在进给速度保持不变情况下，提高铣床转速有利于提高测试结果精密度。

表7 不同铣床转速制样测得的PNMo-8样品结果统计值

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 铣床转速r/min | 统计结果 | C | Fe | Mo | Al | Si | Pr |
| 含量参考值 | 0.021 | 0.146 | 0.061 | 0.015 | 0.018 | 23.725 |
| 168 | 第一次RSD% | 3.131 | 3.61 | 6.072 | 8.035 | 2.807 | 0.182 |
| 第二次RSD% | 2.776 | 2.594 | 6.113 | 8.035 | 0 | 0.268 |
| **RSD%平均值** | 2.9535 | 3.102 | 6.0925 | 8.035 | 1.4035 | 0.225 |
| 232 | 第一次RSD% | 4.703 | 3.011 | 2.525 | 4.329 | 2.84 | 0.515 |
| 第二次RSD% | 3.792 | 2.731 | 4.836 | 7.217 | 1.747 | 0.277 |
| **RSD%平均值** | 4.2475 | 2.871 | 3.6805 | 5.773 | 2.2935 | 0.396 |
| 330 | 第一次RSD% | 4.541 | 2.034 | 4.928 | 6.193 | 2.64 | 0.58 |
| 第二次RSD% | 2.087 | 1.56 | 4.517 | 3.813 | 0 | 0.196 |
| **RSD%平均值** | 3.314 | 1.797 | 4.7225 | 5.003 | 1.32 | 0.388 |

表8 不同铣床转速制样测得的PNMo-7样品结果统计值

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 铣床转速r/min | 统计结果 | C | Fe | Mo | Al | Si | Pr |
| 含量参考值 | 0.038 | 0.414 | 0.054 | 0.013 | 0.033 | 23.917 |
| 168 | 第一次RSD% | 5.2 | 3.08 | 3.727 | 9.856 | 0.985 | 0.469 |
| 第二次RSD% | 4.633 | 3.449 | 4.137 | 7.21 | 2.09 | 0.607 |
| **RSD%平均值** | 4.9165 | 3.2645 | 3.932 | 8.533 | 1.5375 | 0.538 |
| 232 | 第一次RSD% | 2 | 1.469 | 13.883 | 6.98 | 1.351 | 0.257 |
| 第二次RSD% | 3.027 | 2.426 | 6.355 | 6.617 | 1.645 | 0.305 |
| **RSD%平均值** | 2.5135 | 1.9475 | 10.119 | 6.7985 | 1.498 | 0.281 |
| 330 | 第一次RSD% | 3.109 | 1.197 | 5.243 | 6.747 | 1.779 | 0.684 |
| 第二次RSD% | 2.14 | 2.557 | 45.03 | 3.378 | 1.645 | 0.353 |
| **RSD%平均值** | 2.6245 | 1.877 | 25.1365 | 5.0625 | 1.712 | 0.5185 |

1. 精密度实验结果

选取9#，503，PNMo-8，PNMo-9，19#，502，539，2-1，9-200九块样品作为精密度实验样品，依次编号为样品1~样品9。用表4中选取的标准化样品对绘制好的曲线进行全局校正后，用绘制的校准曲线分别对9个样品进行11次独立测定，结果如表9~17所示。测试结果中C、Fe、Mo、Al、Si保留至小数点后4位，Pr保留至小数点后3位，相对标准偏差RSD保留至小数点后2位，数值修约按照GB/T 8170的规定执行。

表9 9# 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.0057  | 0.0709  | 0.0000  | 0.0173  | 0.0176  | 16.886  |
| ASD | 0.0010  | 0.0014  | 0.0001  | 0.0002  | 0.0003  | 0.0648  |
| RSD | 17.21  | 1.92  | 100.00  | 1.23  | 1.50  | 0.38  |
| 1 | 0.0047  | 0.0723  | / | 0.0175  | 0.0179  | 16.997  |
| 2 | 0.0048  | 0.0695  | / | 0.0173  | 0.0174  | 16.925  |
| 3 | 0.0046  | 0.0688  | 0.0004  | 0.0173  | 0.0174  | 16.933  |
| 4 | 0.0070  | 0.0714  | / | 0.0169  | 0.0176  | 16.759  |
| 5 | 0.0048  | 0.0701  | / | 0.0172  | 0.0173  | 16.870  |
| 6 | 0.0064  | 0.0699  | / | 0.0171  | 0.0174  | 16.828  |
| 7 | 0.0070  | 0.0716  | / | 0.0176  | 0.0179  | 16.889  |
| 8 | 0.0065  | 0.0695  | / | 0.0172  | 0.0177  | 16.867  |
| 9 | 0.0064  | 0.0725  | / | 0.0176  | 0.0181  | 16.953  |
| 10 | 0.0058  | 0.0722  | / | 0.0172  | 0.0175  | 16.872  |
| 11 | 0.0048  | 0.0722  | / | 0.0173  | 0.0174  | 16.856  |

表10 539 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.0865  | 0.2231  | 0.0217  | 0.0500  | 0.0633  | 18.817  |
| ASD | 0.0016  | 0.0043  | 0.0009  | 0.0004  | 0.0006  | 0.0825  |
| RSD | 1.86  | 1.91  | 4.19  | 0.90  | 0.97  | 0.44  |
| 1 | 0.0858  | 0.2201  | 0.0214  | 0.0501  | 0.0630  | 18.907  |
| 2 | 0.0856  | 0.2210  | 0.0207  | 0.0493  | 0.0629  | 18.725  |
| 3 | 0.0891  | 0.2238  | 0.0210  | 0.0495  | 0.0640  | 18.627  |
| 4 | 0.0859  | 0.2241  | 0.0218  | 0.0504  | 0.0636  | 18.869  |
| 5 | 0.0844  | 0.2189  | 0.0211  | 0.0497  | 0.0620  | 18.789  |
| 6 | 0.0895  | 0.2324  | 0.0235  | 0.0504  | 0.0637  | 18.882  |
| 7 | 0.0861  | 0.2251  | 0.0216  | 0.0505  | 0.0635  | 18.875  |
| 8 | 0.0858  | 0.2263  | 0.0215  | 0.0506  | 0.0636  | 18.875  |
| 9 | 0.0850  | 0.2172  | 0.0206  | 0.0496  | 0.0625  | 18.793  |
| 10 | 0.0866  | 0.2200  | 0.0223  | 0.0501  | 0.0637  | 18.835  |
| 11 | 0.0876  | 0.2252  | 0.0229  | 0.0503  | 0.0637  | 18.813  |

表11 2-1 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.1563  | 1.0220  | 0.0004  | 0.0064  | 0.0225  | 20.243  |
| ASD | 0.0042  | 0.0243  | 0.0006  | 0.0003  | 0.0003  | 0.0607  |
| RSD | 2.66  | 2.38  | 100.00  | 4.57  | 1.47  | 0.30  |
| 1 | 0.1544  | 1.0221  | / | 0.0060  | 0.0223  | 20.177  |
| 2 | 0.1571  | 1.0153  | 0.0000  | 0.0061  | 0.0227  | 20.201  |
| 3 | 0.1570  | 0.9877  | / | 0.0064  | 0.0222  | 20.217  |
| 4 | 0.1529  | 1.0051  | 0.0018  | 0.0061  | 0.0221  | 20.213  |
| 5 | 0.1533  | 1.0055  | 0.0011  | 0.0064  | 0.0224  | 20.251  |
| 6 | 0.1548  | 1.0259  | 0.0001  | 0.0068  | 0.0224  | 20.354  |
| 7 | 0.1524  | 1.0127  | 0.0006  | 0.0069  | 0.0222  | 20.321  |
| 8 | 0.1531  | 1.0041  | 0.0006  | 0.0063  | 0.0223  | 20.157  |
| 9 | 0.1590  | 1.0515  | / | 0.0064  | 0.0230  | 20.224  |
| 10 | 0.1585  | 1.0400  | / | 0.0065  | 0.0226  | 20.266  |
| 11 | 0.1667  | 1.0720  | / | 0.0061  | 0.0231  | 20.292  |

表12 502 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.0291  | 0.2899  | 0.0141  | 0.0380  | 0.0453  | 23.880  |
| ASD | 0.0008  | 0.0075  | 0.0008  | 0.0005  | 0.0009  | 0.0432  |
| RSD | 2.60  | 2.59  | 5.77  | 1.37  | 1.94  | 0.18  |
| 1 | 0.0291  | 0.2770  | 0.0142  | 0.0372  | 0.0440  | 23.821  |
| 2 | 0.0281  | 0.2961  | 0.0138  | 0.0379  | 0.0457  | 23.905  |
| 3 | 0.0286  | 0.2845  | 0.0140  | 0.0373  | 0.0438  | 23.829  |
| 4 | 0.0288  | 0.2854  | 0.0138  | 0.0374  | 0.0444  | 23.863  |
| 5 | 0.0292  | 0.2911  | 0.0137  | 0.0383  | 0.0461  | 23.836  |
| 6 | 0.0285  | 0.2846  | 0.0151  | 0.0380  | 0.0454  | 23.862  |
| 7 | 0.0294  | 0.2915  | 0.0142  | 0.0383  | 0.0460  | 23.895  |
| 8 | 0.0292  | 0.2829  | 0.0136  | 0.0382  | 0.0447  | 23.875  |
| 9 | 0.0285  | 0.2964  | 0.0161  | 0.0389  | 0.0457  | 23.930  |
| 10 | 0.0301  | 0.3003  | 0.0139  | 0.0384  | 0.0463  | 23.953  |
| 11 | 0.0307  | 0.2986  | 0.0131  | 0.0381  | 0.0457  | 23.916  |

表13 503 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.0108  | 0.1684  | 0.0062  | 0.0651  | 0.0778  | 23.657  |
| ASD | 0.0008  | 0.0036  | 0.0005  | 0.0008  | 0.0010  | 0.0709  |
| RSD | 7.31  | 2.16  | 7.28  | 1.16  | 1.31  | 0.30  |
| 1 | 0.0101  | 0.1685  | 0.0066  | 0.0657  | 0.0779  | 23.773  |
| 2 | 0.0118  | 0.1650  | 0.0054  | 0.0641  | 0.0777  | 23.627  |
| 3 | 0.0110  | 0.1637  | 0.0063  | 0.0646  | 0.0770  | 23.679  |
| 4 | 0.0103  | 0.1694  | 0.0068  | 0.0653  | 0.0773  | 23.663  |
| 5 | 0.0104  | 0.1723  | 0.0065  | 0.0664  | 0.0802  | 23.738  |
| 6 | 0.0110  | 0.1738  | 0.0062  | 0.0661  | 0.0785  | 23.661  |
| 7 | 0.0095  | 0.1642  | 0.0061  | 0.0643  | 0.0765  | 23.581  |
| 8 | 0.0104  | 0.1655  | 0.0057  | 0.0643  | 0.0772  | 23.615  |
| 9 | 0.0108  | 0.1676  | 0.0067  | 0.0652  | 0.0774  | 23.732  |
| 10 | 0.0118  | 0.1694  | 0.0061  | 0.0652  | 0.0777  | 23.616  |
| 11 | 0.0120  | 0.1735  | 0.0057  | 0.0653  | 0.0788  | 23.539  |

表14 PNMo-8 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.0183  | 0.1126  | 0.0533  | 0.0172  | 0.0185  | 23.813  |
| ASD | 0.0012  | 0.0025  | 0.0023  | 0.0002  | 0.0003  | 0.0488  |
| RSD | 6.61  | 2.19  | 4.23  | 1.42  | 1.51  | 0.20  |
| 1 | 0.0181  | 0.1140  | 0.0499  | 0.0170  | 0.0190  | 23.777  |
| 2 | 0.0171  | 0.1109  | 0.0517  | 0.0171  | 0.0185  | 23.805  |
| 3 | 0.0215  | 0.1144  | 0.0549  | 0.0170  | 0.0188  | 23.796  |
| 4 | 0.0177  | 0.1109  | 0.0513  | 0.0172  | 0.0182  | 23.821  |
| 5 | 0.0181  | 0.1129  | 0.0518  | 0.0170  | 0.0186  | 23.732  |
| 6 | 0.0174  | 0.1104  | 0.0515  | 0.0172  | 0.0182  | 23.778  |
| 7 | 0.0179  | 0.1104  | 0.0534  | 0.0175  | 0.0185  | 23.873  |
| 8 | 0.0183  | 0.1124  | 0.0554  | 0.0173  | 0.0182  | 23.842  |
| 9 | 0.0183  | 0.1173  | 0.0535  | 0.0178  | 0.0189  | 23.911  |
| 10 | 0.0190  | 0.1158  | 0.0571  | 0.0171  | 0.0186  | 23.803  |
| 11 | 0.0173  | 0.1098  | 0.0557  | 0.0172  | 0.0184  | 23.802  |

表15 PNMo-9 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.0188  | 0.2536  | 0.0620  | 0.0317  | 0.0354  | 24.208  |
| ASD | 0.0006  | 0.0031  | 0.0012  | 0.0003  | 0.0005  | 0.0343  |
| RSD | 3.21  | 1.21  | 1.88  | 0.81  | 1.28  | 0.14  |
| 1 | 0.0199  | 0.2506  | 0.0612  | 0.0314  | 0.0352  | 24.224  |
| 2 | 0.0185  | 0.2499  | 0.0618  | 0.0314  | 0.0353  | 24.154  |
| 3 | 0.0179  | 0.2543  | 0.0635  | 0.0318  | 0.0350  | 24.248  |
| 4 | 0.0184  | 0.2553  | 0.0620  | 0.0317  | 0.0354  | 24.158  |
| 5 | 0.0184  | 0.2490  | 0.0618  | 0.0315  | 0.0355  | 24.183  |
| 6 | 0.0184  | 0.2516  | 0.0643  | 0.0315  | 0.0348  | 24.172  |
| 7 | 0.0186  | 0.2588  | 0.0621  | 0.0322  | 0.0363  | 24.223  |
| 8 | 0.0192  | 0.2563  | 0.0604  | 0.0317  | 0.0358  | 24.235  |
| 9 | 0.0190  | 0.2524  | 0.0618  | 0.0318  | 0.0348  | 24.218  |
| 10 | 0.0197  | 0.2554  | 0.0623  | 0.0319  | 0.0357  | 24.226  |
| 11 | 0.0188  | 0.2554  | 0.0604  | 0.0320  | 0.0356  | 24.243  |

表16 19# 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.0368  | 0.2878  | 0.0030  | 0.1718  | 0.1186  | 25.671  |
| ASD | 0.0011  | 0.0035  | 0.0005  | 0.0010  | 0.0004  | 0.0506  |
| RSD | 3.10  | 1.22  | 15.92  | 0.59  | 0.33  | 0.20  |
| 1 | 0.0379  | 0.2864  | 0.0023  | 0.1721  | 0.1193  | 25.698  |
| 2 | 0.0387  | 0.2944  | 0.0030  | 0.1742  | 0.1190  | 25.695  |
| 3 | 0.0363  | 0.2892  | 0.0027  | 0.1720  | 0.1188  | 25.695  |
| 4 | 0.0375  | 0.2885  | 0.0037  | 0.1713  | 0.1186  | 25.741  |
| 5 | 0.0351  | 0.2875  | 0.0032  | 0.1721  | 0.1186  | 25.617  |
| 6 | 0.0362  | 0.2892  | 0.0029  | 0.1709  | 0.1185  | 25.682  |
| 7 | 0.0366  | 0.2900  | 0.0027  | 0.1727  | 0.1188  | 25.727  |
| 8 | 0.0375  | 0.2825  | 0.0023  | 0.1710  | 0.1179  | 25.593  |
| 9 | 0.0355  | 0.2817  | 0.0028  | 0.1708  | 0.1183  | 25.597  |
| 10 | 0.0378  | 0.2871  | 0.0035  | 0.1710  | 0.1181  | 25.690  |
| 11 | 0.0358  | 0.2896  | 0.0035  | 0.1721  | 0.1185  | 25.642  |

表17 9-200 精密度实验结果

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 测试次数 | C | Fe | Mo | Al | Si | Pr |
| Avg | 0.4700  | 1.2901  | 0.0019  | 0.0353  | 0.0346  | 32.979  |
| ASD | 0.0133  | 0.0295  | 0.0004  | 0.0003  | 0.0004  | 0.0834  |
| RSD | 2.84  | 2.29  | 20.90  | 0.76  | 1.24  | 0.25  |
| 1 | 0.4661  | 1.2884  | 0.0018  | 0.0352  | 0.0347  | 32.957  |
| 2 | 0.4736  | 1.3116  | 0.0026  | 0.0356  | 0.0349  | 33.012  |
| 3 | 0.4619  | 1.2360  | 0.0022  | 0.0354  | 0.0345  | 32.942  |
| 4 | 0.4877  | 1.3283  | 0.0020  | 0.0352  | 0.0344  | 33.138  |
| 5 | 0.4759  | 1.2896  | 0.0017  | 0.0350  | 0.0345  | 32.991  |
| 6 | 0.4644  | 1.2899  | 0.0023  | 0.0353  | 0.0352  | 32.985  |
| 7 | 0.4693  | 1.3206  | 0.0020  | 0.0350  | 0.0346  | 32.951  |
| 8 | 0.4561  | 1.2769  | 0.0015  | 0.0355  | 0.0342  | 32.894  |
| 9 | 0.4650  | 1.2761  | 0.0020  | 0.0351  | 0.0346  | 32.939  |
| 10 | 0.4519  | 1.2514  | 0.0020  | 0.0347  | 0.0336  | 32.853  |
| 11 | 0.4975  | 1.3225  | 0.0011  | 0.0355  | 0.0350  | 33.104  |

**附录1：不同制样方式精密度原始数据**

附表1.1 PNMo-8样品40目砂带磨样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.019 | 0.109 | 0.059 | 0.017 | 0.018 | 23.693 | 76.085 |
| **SD** | 0.001 | 0.002 | 0.003 | 0 | 0 | 0.023 | 0.023 |
| **RSD** | 6.077 | 1.497 | 4.449 | 2.451 | 1.747 | 0.095 | 0.03 |
| 1 | 0.019 | 0.112 | 0.058 | 0.018 | 0.018 | 23.653 | 76.123 |
| 2 | 0.018 | 0.109 | 0.06 | 0.017 | 0.018 | 23.699 | 76.079 |
| 3 | 0.019 | 0.108 | 0.061 | 0.017 | 0.018 | 23.676 | 76.101 |
| 4 | 0.019 | 0.11 | 0.059 | 0.017 | 0.018 | 23.689 | 76.088 |
| 5 | 0.019 | 0.108 | 0.059 | 0.017 | 0.018 | 23.687 | 76.092 |
| 6 | 0.018 | 0.108 | 0.058 | 0.017 | 0.018 | 23.684 | 76.096 |
| 7 | 0.019 | 0.108 | 0.064 | 0.018 | 0.018 | 23.687 | 76.086 |
| 8 | 0.018 | 0.11 | 0.058 | 0.017 | 0.018 | 23.713 | 76.067 |
| 9 | 0.019 | 0.108 | 0.054 | 0.017 | 0.018 | 23.705 | 76.079 |
| 10 | 0.022 | 0.112 | 0.057 | 0.017 | 0.019 | 23.737 | 76.036 |

附表1.2 PNMo-8样品40目砂带磨样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.018 | 0.111 | 0.059 | 0.018 | 0.018 | 23.715 | 76.061 |
| **SD** | 0.001 | 0.002 | 0.001 | 0 | 0 | 0.026 | 0.026 |
| **RSD** | 3.171 | 1.699 | 2.451 | 1.767 | 0 | 0.108 | 0.034 |
| 1 | 0.018 | 0.114 | 0.059 | 0.018 | 0.018 | 23.745 | 76.029 |
| 2 | 0.018 | 0.111 | 0.059 | 0.017 | 0.018 | 23.745 | 76.031 |
| 3 | 0.017 | 0.111 | 0.06 | 0.018 | 0.018 | 23.727 | 76.048 |
| 4 | 0.018 | 0.111 | 0.058 | 0.018 | 0.018 | 23.668 | 76.109 |
| 5 | 0.018 | 0.112 | 0.059 | 0.018 | 0.018 | 23.693 | 76.081 |
| 6 | 0.018 | 0.113 | 0.058 | 0.018 | 0.018 | 23.689 | 76.085 |
| 7 | 0.018 | 0.109 | 0.061 | 0.018 | 0.018 | 23.723 | 76.053 |
| 8 | 0.018 | 0.109 | 0.058 | 0.018 | 0.018 | 23.712 | 76.066 |
| 9 | 0.019 | 0.112 | 0.057 | 0.018 | 0.018 | 23.737 | 76.038 |
| 10 | 0.017 | 0.108 | 0.056 | 0.018 | 0.018 | 23.711 | 76.071 |

附表1.3 PNMo-8样品60目砂带磨样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.019 | 0.115 | 0.061 | 0.018 | 0.018 | 23.578 | 76.191 |
| **SD** | 0 | 0.003 | 0.004 | 0.001 | 0 | 0.027 | 0.029 |
| **RSD** | 1.673 | 2.971 | 6.312 | 3.8 | 0 | 0.114 | 0.038 |
| 1 | 0.019 | 0.119 | 0.059 | 0.018 | 0.018 | 23.576 | 76.191 |
| 2 | 0.019 | 0.118 | 0.056 | 0.018 | 0.018 | 23.589 | 76.182 |
| 3 | 0.019 | 0.117 | 0.056 | 0.018 | 0.018 | 23.586 | 76.186 |
| 4 | 0.019 | 0.109 | 0.062 | 0.018 | 0.018 | 23.585 | 76.189 |
| 5 | 0.019 | 0.112 | 0.058 | 0.018 | 0.018 | 23.524 | 76.251 |
| 6 | 0.018 | 0.11 | 0.061 | 0.019 | 0.018 | 23.583 | 76.191 |
| 7 | 0.019 | 0.115 | 0.062 | 0.018 | 0.018 | 23.545 | 76.223 |
| 8 | 0.019 | 0.117 | 0.063 | 0.019 | 0.018 | 23.573 | 76.191 |
| 9 | 0.019 | 0.116 | 0.069 | 0.018 | 0.018 | 23.595 | 76.164 |
| 10 | 0.019 | 0.116 | 0.061 | 0.02 | 0.018 | 23.622 | 76.144 |

附表1.4 PNMo-8样品60目砂带磨样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.019 | 0.114 | 0.061 | 0.018 | 0.018 | 23.673 | 76.097 |
| **SD** | 0.001 | 0.003 | 0.002 | 0.001 | 0 | 0.05 | 0.05 |
| **RSD** | 2.849 | 2.246 | 2.603 | 5.184 | 0 | 0.212 | 0.066 |
| 1 | 0.019 | 0.112 | 0.059 | 0.018 | 0.018 | 23.607 | 76.166 |
| 2 | 0.018 | 0.116 | 0.06 | 0.018 | 0.018 | 23.645 | 76.124 |
| 3 | 0.019 | 0.118 | 0.06 | 0.018 | 0.018 | 23.608 | 76.159 |
| 4 | 0.018 | 0.114 | 0.064 | 0.021 | 0.018 | 23.696 | 76.068 |
| 5 | 0.019 | 0.113 | 0.062 | 0.018 | 0.018 | 23.668 | 76.102 |
| 6 | 0.019 | 0.112 | 0.059 | 0.018 | 0.018 | 23.711 | 76.064 |
| 7 | 0.019 | 0.115 | 0.06 | 0.018 | 0.018 | 23.765 | 76.003 |
| 8 | 0.018 | 0.112 | 0.06 | 0.018 | 0.018 | 23.711 | 76.063 |
| 9 | 0.018 | 0.117 | 0.062 | 0.018 | 0.018 | 23.637 | 76.13 |
| 10 | 0.018 | 0.11 | 0.06 | 0.018 | 0.018 | 23.685 | 76.091 |

附表1.5 PNMo-8样品80目砂带磨样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.019 | 0.123 | 0.062 | 0.018 | 0.019 | 23.427 | 76.332 |
| **SD** | 0.001 | 0.003 | 0.014 | 0.001 | 0 | 0.079 | 0.088 |
| **RSD** | 4.108 | 2.618 | 22.326 | 3.688 | 0 | 0.339 | 0.115 |
| 1 | 0.018 | 0.124 | 0.057 | 0.018 | 0.019 | 23.355 | 76.408 |
| 2 | 0.019 | 0.122 | 0.053 | 0.018 | 0.019 | 23.37 | 76.4 |
| 3 | 0.019 | 0.125 | 0.054 | 0.018 | 0.019 | 23.468 | 76.297 |
| 4 | 0.02 | 0.122 | 0.1 | 0.018 | 0.019 | 23.534 | 76.188 |
| 5 | 0.021 | 0.128 | 0.055 | 0.02 | 0.019 | 23.591 | 76.165 |
| 6 | 0.019 | 0.12 | 0.058 | 0.018 | 0.019 | 23.406 | 76.36 |
| 7 | 0.019 | 0.125 | 0.058 | 0.018 | 0.019 | 23.413 | 76.347 |
| 8 | 0.019 | 0.122 | 0.062 | 0.019 | 0.019 | 23.387 | 76.371 |
| 9 | 0.019 | 0.118 | 0.067 | 0.018 | 0.019 | 23.365 | 76.394 |
| 10 | 0.019 | 0.118 | 0.058 | 0.018 | 0.019 | 23.38 | 76.389 |

附表1.6 PNMo-8样品80目砂带磨样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.019 | 0.12 | 0.059 | 0.018 | 0.018 | 23.468 | 76.297 |
| **SD** | 0.001 | 0.003 | 0.003 | 0.001 | 0 | 0.087 | 0.087 |
| **RSD** | 6.857 | 2.53 | 4.559 | 3.688 | 2.64 | 0.372 | 0.114 |
| 1 | 0.018 | 0.119 | 0.058 | 0.018 | 0.019 | 23.417 | 76.351 |
| 2 | 0.018 | 0.12 | 0.057 | 0.018 | 0.018 | 23.412 | 76.356 |
| 3 | 0.019 | 0.118 | 0.06 | 0.018 | 0.018 | 23.399 | 76.367 |
| 4 | 0.021 | 0.115 | 0.062 | 0.018 | 0.018 | 23.484 | 76.282 |
| 5 | 0.019 | 0.124 | 0.06 | 0.018 | 0.019 | 23.421 | 76.34 |
| 6 | 0.019 | 0.12 | 0.061 | 0.019 | 0.018 | 23.484 | 76.279 |
| 7 | 0.019 | 0.115 | 0.061 | 0.02 | 0.018 | 23.536 | 76.231 |
| 8 | 0.022 | 0.122 | 0.053 | 0.018 | 0.019 | 23.683 | 76.083 |
| 9 | 0.019 | 0.123 | 0.057 | 0.018 | 0.018 | 23.43 | 76.335 |
| 10 | 0.018 | 0.12 | 0.06 | 0.018 | 0.018 | 23.414 | 76.351 |

附表1.7 PNMo-7样品40目砂带磨样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.036 | 0.378 | 0.044 | 0.014 | 0.032 | 25.372 | 74.123 |
| **SD** | 0.001 | 0.008 | 0.002 | 0.001 | 0 | 0.062 | 0.062 |
| **RSD** | 2.328 | 2.173 | 4.417 | 9.353 | 0 | 0.244 | 0.083 |
| 1 | 0.038 | 0.384 | 0.041 | 0.013 | 0.032 | 25.363 | 74.13 |
| 2 | 0.036 | 0.388 | 0.043 | 0.014 | 0.032 | 25.369 | 74.118 |
| 3 | 0.036 | 0.365 | 0.047 | 0.016 | 0.032 | 25.45 | 74.055 |
| 4 | 0.036 | 0.379 | 0.045 | 0.015 | 0.032 | 25.392 | 74.101 |
| 5 | 0.036 | 0.371 | 0.043 | 0.013 | 0.032 | 25.447 | 74.059 |
| 6 | 0.038 | 0.375 | 0.044 | 0.016 | 0.032 | 25.415 | 74.082 |
| 7 | 0.037 | 0.393 | 0.044 | 0.012 | 0.032 | 25.402 | 74.08 |
| 8 | 0.036 | 0.376 | 0.044 | 0.015 | 0.032 | 25.306 | 74.192 |
| 9 | 0.036 | 0.378 | 0.047 | 0.014 | 0.032 | 25.324 | 74.171 |
| 10 | 0.036 | 0.374 | 0.042 | 0.015 | 0.032 | 25.258 | 74.243 |

附表1.8 PNMo-7样品40目砂带磨样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.036 | 0.378 | 0.044 | 0.014 | 0.032 | 25.224 | 74.273 |
| **SD** | 0.001 | 0.008 | 0.002 | 0.001 | 0.001 | 0.057 | 0.061 |
| **RSD** | 1.852 | 2.025 | 3.453 | 7.154 | 2.481 | 0.225 | 0.082 |
| 1 | 0.037 | 0.379 | 0.041 | 0.013 | 0.032 | 25.312 | 74.185 |
| 2 | 0.036 | 0.389 | 0.044 | 0.013 | 0.033 | 25.261 | 74.224 |
| 3 | 0.037 | 0.388 | 0.041 | 0.013 | 0.033 | 25.236 | 74.252 |
| 4 | 0.036 | 0.383 | 0.045 | 0.013 | 0.032 | 25.277 | 74.214 |
| 5 | 0.036 | 0.377 | 0.043 | 0.014 | 0.032 | 25.265 | 74.233 |
| 6 | 0.036 | 0.376 | 0.045 | 0.013 | 0.032 | 25.208 | 74.29 |
| 7 | 0.035 | 0.373 | 0.044 | 0.015 | 0.031 | 25.153 | 74.347 |
| 8 | 0.036 | 0.365 | 0.044 | 0.015 | 0.031 | 25.201 | 74.308 |
| 9 | 0.036 | 0.377 | 0.045 | 0.015 | 0.031 | 25.194 | 74.302 |
| 10 | 0.035 | 0.369 | 0.044 | 0.015 | 0.031 | 25.132 | 74.374 |

附表1.9 PNMo-7样品60目砂带磨样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.036 | 0.381 | 0.043 | 0.015 | 0.032 | 25.489 | 74.004 |
| **SD** | 0.001 | 0.01 | 0.001 | 0.001 | 0.001 | 0.07 | 0.077 |
| **RSD** | 2.613 | 2.544 | 2.846 | 7.465 | 1.768 | 0.274 | 0.104 |
| 1 | 0.036 | 0.374 | 0.043 | 0.013 | 0.032 | 25.408 | 74.094 |
| 2 | 0.035 | 0.365 | 0.044 | 0.015 | 0.031 | 25.433 | 74.075 |
| 3 | 0.037 | 0.383 | 0.044 | 0.015 | 0.032 | 25.494 | 73.995 |
| 4 | 0.036 | 0.372 | 0.044 | 0.016 | 0.032 | 25.519 | 73.981 |
| 5 | 0.036 | 0.383 | 0.044 | 0.015 | 0.032 | 25.533 | 73.957 |
| 6 | 0.036 | 0.391 | 0.043 | 0.015 | 0.033 | 25.49 | 73.993 |
| 7 | 0.037 | 0.39 | 0.044 | 0.015 | 0.032 | 25.494 | 73.988 |
| 8 | 0.038 | 0.388 | 0.04 | 0.013 | 0.032 | 25.627 | 73.861 |
| 9 | 0.037 | 0.391 | 0.043 | 0.014 | 0.033 | 25.516 | 73.966 |
| 10 | 0.035 | 0.37 | 0.043 | 0.013 | 0.032 | 25.381 | 74.126 |

附表1.10 PNMo-7样品60目砂带磨样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.036 | 0.382 | 0.044 | 0.014 | 0.032 | 25.36 | 74.132 |
| **SD** | 0.001 | 0.007 | 0.003 | 0.001 | 0 | 0.043 | 0.042 |
| **RSD** | 1.859 | 1.798 | 7.449 | 8.754 | 0.991 | 0.168 | 0.057 |
| 1 | 0.037 | 0.38 | 0.042 | 0.013 | 0.032 | 25.33 | 74.166 |
| 2 | 0.036 | 0.374 | 0.052 | 0.015 | 0.032 | 25.308 | 74.183 |
| 3 | 0.037 | 0.384 | 0.043 | 0.014 | 0.032 | 25.297 | 74.194 |
| 4 | 0.037 | 0.383 | 0.044 | 0.013 | 0.032 | 25.34 | 74.151 |
| 5 | 0.036 | 0.385 | 0.041 | 0.014 | 0.032 | 25.336 | 74.156 |
| 6 | 0.036 | 0.367 | 0.041 | 0.016 | 0.031 | 25.405 | 74.103 |
| 7 | 0.035 | 0.387 | 0.045 | 0.016 | 0.032 | 25.386 | 74.1 |
| 8 | 0.037 | 0.39 | 0.042 | 0.013 | 0.032 | 25.398 | 74.088 |
| 9 | 0.036 | 0.38 | 0.042 | 0.016 | 0.032 | 25.403 | 74.091 |
| 10 | 0.036 | 0.387 | 0.043 | 0.015 | 0.032 | 25.402 | 74.085 |

附表1.11 PNMo-7样品80目砂带磨样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.036 | 0.377 | 0.044 | 0.015 | 0.032 | 25.588 | 73.908 |
| **SD** | 0.001 | 0.007 | 0.002 | 0.001 | 0 | 0.077 | 0.08 |
| **RSD** | 1.572 | 1.77 | 5.088 | 4.444 | 1.495 | 0.3 | 0.109 |
| 1 | 0.037 | 0.375 | 0.044 | 0.015 | 0.032 | 25.457 | 74.04 |
| 2 | 0.036 | 0.371 | 0.045 | 0.015 | 0.032 | 25.481 | 74.021 |
| 3 | 0.035 | 0.38 | 0.044 | 0.015 | 0.033 | 25.568 | 73.925 |
| 4 | 0.036 | 0.381 | 0.041 | 0.015 | 0.032 | 25.576 | 73.919 |
| 5 | 0.036 | 0.384 | 0.043 | 0.014 | 0.033 | 25.678 | 73.813 |
| 6 | 0.036 | 0.368 | 0.045 | 0.015 | 0.032 | 25.558 | 73.946 |
| 7 | 0.036 | 0.375 | 0.042 | 0.016 | 0.032 | 25.624 | 73.875 |
| 8 | 0.036 | 0.368 | 0.049 | 0.016 | 0.032 | 25.636 | 73.863 |
| 9 | 0.036 | 0.377 | 0.042 | 0.015 | 0.032 | 25.612 | 73.885 |
| 10 | 0.037 | 0.388 | 0.044 | 0.014 | 0.033 | 25.691 | 73.793 |

附表1.12 PNMo-7样品80目砂带磨样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.036 | 0.381 | 0.044 | 0.016 | 0.032 | 25.543 | 73.948 |
| **SD** | 0.001 | 0.006 | 0.001 | 0 | 0 | 0.039 | 0.037 |
| **RSD** | 1.964 | 1.51 | 2.143 | 2.946 | 0.985 | 0.151 | 0.05 |
| 1 | 0.036 | 0.377 | 0.043 | 0.017 | 0.032 | 25.54 | 73.956 |
| 2 | 0.035 | 0.382 | 0.046 | 0.016 | 0.032 | 25.518 | 73.971 |
| 3 | 0.035 | 0.396 | 0.044 | 0.016 | 0.032 | 25.535 | 73.943 |
| 4 | 0.036 | 0.375 | 0.044 | 0.015 | 0.032 | 25.586 | 73.911 |
| 5 | 0.035 | 0.384 | 0.045 | 0.016 | 0.032 | 25.538 | 73.95 |
| 6 | 0.035 | 0.379 | 0.043 | 0.016 | 0.032 | 25.563 | 73.932 |
| 7 | 0.037 | 0.381 | 0.044 | 0.016 | 0.032 | 25.6 | 73.891 |
| 8 | 0.036 | 0.378 | 0.043 | 0.016 | 0.032 | 25.573 | 73.923 |
| 9 | 0.036 | 0.381 | 0.044 | 0.016 | 0.033 | 25.476 | 74.014 |
| 10 | 0.035 | 0.382 | 0.044 | 0.016 | 0.032 | 25.5 | 73.99 |

附表1.13 PNMo-8样品168r/min铣床制样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.02 | 0.109 | 0.045 | 0.015 | 0.018 | 24.994 | 74.798 |
| **SD** | 0.001 | 0.004 | 0.003 | 0.001 | 0.001 | 0.045 | 0.045 |
| **RSD** | 3.131 | 3.61 | 6.072 | 8.035 | 2.807 | 0.182 | 0.06 |
| 1 | 0.021 | 0.115 | 0.047 | 0.014 | 0.019 | 24.964 | 74.82 |
| 2 | 0.02 | 0.1 | 0.048 | 0.017 | 0.018 | 24.944 | 74.854 |
| 3 | 0.02 | 0.11 | 0.049 | 0.015 | 0.018 | 24.978 | 74.81 |
| 4 | 0.02 | 0.11 | 0.047 | 0.014 | 0.018 | 24.956 | 74.836 |
| 5 | 0.021 | 0.112 | 0.046 | 0.014 | 0.019 | 24.991 | 74.798 |
| 6 | 0.02 | 0.111 | 0.044 | 0.014 | 0.019 | 25.017 | 74.774 |
| 7 | 0.021 | 0.11 | 0.043 | 0.014 | 0.019 | 25.074 | 74.718 |
| 8 | 0.02 | 0.111 | 0.04 | 0.015 | 0.018 | 25.037 | 74.76 |
| 9 | 0.02 | 0.107 | 0.043 | 0.015 | 0.018 | 25.04 | 74.756 |
| 10 | 0.019 | 0.108 | 0.046 | 0.017 | 0.018 | 24.943 | 74.849 |

附表1.14 PNMo-8样品168r/min铣床制样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.019 | 0.107 | 0.046 | 0.015 | 0.018 | 24.715 | 75.08 |
| **SD** | 0.001 | 0.003 | 0.003 | 0.001 | 0 | 0.066 | 0.068 |
| **RSD** | 2.776 | 2.594 | 6.113 | 8.035 | 0 | 0.268 | 0.09 |
| 1 | 0.019 | 0.11 | 0.053 | 0.016 | 0.018 | 24.707 | 75.078 |
| 2 | 0.019 | 0.105 | 0.047 | 0.014 | 0.018 | 24.769 | 75.028 |
| 3 | 0.019 | 0.107 | 0.048 | 0.017 | 0.018 | 24.821 | 74.97 |
| 4 | 0.019 | 0.107 | 0.046 | 0.014 | 0.018 | 24.777 | 75.019 |
| 5 | 0.019 | 0.109 | 0.046 | 0.014 | 0.018 | 24.683 | 75.11 |
| 6 | 0.018 | 0.103 | 0.045 | 0.014 | 0.018 | 24.703 | 75.098 |
| 7 | 0.018 | 0.112 | 0.046 | 0.016 | 0.018 | 24.689 | 75.101 |
| 8 | 0.018 | 0.105 | 0.046 | 0.016 | 0.018 | 24.608 | 75.189 |
| 9 | 0.018 | 0.105 | 0.043 | 0.014 | 0.018 | 24.635 | 75.168 |
| 10 | 0.019 | 0.109 | 0.043 | 0.014 | 0.018 | 24.756 | 75.041 |

附表1.15 PNMo-8样品232r/min铣床制样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.021 | 0.115 | 0.056 | 0.016 | 0.019 | 24.201 | 75.572 |
| **SD** | 0.001 | 0.003 | 0.001 | 0.001 | 0.001 | 0.125 | 0.127 |
| **RSD** | 4.703 | 3.011 | 2.525 | 4.329 | 2.84 | 0.515 | 0.168 |
| 1 | 0.021 | 0.112 | 0.057 | 0.017 | 0.019 | 24.255 | 75.52 |
| 2 | 0.024 | 0.122 | 0.053 | 0.016 | 0.019 | 24.499 | 75.267 |
| 3 | 0.022 | 0.113 | 0.057 | 0.016 | 0.019 | 24.222 | 75.55 |
| 4 | 0.021 | 0.119 | 0.056 | 0.016 | 0.019 | 24.168 | 75.602 |
| 5 | 0.021 | 0.115 | 0.056 | 0.016 | 0.018 | 24.157 | 75.617 |
| 6 | 0.022 | 0.113 | 0.055 | 0.016 | 0.018 | 24.177 | 75.599 |
| 7 | 0.021 | 0.112 | 0.058 | 0.018 | 0.018 | 24.132 | 75.642 |
| 8 | 0.021 | 0.113 | 0.056 | 0.016 | 0.019 | 24.138 | 75.637 |
| 9 | 0.021 | 0.114 | 0.056 | 0.016 | 0.018 | 24.06 | 75.715 |
| 10 | 0.021 | 0.115 | 0.056 | 0.016 | 0.019 | 24.201 | 75.572 |

附表1.16 PNMo-8样品232r/min铣床制样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.021 | 0.115 | 0.056 | 0.016 | 0.018 | 23.926 | 75.848 |
| **SD** | 0.001 | 0.003 | 0.003 | 0.001 | 0 | 0.066 | 0.066 |
| **RSD** | 3.792 | 2.731 | 4.836 | 7.217 | 1.747 | 0.277 | 0.087 |
| 1 | 0.02 | 0.115 | 0.059 | 0.018 | 0.018 | 23.847 | 75.923 |
| 2 | 0.02 | 0.111 | 0.057 | 0.018 | 0.018 | 23.845 | 75.932 |
| 3 | 0.02 | 0.115 | 0.055 | 0.016 | 0.018 | 23.861 | 75.915 |
| 4 | 0.022 | 0.112 | 0.054 | 0.015 | 0.018 | 24.029 | 75.75 |
| 5 | 0.021 | 0.117 | 0.053 | 0.016 | 0.018 | 23.988 | 75.787 |
| 6 | 0.021 | 0.113 | 0.053 | 0.015 | 0.018 | 23.989 | 75.79 |
| 7 | 0.021 | 0.115 | 0.054 | 0.016 | 0.018 | 23.912 | 75.865 |
| 8 | 0.021 | 0.121 | 0.061 | 0.015 | 0.019 | 23.949 | 75.815 |
| 9 | 0.02 | 0.113 | 0.058 | 0.016 | 0.018 | 23.882 | 75.892 |
| 10 | 0.022 | 0.119 | 0.056 | 0.015 | 0.018 | 23.962 | 75.808 |

附表1.17 PNMo-8样品330r/min铣床制样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.022 | 0.117 | 0.053 | 0.016 | 0.018 | 24.44 | 75.334 |
| **SD** | 0.001 | 0.002 | 0.003 | 0.001 | 0 | 0.142 | 0.142 |
| **RSD** | 4.541 | 2.034 | 4.928 | 6.193 | 2.64 | 0.58 | 0.189 |
| 1 | 0.023 | 0.115 | 0.057 | 0.016 | 0.018 | 24.401 | 75.37 |
| 2 | 0.02 | 0.113 | 0.054 | 0.018 | 0.018 | 24.348 | 75.429 |
| 3 | 0.022 | 0.119 | 0.051 | 0.015 | 0.019 | 24.373 | 75.4 |
| 4 | 0.023 | 0.121 | 0.048 | 0.015 | 0.019 | 24.736 | 75.038 |
| 5 | 0.022 | 0.116 | 0.052 | 0.015 | 0.019 | 24.412 | 75.364 |
| 6 | 0.022 | 0.119 | 0.055 | 0.015 | 0.018 | 24.389 | 75.383 |
| 7 | 0.022 | 0.117 | 0.054 | 0.016 | 0.018 | 24.448 | 75.325 |
| 8 | 0.021 | 0.116 | 0.054 | 0.015 | 0.018 | 24.399 | 75.378 |
| 9 | 0.023 | 0.118 | 0.052 | 0.015 | 0.018 | 24.639 | 75.133 |
| 10 | 0.021 | 0.115 | 0.056 | 0.016 | 0.018 | 24.256 | 75.518 |

附表1.18 PNMo-8样品330r/min铣床制样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.02 | 0.115 | 0.056 | 0.018 | 0.018 | 24.289 | 75.484 |
| **SD** | 0 | 0.002 | 0.003 | 0.001 | 0 | 0.048 | 0.048 |
| **RSD** | 2.087 | 1.56 | 4.517 | 3.813 | 0 | 0.196 | 0.063 |
| 1 | 0.02 | 0.115 | 0.061 | 0.018 | 0.018 | 24.219 | 75.549 |
| 2 | 0.02 | 0.115 | 0.054 | 0.018 | 0.018 | 24.254 | 75.521 |
| 3 | 0.02 | 0.114 | 0.056 | 0.018 | 0.018 | 24.297 | 75.477 |
| 4 | 0.021 | 0.116 | 0.054 | 0.018 | 0.018 | 24.319 | 75.454 |
| 5 | 0.02 | 0.118 | 0.055 | 0.018 | 0.018 | 24.304 | 75.467 |
| 6 | 0.021 | 0.112 | 0.058 | 0.016 | 0.018 | 24.241 | 75.534 |
| 7 | 0.02 | 0.114 | 0.06 | 0.017 | 0.018 | 24.392 | 75.379 |
| 8 | 0.02 | 0.117 | 0.057 | 0.018 | 0.018 | 24.297 | 75.473 |
| 9 | 0.02 | 0.115 | 0.055 | 0.018 | 0.018 | 24.287 | 75.488 |
| 10 | 0.02 | 0.113 | 0.054 | 0.018 | 0.018 | 24.28 | 75.497 |

附表1.19 PNMo-7样品168r/min铣床制样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.038 | 0.383 | 0.04 | 0.013 | 0.032 | 25.482 | 74.012 |
| **SD** | 0.002 | 0.012 | 0.002 | 0.001 | 0 | 0.119 | 0.129 |
| **RSD** | 5.2 | 3.08 | 3.727 | 9.856 | 0.985 | 0.469 | 0.174 |
| 1 | 0.038 | 0.382 | 0.042 | 0.012 | 0.032 | 25.46 | 74.034 |
| 2 | 0.04 | 0.401 | 0.038 | 0.012 | 0.033 | 25.766 | 73.71 |
| 3 | 0.04 | 0.394 | 0.038 | 0.012 | 0.032 | 25.527 | 73.958 |
| 4 | 0.039 | 0.397 | 0.04 | 0.012 | 0.032 | 25.504 | 73.975 |
| 5 | 0.038 | 0.375 | 0.04 | 0.012 | 0.032 | 25.531 | 73.971 |
| 6 | 0.038 | 0.392 | 0.041 | 0.012 | 0.032 | 25.481 | 74.004 |
| 7 | 0.037 | 0.373 | 0.04 | 0.012 | 0.032 | 25.433 | 74.074 |
| 8 | 0.035 | 0.372 | 0.042 | 0.015 | 0.032 | 25.325 | 74.18 |
| 9 | 0.034 | 0.369 | 0.041 | 0.015 | 0.032 | 25.378 | 74.131 |
| 10 | 0.037 | 0.376 | 0.042 | 0.013 | 0.032 | 25.416 | 74.085 |

附表1.20 PNMo-7样品168r/min铣床制样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.036 | 0.37 | 0.041 | 0.013 | 0.032 | 25.325 | 74.182 |
| **SD** | 0.002 | 0.013 | 0.002 | 0.001 | 0.001 | 0.154 | 0.162 |
| **RSD** | 4.633 | 3.449 | 4.137 | 7.21 | 2.09 | 0.607 | 0.219 |
| 1 | 0.034 | 0.36 | 0.041 | 0.014 | 0.031 | 25.2 | 74.319 |
| 2 | 0.035 | 0.349 | 0.042 | 0.014 | 0.032 | 25.333 | 74.196 |
| 3 | 0.035 | 0.369 | 0.042 | 0.014 | 0.032 | 25.349 | 74.158 |
| 4 | 0.036 | 0.384 | 0.042 | 0.014 | 0.033 | 25.429 | 74.062 |
| 5 | 0.036 | 0.369 | 0.04 | 0.013 | 0.032 | 25.411 | 74.099 |
| 6 | 0.04 | 0.396 | 0.038 | 0.011 | 0.033 | 25.669 | 73.813 |
| 7 | 0.036 | 0.364 | 0.042 | 0.014 | 0.032 | 25.236 | 74.276 |
| 8 | 0.035 | 0.367 | 0.044 | 0.013 | 0.032 | 25.267 | 74.243 |
| 9 | 0.035 | 0.372 | 0.043 | 0.014 | 0.033 | 25.231 | 74.272 |
| 10 | 0.037 | 0.372 | 0.04 | 0.013 | 0.033 | 25.125 | 74.379 |

附表1.21 PNMo-7样品232r/min铣床制样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.037 | 0.378 | 0.057 | 0.015 | 0.031 | 24.593 | 74.889 |
| **SD** | 0.001 | 0.006 | 0.008 | 0.001 | 0 | 0.063 | 0.062 |
| **RSD** | 2 | 1.469 | 13.883 | 6.98 | 1.351 | 0.257 | 0.083 |
| 1 | 0.036 | 0.372 | 0.079 | 0.016 | 0.031 | 24.579 | 74.886 |
| 2 | 0.037 | 0.369 | 0.053 | 0.016 | 0.031 | 24.587 | 74.908 |
| 3 | 0.036 | 0.386 | 0.054 | 0.016 | 0.032 | 24.627 | 74.849 |
| 4 | 0.038 | 0.376 | 0.055 | 0.013 | 0.031 | 24.663 | 74.824 |
| 5 | 0.038 | 0.376 | 0.054 | 0.015 | 0.031 | 24.695 | 74.792 |
| 6 | 0.037 | 0.386 | 0.054 | 0.014 | 0.031 | 24.611 | 74.866 |
| 7 | 0.037 | 0.378 | 0.057 | 0.016 | 0.032 | 24.586 | 74.894 |
| 8 | 0.037 | 0.379 | 0.055 | 0.016 | 0.031 | 24.584 | 74.899 |
| 9 | 0.036 | 0.378 | 0.053 | 0.016 | 0.031 | 24.503 | 74.982 |
| 10 | 0.037 | 0.383 | 0.054 | 0.016 | 0.031 | 24.489 | 74.99 |

附表1.22 PNMo-7样品232r/min铣床制样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.038 | 0.386 | 0.054 | 0.015 | 0.031 | 24.571 | 74.904 |
| **SD** | 0.001 | 0.009 | 0.003 | 0.001 | 0.001 | 0.075 | 0.082 |
| **RSD** | 3.027 | 2.426 | 6.355 | 6.617 | 1.645 | 0.305 | 0.109 |
| 1 | 0.038 | 0.387 | 0.055 | 0.015 | 0.031 | 24.559 | 74.915 |
| 2 | 0.036 | 0.373 | 0.057 | 0.016 | 0.031 | 24.447 | 75.04 |
| 3 | 0.039 | 0.379 | 0.051 | 0.013 | 0.031 | 24.591 | 74.896 |
| 4 | 0.039 | 0.391 | 0.055 | 0.014 | 0.032 | 24.652 | 74.817 |
| 5 | 0.04 | 0.405 | 0.05 | 0.014 | 0.032 | 24.7 | 74.759 |
| 6 | 0.038 | 0.379 | 0.054 | 0.014 | 0.031 | 24.549 | 74.936 |
| 7 | 0.039 | 0.391 | 0.052 | 0.015 | 0.032 | 24.629 | 74.842 |
| 8 | 0.037 | 0.381 | 0.055 | 0.016 | 0.031 | 24.546 | 74.935 |
| 9 | 0.038 | 0.38 | 0.061 | 0.015 | 0.031 | 24.49 | 74.986 |
| 10 | 0.039 | 0.393 | 0.05 | 0.014 | 0.032 | 24.553 | 74.918 |

附表1.23 PNMo-7样品330r/min铣床制样精密度数据（第一次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.037 | 0.391 | 0.054 | 0.016 | 0.032 | 24.628 | 74.843 |
| **SD** | 0.001 | 0.005 | 0.003 | 0.001 | 0.001 | 0.168 | 0.168 |
| **RSD** | 3.109 | 1.197 | 5.243 | 6.747 | 1.779 | 0.684 | 0.224 |
| 1 | 0.04 | 0.397 | 0.052 | 0.013 | 0.031 | 24.556 | 74.912 |
| 2 | 0.037 | 0.385 | 0.057 | 0.016 | 0.032 | 24.539 | 74.934 |
| 3 | 0.038 | 0.397 | 0.052 | 0.016 | 0.033 | 24.595 | 74.87 |
| 4 | 0.037 | 0.39 | 0.054 | 0.016 | 0.032 | 24.548 | 74.923 |
| 5 | 0.038 | 0.388 | 0.051 | 0.016 | 0.032 | 24.534 | 74.942 |
| 6 | 0.037 | 0.396 | 0.06 | 0.015 | 0.032 | 24.623 | 74.838 |
| 7 | 0.037 | 0.393 | 0.052 | 0.016 | 0.032 | 24.521 | 74.948 |
| 8 | 0.037 | 0.386 | 0.053 | 0.016 | 0.032 | 24.485 | 74.992 |
| 9 | 0.036 | 0.391 | 0.055 | 0.017 | 0.032 | 24.932 | 74.538 |
| 10 | 0.036 | 0.386 | 0.052 | 0.016 | 0.031 | 24.947 | 74.532 |

附表1.24 PNMo-7样品330r/min铣床制样精密度数据（第二次）

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **C** | **Fe** | **Mo** | **Al** | **Si** | **Pr** | **Nd** |
| **Avg** | 0.039 | 0.404 | 0.059 | 0.014 | 0.031 | 24.885 | 74.566 |
| **SD** | 0.001 | 0.01 | 0.027 | 0 | 0.001 | 0.088 | 0.092 |
| **RSD** | 2.14 | 2.557 | 45.03 | 3.378 | 1.645 | 0.353 | 0.124 |
| 1 | 0.04 | 0.423 | 0.051 | 0.015 | 0.032 | 25.076 | 74.364 |
| 2 | 0.04 | 0.397 | 0.052 | 0.014 | 0.031 | 24.946 | 74.519 |
| 3 | 0.039 | 0.4 | 0.135 | 0.014 | 0.031 | 24.809 | 74.572 |
| 4 | 0.038 | 0.406 | 0.052 | 0.014 | 0.031 | 24.887 | 74.572 |
| 5 | 0.04 | 0.41 | 0.049 | 0.014 | 0.032 | 24.876 | 74.58 |
| 6 | 0.04 | 0.418 | 0.05 | 0.014 | 0.032 | 24.935 | 74.51 |
| 7 | 0.04 | 0.397 | 0.049 | 0.014 | 0.031 | 24.89 | 74.579 |
| 8 | 0.039 | 0.389 | 0.051 | 0.015 | 0.031 | 24.792 | 74.685 |
| 9 | 0.038 | 0.401 | 0.051 | 0.015 | 0.031 | 24.777 | 74.687 |
| 10 | 0.04 | 0.4 | 0.052 | 0.014 | 0.032 | 24.865 | 74.597 |