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ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย



Appendices

ศูนย์วิทยทรัพยากร
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Appendix A

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Table A1 Quantitative analysis of magnesium of catalyst support from catalyst preparation for producing low molecular weight HDPE

| Sample | Volume of EDTA (ml) | | | Concentration of magnesium (mmol/l) | | | Average Concentration (mmol/l) |
|--------|------------------------|-----------------|-----------------|--|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| R1-01 | 19.5 | 19.5 | 19.5 | 975.0 | 975.0 | 975.0 | 975.0 |
| R1-02 | 21.6 | 21.8 | 21.9 | 1,080.0 | 1,090.0 | 1,095.0 | 1,088.3 |
| R1-03 | 18.0 | 17.8 | 17.8 | 900.0 | 890.0 | 890.0 | 893.3 |
| R2-01 | 15.2 | 15.2 | 15.3 | 760.0 | 760.0 | 765.0 | 761.7 |
| R2-02 | 18.9 | 18.8 | 18.8 | 942.5 | 940.0 | 940.0 | 940.8 |
| R2-03 | 17.1 | 17.1 | 17.1 | 855.0 | 855.0 | 852.5 | 854.2 |
| R3-01 | 23.0 | 22.8 | 22.9 | 1,150.0 | 1,140.0 | 1,142.5 | 1,144.2 |
| R3-02 | 19.7 | 19.6 | 19.6 | 982.5 | 980.0 | 977.5 | 980.0 |
| R3-03 | 19.4 | 19.4 | 19.3 | 970.0 | 970.0 | 965.0 | 968.3 |
| R4-01 | 24.7 | 24.5 | 24.6 | 1,235.0 | 1,225.0 | 1,227.5 | 1,229.2 |
| R4-02 | 17.6 | 17.5 | 17.6 | 880.0 | 875.0 | 877.5 | 877.5 |
| R4-03 | 19.2 | 19.3 | 19.3 | 957.5 | 965.0 | 965.0 | 962.5 |
| R5-01 | 21.0 | 20.9 | 21.1 | 1,050.0 | 1,045.0 | 1,055.0 | 1,050.0 |
| R5-02 | 27.3 | 27.0 | 27.1 | 1,365.0 | 1,350.0 | 1,355.0 | 1,356.7 |
| R5-03 | 16.6 | 16.5 | 16.5 | 830.0 | 825.0 | 825.0 | 826.7 |

Table A2 Quantitative analysis of total titanium of catalyst support from catalyst preparation for producing low molecular weight HDPE

| Sample | Volume of Ce(IV)SO ₄ (ml) | | | Concentration of total titanium (mmol/l) | | | Average concentration (mmol/l) |
|--------|---|-----------------|-----------------|--|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| R1-01 | 29.4 | 29.2 | 29.3 | 293.5 | 291.5 | 292.5 | 292.5 |
| R1-02 | 28.4 | 28.2 | 28.3 | 284.0 | 282.0 | 283.0 | 283.0 |
| R1-03 | 25.1 | 24.9 | 25.0 | 251.0 | 249.0 | 250.0 | 250.0 |
| R2-01 | 8.1 | 7.9 | 8.0 | 81.0 | 79.0 | 80.0 | 80.0 |
| R2-02 | 9.6 | 9.4 | 9.5 | 96.0 | 94.0 | 95.0 | 95.0 |
| R2-03 | 8.9 | 8.7 | 8.8 | 89.0 | 87.0 | 88.0 | 88.0 |
| R3-01 | 10.4 | 10.2 | 10.3 | 104.0 | 102.0 | 103.0 | 103.0 |
| R3-02 | 9.9 | 9.7 | 9.8 | 99.0 | 97.0 | 98.0 | 98.0 |
| R3-03 | 9.3 | 9.1 | 9.2 | 93.0 | 91.0 | 92.0 | 92.0 |
| R4-01 | 8.7 | 8.5 | 8.6 | 87.0 | 85.0 | 86.0 | 86.0 |
| R4-02 | 8.0 | 7.8 | 7.9 | 80.0 | 78.0 | 79.0 | 79.0 |
| R4-03 | 7.8 | 7.6 | 7.7 | 78.0 | 76.0 | 77.0 | 77.0 |
| R5-01 | 8.5 | 8.3 | 8.4 | 85.0 | 83.0 | 84.0 | 84.0 |
| R5-02 | 9.6 | 9.4 | 9.5 | 96.0 | 94.0 | 95.0 | 95.0 |
| R5-03 | 6.3 | 6.1 | 6.2 | 63.0 | 61.0 | 62.0 | 62.0 |

Table A3 Quantitative analysis of chloride of catalyst support from catalyst
for producing low molecular weight HDPE

| Sample | Volume of AgNO ₃ (ml) | | | Concentration of chloride (mmol/l) | | | Average concentration (mmol/l) |
|--------|-------------------------------------|-----------------|-----------------|--|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| R1-01 | 24.06 | 24.11 | 24.07 | 2,406 | 2,411 | 2,407 | 2,408 |
| R1-02 | 25.56 | 25.61 | 25.57 | 2,556 | 2,561 | 2,557 | 2,558 |
| R1-03 | 21.50 | 21.55 | 21.51 | 2,150 | 2,155 | 2,151 | 2,152 |
| R2-01 | 17.35 | 17.40 | 17.36 | 1,735 | 1,740 | 1,736 | 1,737 |
| R2-02 | 20.96 | 21.01 | 20.97 | 2,096 | 2,101 | 2,097 | 2,098 |
| R2-03 | 19.38 | 19.42 | 19.37 | 1,938 | 1,942 | 1,937 | 1,939 |
| R3-01 | 25.51 | 25.55 | 25.50 | 2,551 | 2,555 | 2,550 | 2,552 |
| R3-02 | 21.35 | 21.39 | 21.34 | 2,135 | 2,139 | 2,134 | 2,136 |
| R3-03 | 21.49 | 21.53 | 21.48 | 2,149 | 2,153 | 2,148 | 2,150 |
| R4-01 | 26.90 | 26.94 | 26.89 | 2,690 | 2,694 | 2,689 | 2,691 |
| R4-02 | 19.65 | 19.64 | 19.69 | 1,965 | 1,964 | 1,969 | 1,966 |
| R4-03 | 21.45 | 21.44 | 21.49 | 2,145 | 2,144 | 2,149 | 2,146 |
| R5-01 | 23.20 | 23.19 | 23.24 | 2,320 | 2,319 | 2,324 | 2,321 |
| R5-02 | 29.98 | 29.97 | 30.02 | 2,998 | 2,997 | 3,002 | 2,999 |
| R5-03 | 18.26 | 18.25 | 18.30 | 1,826 | 1,825 | 1,830 | 1,827 |

Table A4 Molar ratio of Mg:Ti:Cl catalyst support for producing low molecular weight HDPE

| Sample | Concentration of element (mmol/l) | | | Molar ratio of Mg:Ti:Cl | | | Average molar ratio of Mg:Ti:Cl |
|--------|--------------------------------------|-------|-------|----------------------------|-------|------|---------------------------------------|
| | Mg | Ti | Cl | Mg | Ti | Cl | |
| R1-01 | 975.0 | 292.5 | 2,408 | 1 | 0.300 | 2.47 | 1:0.280:2.41 |
| R1-02 | 1,088.5 | 283.0 | 2,558 | 1 | 0.260 | 2.35 | |
| R1-03 | 892.9 | 250.0 | 2,152 | 1 | 0.280 | 2.41 | |
| R2-01 | 761.9 | 80.0 | 1,737 | 1 | 0.105 | 2.28 | 1:0.103:2.26 |
| R2-02 | 940.6 | 95.0 | 2,098 | 1 | 0.101 | 2.23 | |
| R2-03 | 854.4 | 88.0 | 1,939 | 1 | 0.103 | 2.27 | |
| R3-01 | 1,144.4 | 103.0 | 2,552 | 1 | 0.090 | 2.23 | 1:0.095:2.21 |
| R3-02 | 980.0 | 98.0 | 2,136 | 1 | 0.100 | 2.18 | |
| R3-03 | 968.4 | 92.0 | 2,150 | 1 | 0.095 | 2.22 | |
| R4-01 | 1,228.6 | 86.0 | 2,691 | 1 | 0.070 | 2.19 | 1:0.080:2.22 |
| R4-02 | 877.8 | 79.0 | 1,966 | 1 | 0.090 | 2.24 | |
| R4-03 | 962.5 | 77.0 | 2,146 | 1 | 0.080 | 2.23 | |
| R5-01 | 1,050.0 | 84.0 | 2,321 | 1 | 0.080 | 2.21 | 1:0.075:2.21 |
| R5-02 | 1,357.1 | 95.0 | 2,999 | 1 | 0.070 | 2.21 | |
| R5-03 | 826.7 | 62.0 | 1,827 | 1 | 0.075 | 2.21 | |

Table A5 Quantitative analysis of total titanium of supported catalyst for producing low molecular weight HDPE

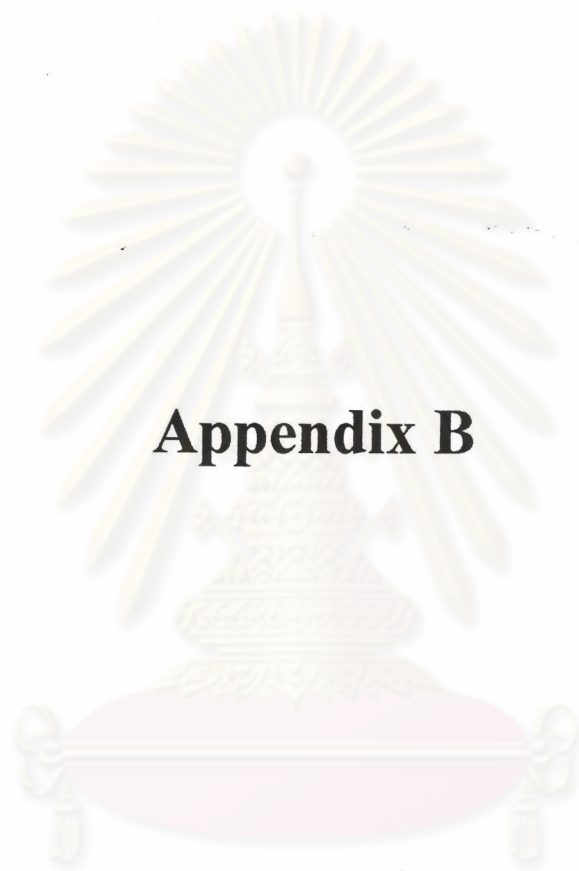
| Sample | Volume of Ce(IV)SO ₄ (ml) | | | Concentration of total titanium (mmol/l) | | | Average concentration (mmol/l) |
|--------|---|-----------------|-----------------|--|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| R1-01 | 31.3 | 31.5 | 31.5 | 125.0 | 126.0 | 126.0 | 125.7 |
| R1-02 | 28.3 | 28.3 | 27.9 | 113.0 | 113.0 | 111.5 | 112.5 |
| R1-03 | 24.5 | 24.3 | 24.4 | 98.0 | 97.0 | 97.5 | 97.5 |
| R2-01 | 26.5 | 26.3 | 26.1 | 106.0 | 105.0 | 104.5 | 105.2 |
| R2-02 | 29.5 | 29.8 | 29.5 | 118.0 | 119.0 | 118.0 | 118.3 |
| R2-03 | 31.0 | 31.3 | 31.1 | 124.0 | 125.0 | 124.5 | 124.5 |
| R3-01 | 24.0 | 24.3 | 24.0 | 96.0 | 97.0 | 96.0 | 96.3 |
| R3-02 | 34.0 | 34.3 | 34.0 | 136.0 | 137.0 | 136.0 | 136.3 |
| R3-03 | 28.8 | 29.0 | 28.6 | 115.0 | 116.0 | 114.5 | 115.2 |
| R4-01 | 24.3 | 24.5 | 24.6 | 97.0 | 98.0 | 98.5 | 97.8 |
| R4-02 | 28.8 | 29.0 | 28.6 | 115.0 | 116.0 | 114.5 | 115.2 |
| R4-03 | 31.5 | 31.8 | 31.9 | 126.0 | 127.0 | 127.5 | 126.8 |
| R5-01 | 23.5 | 23.8 | 23.6 | 94.0 | 95.0 | 94.5 | 94.5 |
| R5-02 | 21.5 | 21.8 | 21.9 | 86.0 | 87.0 | 87.5 | 86.8 |
| R5-03 | 34.3 | 34.5 | 34.4 | 137.0 | 138.0 | 137.5 | 137.5 |

Table A6 Quantitative analysis of Ti(III) of supported catalyst for producing low molecular weight HDPE

| Sample | Volume of Ce(IV)SO ₄ (ml) | | | Concentration of Ti(III) (mmol/l) | | | Average concentration (mmol/l) |
|--------|---|-----------------|-----------------|---|-----------------|-----------------|-----------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| R1-01 | 5.9 | 5.9 | 5.9 | 59.0 | 59.0 | 58.5 | 58.8 |
| R1-02 | 6.2 | 6.2 | 6.2 | 61.5 | 62.0 | 62.0 | 61.8 |
| R1-03 | 4.3 | 4.3 | 4.3 | 42.5 | 43.0 | 42.5 | 42.7 |
| R2-01 | 5.2 | 5.2 | 5.2 | 51.5 | 52.0 | 52.0 | 51.8 |
| R2-02 | 4.8 | 4.8 | 4.8 | 47.5 | 48.0 | 48.0 | 47.8 |
| R2-03 | 6.1 | 6.1 | 6.1 | 61.0 | 60.5 | 61.0 | 60.8 |
| R3-01 | 4.0 | 4.1 | 4.0 | 40.0 | 41.0 | 40.0 | 40.3 |
| R3-02 | 6.1 | 6.2 | 6.3 | 61.0 | 62.0 | 62.5 | 61.8 |
| R3-03 | 6.6 | 6.7 | 6.6 | 66.0 | 67.0 | 66.0 | 66.3 |
| R4-01 | 3.4 | 3.5 | 3.5 | 34.0 | 35.0 | 35.0 | 34.7 |
| R4-02 | 5.5 | 5.6 | 5.5 | 54.5 | 55.5 | 55.0 | 55.0 |
| R4-03 | 6.0 | 6.1 | 6.0 | 60.0 | 61.0 | 60.0 | 60.3 |
| R5-01 | 4.3 | 4.4 | 4.3 | 42.5 | 43.5 | 42.5 | 42.8 |
| R5-02 | 4.2 | 4.3 | 4.2 | 42.0 | 43.0 | 42.0 | 42.3 |
| R5-03 | 6.7 | 6.8 | 6.9 | 67.0 | 68.0 | 68.5 | 67.8 |

Table A7 Percentage of Ti(III) of supported catalyst for producing low molecular weight HDPE

| Sample | Ti(III) concentration (mmol/l) | Total titanium concentration (mmol/l) | Percentage of Ti(III) (%) | Average percentage of Ti(III) (%) |
|--------|--------------------------------------|---|---------------------------------|--|
| R1-01 | 58.8 | 125.7 | 46.8 | 48.5 |
| R1-02 | 61.8 | 112.5 | 55.0 | |
| R1-03 | 42.7 | 97.5 | 43.8 | |
| R2-01 | 51.8 | 105.2 | 49.3 | 46.2 |
| R2-02 | 47.8 | 118.3 | 40.4 | |
| R2-03 | 60.8 | 124.5 | 48.9 | |
| R3-01 | 40.3 | 96.3 | 41.9 | 48.3 |
| R3-02 | 61.8 | 136.3 | 45.4 | |
| R3-03 | 66.3 | 115.2 | 57.6 | |
| R4-01 | 34.7 | 97.8 | 35.4 | 43.6 |
| R4-02 | 55.0 | 115.2 | 47.8 | |
| R4-03 | 60.3 | 126.8 | 47.6 | |
| R5-01 | 42.8 | 94.5 | 45.3 | 47.8 |
| R5-02 | 42.3 | 86.8 | 48.8 | |
| R5-03 | 67.8 | 137.5 | 49.3 | |



Appendix B

ศูนย์วิทยทรัพยากร
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Table B1 Quantitative analysis of magnesium of catalyst support for producing high molecular weight HDPE

| Sample | Volume of EDTA (ml) | | | Concentration of magnesium (mmol/l) | | | Average concentration (mmol/l) |
|--------|------------------------|-----------------|-----------------|---|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0-01 | 10.1 | 10.0 | 10.2 | 504.3 | 499.3 | 509.3 | 504.3 |
| W0-02 | 10.5 | 10.6 | 10.4 | 524.1 | 529.1 | 519.1 | 524.1 |
| W0-03 | 8.8 | 8.9 | 9.0 | 441.4 | 446.4 | 451.4 | 446.4 |
| W1-01 | 2.9 | 3.0 | 3.1 | 145.9 | 150.9 | 155.9 | 150.9 |
| W1-02 | 3.1 | 3.0 | 3.2 | 154.0 | 149.0 | 159.0 | 154.0 |
| W1-03 | 3.1 | 3.2 | 3.0 | 156.3 | 161.3 | 151.3 | 156.3 |
| W2-01 | 4.6 | 4.5 | 4.7 | 230.4 | 225.4 | 235.4 | 230.4 |
| W2-02 | 5.1 | 5.0 | 4.9 | 256.3 | 251.3 | 246.3 | 251.3 |
| W2-03 | 4.3 | 4.2 | 4.4 | 217.5 | 212.5 | 222.5 | 217.5 |
| W3-01 | 5.5 | 5.4 | 5.3 | 273.8 | 268.8 | 263.8 | 268.8 |
| W3-02 | 6.6 | 6.5 | 6.7 | 329.2 | 324.2 | 334.2 | 329.2 |
| W3-03 | 5.6 | 5.5 | 5.4 | 280.0 | 275.0 | 270.0 | 275.0 |
| W4-01 | 8.8 | 8.7 | 8.9 | 442.1 | 437.1 | 447.1 | 442.1 |
| W4-02 | 9.4 | 9.3 | 9.2 | 468.4 | 463.4 | 458.4 | 463.4 |
| W4-03 | 6.0 | 5.9 | 6.1 | 302.4 | 297.4 | 307.4 | 302.4 |
| W10-01 | 17.1 | 17.0 | 16.9 | 857.3 | 852.3 | 847.3 | 852.3 |
| W10-02 | 15.8 | 15.7 | 15.9 | 787.5 | 782.5 | 792.5 | 787.5 |
| W10-03 | 19.0 | 18.9 | 18.8 | 949.4 | 944.4 | 939.4 | 944.4 |

Table B2 Quantitative analysis of total titanium of supported catalyst for producing high molecular weight HDPE after redox reaction at 25 °C

| Sample | Volume of Ce(IV)SO ₄ (ml) | | | Concentration of total titanium (mmol/l) | | | Average concentration (mmol/l) |
|--------|---|-----------------|-----------------|--|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0-01 | 29.4 | 29.3 | 29.2 | 293.5 | 292.5 | 291.5 | 292.5 |
| W0-02 | 28.2 | 28.4 | 28.3 | 282.0 | 284.0 | 283.0 | 283.0 |
| W0-03 | 25.0 | 24.9 | 25.1 | 250.0 | 249.0 | 251.0 | 250.0 |
| W1-01 | 7.9 | 8.1 | 8.0 | 79.0 | 81.0 | 80.0 | 80.0 |
| W1-02 | 9.6 | 9.5 | 9.4 | 96.0 | 95.0 | 94.0 | 95.0 |
| W1-03 | 8.9 | 8.7 | 8.8 | 89.0 | 87.0 | 88.0 | 88.0 |
| W2-01 | 10.4 | 10.3 | 10.2 | 104.0 | 103.0 | 102.0 | 103.0 |
| W2-02 | 9.7 | 9.9 | 9.8 | 97.0 | 99.0 | 98.0 | 98.0 |
| W2-03 | 9.3 | 9.2 | 9.1 | 93.0 | 92.0 | 91.0 | 92.0 |
| W3-01 | 8.5 | 8.7 | 8.6 | 85.0 | 87.0 | 86.0 | 86.0 |
| W3-02 | 8.0 | 7.9 | 7.8 | 80.0 | 79.0 | 78.0 | 79.0 |
| W3-03 | 7.6 | 7.8 | 7.7 | 76.0 | 78.0 | 77.0 | 77.0 |
| W4-01 | 8.5 | 8.4 | 8.3 | 85.0 | 84.0 | 83.0 | 84.0 |
| W4-02 | 9.4 | 9.6 | 9.5 | 94.0 | 96.0 | 95.0 | 95.0 |
| W4-03 | 6.3 | 6.2 | 6.1 | 63.0 | 62.0 | 61.0 | 62.0 |
| W10-01 | 7.4 | 7.5 | 7.6 | 74.0 | 75.0 | 76.0 | 75.0 |
| W10-02 | 6.3 | 6.2 | 6.4 | 63.0 | 62.0 | 64.0 | 63.0 |
| W10-03 | 6.7 | 6.8 | 6.9 | 67.0 | 68.0 | 69.0 | 68.0 |

Table B3 Quantitative analysis of chloride of catalyst support for producing high molecular weight HDPE

| Sample | Volume of AgNO ₃ (ml) | | | Concentration of chloride (mmol/l) | | | Average concentration (mmol/l) |
|--------|-------------------------------------|-----------------|-----------------|--|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0-01 | 14.41 | 14.45 | 14.40 | 1,441 | 1,445 | 1,440 | 1,442 |
| W0-02 | 16.80 | 16.81 | 16.85 | 1,680 | 1,681 | 1,685 | 1,682 |
| W0-03 | 13.65 | 13.60 | 13.61 | 1,365 | 1,360 | 1,361 | 1,362 |
| W1-01 | 3.89 | 3.90 | 3.94 | 389 | 390 | 394 | 391 |
| W1-02 | 4.25 | 4.29 | 4.24 | 425 | 429 | 424 | 426 |
| W1-03 | 4.18 | 4.17 | 4.22 | 418 | 417 | 422 | 419 |
| W2-01 | 6.56 | 6.60 | 6.55 | 656 | 660 | 655 | 657 |
| W2-02 | 5.63 | 5.64 | 5.68 | 563 | 564 | 568 | 565 |
| W2-03 | 5.54 | 5.58 | 5.53 | 554 | 558 | 553 | 555 |
| W3-01 | 6.78 | 6.79 | 6.83 | 678 | 679 | 683 | 680 |
| W3-02 | 8.38 | 8.42 | 8.37 | 838 | 842 | 837 | 839 |
| W3-03 | 6.97 | 6.98 | 7.02 | 697 | 698 | 702 | 699 |
| W4-01 | 12.37 | 12.41 | 12.36 | 1,237 | 1,241 | 1,236 | 1,238 |
| W4-02 | 10.92 | 10.93 | 10.97 | 1,092 | 1,093 | 1,097 | 1,094 |
| W4-03 | 7.79 | 7.83 | 7.78 | 779 | 783 | 778 | 780 |
| W10-01 | 18.13 | 18.14 | 18.18 | 1,813 | 1,814 | 1,818 | 1,815 |
| W10-02 | 17.24 | 17.28 | 17.23 | 1,724 | 1,728 | 1,723 | 1,725 |
| W10-03 | 20.38 | 20.39 | 20.43 | 2,038 | 2,039 | 2,043 | 2,040 |

Table B4 Molar ratio of Mg:Ti:Cl of catalyst support for producing high molecular weight HDPE

| Sample | Concentration of element (mmol/l) | | | Molar ratio of Mg:Ti:Cl | | | Average molar ratio of Mg:Ti:Cl |
|--------|--------------------------------------|-------|-------|----------------------------|-------|------|---------------------------------------|
| | Mg | Ti | Cl | Mg | Ti | Cl | |
| W0-01 | 504.3 | 292.5 | 1,442 | 1 | 0.580 | 2.86 | 1:0.560:3.04 |
| W0-02 | 524.1 | 283.0 | 1,682 | 1 | 0.540 | 3.21 | |
| W0-03 | 446.4 | 250.0 | 1,362 | 1 | 0.560 | 3.05 | |
| W1-01 | 150.9 | 80.0 | 391 | 1 | 0.530 | 2.59 | 1:0.570:2.68 |
| W1-02 | 154.0 | 95.0 | 426 | 1 | 0.617 | 2.77 | |
| W1-03 | 156.3 | 88.0 | 419 | 1 | 0.563 | 2.68 | |
| W2-01 | 230.4 | 103.0 | 657 | 1 | 0.447 | 2.85 | 1:0.420:2.55 |
| W2-02 | 251.3 | 98.0 | 565 | 1 | 0.390 | 2.25 | |
| W2-03 | 217.5 | 92.0 | 555 | 1 | 0.423 | 2.55 | |
| W3-01 | 268.8 | 86.0 | 680 | 1 | 0.320 | 2.53 | 1:0.280:2.54 |
| W3-02 | 329.2 | 79.0 | 839 | 1 | 0.240 | 2.55 | |
| W3-03 | 275.0 | 77.0 | 699 | 1 | 0.280 | 2.54 | |
| W4-01 | 442.1 | 84.0 | 1,238 | 1 | 0.190 | 2.80 | 1:2.00:2.58 |
| W4-02 | 463.4 | 95.0 | 1,094 | 1 | 0.205 | 2.36 | |
| W4-03 | 302.4 | 62.0 | 780 | 1 | 0.205 | 2.58 | |
| W10-01 | 852.3 | 75.0 | 1,815 | 1 | 0.088 | 2.13 | 1:0.080:2.16 |
| W10-02 | 787.5 | 63.0 | 1,725 | 1 | 0.080 | 2.19 | |
| W10-03 | 944.4 | 68.0 | 2,040 | 1 | 0.072 | 2.16 | |

Table B5 Quantitative analysis of total titanium of supported catalyst for producing high molecular weight HDPE after redox reaction at 25 °C

| Sample | Volume of Ce(IV)SO ₄ (ml) | | | Concentration of total titanium (mmol/l) | | | Average concentration (mmol/l) |
|----------|---|-----------------|-----------------|--|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0RT-01 | 8.7 | 8.6 | 8.8 | 86.5 | 85.5 | 87.5 | 86.5 |
| W0RT-02 | 7.5 | 7.4 | 7.3 | 75.2 | 74.2 | 73.2 | 74.2 |
| W0RT-03 | 8.9 | 9.1 | 9.0 | 89.0 | 91.0 | 90.0 | 90.0 |
| W1RT-01 | 11.3 | 11.2 | 11.1 | 112.6 | 111.6 | 110.6 | 111.6 |
| W1RT-02 | 9.5 | 9.4 | 9.6 | 95.3 | 94.3 | 96.3 | 95.3 |
| W1RT-03 | 12.0 | 12.1 | 11.9 | 120.3 | 121.3 | 119.3 | 120.3 |
| W2RT-01 | 8.9 | 8.8 | 9.0 | 88.6 | 87.6 | 89.6 | 88.6 |
| W2RT-02 | 11.1 | 11.0 | 10.9 | 111.0 | 110.0 | 109.0 | 110.0 |
| W2RT-03 | 8.9 | 8.8 | 9.0 | 89.4 | 88.4 | 90.4 | 89.4 |
| W3RT-01 | 12.8 | 12.7 | 12.6 | 127.7 | 126.7 | 125.7 | 126.7 |
| W3RT-02 | 10.5 | 10.4 | 10.6 | 105.3 | 104.3 | 106.3 | 105.3 |
| W3RT-03 | 8.7 | 8.6 | 8.5 | 87.3 | 86.3 | 85.3 | 86.3 |
| W4RT-01 | 13.0 | 12.9 | 13.1 | 129.8 | 128.8 | 130.8 | 129.8 |
| W4RT-02 | 12.4 | 12.3 | 12.2 | 123.5 | 122.5 | 121.5 | 122.5 |
| W4RT-03 | 11.0 | 10.9 | 11.1 | 110.0 | 109.0 | 111.0 | 110.0 |
| W10RT-01 | 10.8 | 10.7 | 10.6 | 107.5 | 106.5 | 105.5 | 106.5 |
| W10RT-02 | 12.1 | 12.0 | 12.2 | 121.1 | 120.1 | 122.1 | 121.1 |
| W10RT-03 | 10.1 | 10.0 | 9.9 | 100.6 | 99.6 | 98.6 | 99.6 |

Table B6 Quantitative analysis of Ti(III) of supported catalyst for producing high molecular weight HDPE after redox reaction at 25 °C

| Sample | Volume of Ce(IV)SO ₄ (ml) | | | Concentration of Ti(III) (mmol/l) | | | Average concentration (mmol/l) |
|----------|---|-----------------|-----------------|---|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0RT-01 | 4.7 | 4.6 | 4.8 | 47.0 | 46.0 | 48.0 | 47.0 |
| W0RT-02 | 3.8 | 3.7 | 3.6 | 37.5 | 36.5 | 35.5 | 36.5 |
| W0RT-03 | 4.5 | 4.7 | 4.6 | 45.4 | 47.4 | 46.4 | 46.4 |
| W1RT-01 | 4.3 | 4.2 | 4.1 | 43.2 | 42.2 | 41.2 | 42.2 |
| W1RT-02 | 5.0 | 4.9 | 5.1 | 49.6 | 48.6 | 50.6 | 49.6 |
| W1RT-03 | 5.4 | 5.5 | 5.3 | 54.0 | 55.0 | 53.0 | 54.0 |
| W2RT-01 | 4.5 | 4.4 | 4.6 | 44.7 | 43.7 | 45.7 | 44.7 |
| W2RT-02 | 3.9 | 3.8 | 3.7 | 39.3 | 38.3 | 37.3 | 38.3 |
| W2RT-03 | 3.8 | 3.7 | 3.9 | 38.0 | 37.0 | 39.0 | 38.0 |
| W3RT-01 | 4.8 | 4.7 | 4.6 | 47.7 | 46.7 | 45.7 | 46.7 |
| W3RT-02 | 4.9 | 4.8 | 5.0 | 49.1 | 48.1 | 50.1 | 49.1 |
| W3RT-03 | 3.7 | 3.6 | 3.5 | 37.2 | 36.2 | 35.2 | 36.2 |
| W4RT-01 | 4.2 | 4.1 | 4.3 | 42.0 | 41.0 | 43.0 | 42.0 |
| W4RT-02 | 4.7 | 4.6 | 4.5 | 47.1 | 46.1 | 45.1 | 46.1 |
| W4RT-03 | 4.0 | 3.9 | 4.1 | 40.1 | 39.1 | 41.1 | 40.1 |
| W10RT-01 | 4.0 | 3.9 | 3.8 | 39.6 | 38.6 | 37.6 | 38.6 |
| W10RT-02 | 3.4 | 3.3 | 3.5 | 33.5 | 32.5 | 34.5 | 33.5 |
| W10RT-03 | 3.3 | 3.2 | 3.1 | 32.7 | 31.7 | 30.7 | 31.7 |

Table B7 Percentage of reduction of supported catalyst for producing high molecular weight HDPE after redox reaction at 25 °C

| Sample | Ti(III) concentration (mmol/l) | Total titanium concentration (mmol/l) | Percentage of reduction (%) | Average of percentage of reduction (%) |
|----------|--------------------------------------|---|-----------------------------------|---|
| W0RT-01 | 47.0 | 86.5 | 54.3 | 51.7 |
| W0RT-02 | 36.5 | 74.2 | 49.2 | |
| W0RT-03 | 46.4 | 90.0 | 51.6 | |
| W1RT-01 | 42.2 | 111.6 | 37.8 | 44.9 |
| W1RT-02 | 49.6 | 95.3 | 52.0 | |
| W1RT-03 | 54.0 | 120.3 | 44.9 | |
| W2RT-01 | 44.7 | 88.6 | 50.4 | 42.6 |
| W2RT-02 | 38.3 | 110.0 | 34.9 | |
| W2RT-03 | 38.0 | 89.4 | 42.5 | |
| W3RT-01 | 46.7 | 126.7 | 36.8 | 41.8 |
| W3RT-02 | 49.1 | 105.3 | 46.7 | |
| W3RT-03 | 36.2 | 86.3 | 41.9 | |
| W4RT-01 | 42.0 | 129.8 | 32.4 | 35.5 |
| W4RT-02 | 46.1 | 122.5 | 37.7 | |
| W4RT-03 | 40.1 | 110.0 | 36.5 | |
| W10RT-01 | 38.6 | 106.5 | 36.2 | 31.9 |
| W10RT-02 | 33.5 | 121.1 | 27.7 | |
| W10RT-03 | 31.7 | 99.6 | 31.8 | |

Table B8 Quantitative analysis of total titanium of supported catalyst for producing high molecular weight HDPE with redox reaction at 120 °C

| Sample | Volume of Ce(IV)SO ₄ (ml) | | | Concentration of total titanium (mmol/l) | | | Average concentration (mmol/l) |
|----------|---|-----------------|-----------------|--|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0HT-01 | 11.0 | 10.9 | 11.1 | 109.6 | 108.6 | 110.6 | 109.6 |
| W0HT-02 | 8.8 | 8.7 | 8.6 | 88.4 | 87.4 | 86.4 | 87.4 |
| W0HT-03 | 12.8 | 13.0 | 12.9 | 127.7 | 129.7 | 128.7 | 128.7 |
| W1HT-01 | 12.3 | 12.2 | 12.1 | 123.3 | 122.3 | 121.3 | 122.3 |
| W1HT-02 | 9.3 | 9.2 | 9.4 | 93.3 | 92.3 | 94.3 | 93.3 |
| W1HT-03 | 11.2 | 11.3 | 11.1 | 112.0 | 113.0 | 111.0 | 112.0 |
| W2HT-01 | 10.3 | 10.2 | 10.4 | 103.3 | 102.3 | 104.3 | 103.3 |
| W2HT-02 | 13.3 | 13.2 | 13.1 | 132.8 | 131.8 | 130.8 | 131.8 |
| W2HT-03 | 12.1 | 12.0 | 12.2 | 120.5 | 119.5 | 121.5 | 120.5 |
| W3HT-01 | 11.3 | 11.2 | 11.1 | 113.0 | 112.0 | 111.0 | 112.0 |
| W3HT-02 | 10.5 | 10.4 | 10.6 | 104.5 | 103.5 | 105.5 | 104.5 |
| W3HT-03 | 12.4 | 12.3 | 12.2 | 124.1 | 123.1 | 122.1 | 123.1 |
| W4HT-01 | 12.5 | 12.4 | 12.6 | 124.5 | 123.5 | 125.5 | 124.5 |
| W4HT-02 | 12.9 | 12.8 | 12.7 | 128.8 | 127.8 | 126.8 | 127.8 |
| W4HT-03 | 10.9 | 10.8 | 11.0 | 108.5 | 107.5 | 109.5 | 108.5 |
| W10HT-01 | 8.5 | 8.4 | 8.3 | 85.3 | 84.3 | 83.3 | 84.3 |
| W10HT-02 | 9.8 | 9.7 | 9.9 | 97.6 | 96.6 | 98.6 | 97.6 |
| W10HT-03 | 9.2 | 9.1 | 9.0 | 92.4 | 91.4 | 90.4 | 91.4 |

Table B9 Quantitative analysis of Ti(III) of supported catalyst for producing high molecular weight HDPE after redox reaction at 120 °C

| Sample | Volume of Ce(IV)SO ₄ (ml) | | | Concentration of Ti(III) (mmol/l) | | | Average concentration (mmol/l) |
|----------|---|-----------------|-----------------|---|-----------------|-----------------|--------------------------------------|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0HT-01 | 7.8 | 7.7 | 7.9 | 78.5 | 77.5 | 79.5 | 78.5 |
| W0HT-02 | 5.2 | 5.1 | 5.0 | 52.2 | 51.2 | 50.2 | 51.2 |
| W0HT-03 | 8.3 | 8.5 | 8.4 | 82.8 | 84.8 | 83.8 | 83.8 |
| W1HT-01 | 6.3 | 6.2 | 6.1 | 62.9 | 61.9 | 60.9 | 61.9 |
| W1HT-02 | 6.7 | 6.6 | 6.8 | 67.0 | 66.0 | 68.0 | 67.0 |
| W1HT-03 | 6.9 | 7.0 | 6.8 | 68.5 | 69.5 | 67.5 | 68.5 |
| W2HT-01 | 6.1 | 6.0 | 6.2 | 60.6 | 59.6 | 61.6 | 60.6 |
| W2HT-02 | 6.1 | 6.0 | 5.9 | 61.0 | 60.0 | 59.0 | 60.0 |
| W2HT-03 | 6.3 | 6.2 | 6.4 | 62.8 | 61.8 | 63.8 | 62.8 |
| W3HT-01 | 7.6 | 7.5 | 7.4 | 75.7 | 74.7 | 73.7 | 74.7 |
| W3HT-02 | 6.4 | 6.3 | 6.5 | 64.2 | 63.2 | 65.2 | 64.2 |
| W3HT-03 | 8.0 | 7.9 | 7.8 | 79.9 | 78.9 | 77.9 | 78.9 |
| W4HT-01 | 5.6 | 5.5 | 5.7 | 55.9 | 54.9 | 56.9 | 55.9 |
| W4HT-02 | 5.4 | 5.3 | 5.2 | 53.7 | 52.7 | 51.7 | 52.7 |
| W4HT-03 | 4.7 | 4.6 | 4.8 | 46.8 | 45.8 | 47.8 | 46.8 |
| W10HT-01 | 5.6 | 5.5 | 5.4 | 55.5 | 54.5 | 53.5 | 54.5 |
| W10HT-02 | 3.9 | 3.8 | 4.0 | 39.4 | 38.4 | 40.4 | 39.4 |
| W10HT-03 | 4.9 | 4.8 | 4.7 | 49.0 | 48.0 | 47.0 | 48.0 |

Table B10 Percentage of reduction of supported catalyst for producing high molecular weight HDPE after redox reaction at 120 °C

| Sample | Ti(III) concentration (mmol/l) | Total titanium concentration (mmol/l) | Percentage of reduction (%) | Average of percentage of reduction (%) |
|----------|--------------------------------------|---|-----------------------------------|---|
| W0HT-01 | 78.5 | 109.6 | 71.6 | 65.1 |
| W0HT-02 | 51.2 | 87.4 | 58.6 | |
| W0HT-03 | 83.8 | 128.7 | 65.1 | |
| W1HT-01 | 61.9 | 122.3 | 50.6 | 61.2 |
| W1HT-02 | 67.0 | 93.3 | 71.8 | |
| W1HT-03 | 68.5 | 112.0 | 61.2 | |
| W2HT-01 | 60.6 | 103.3 | 58.7 | 52.1 |
| W2HT-02 | 60.0 | 131.8 | 45.5 | |
| W2HT-03 | 62.8 | 120.5 | 52.1 | |
| W3HT-01 | 74.7 | 112.0 | 66.7 | 64.1 |
| W3HT-02 | 64.2 | 104.5 | 61.5 | |
| W3HT-03 | 78.9 | 123.1 | 64.07 | |
| W4HT-01 | 55.9 | 124.5 | 44.9 | 43.1 |
| W4HT-02 | 52.7 | 127.8 | 41.3 | |
| W4HT-03 | 46.8 | 108.5 | 43.09 | |
| W10HT-01 | 54.5 | 84.3 | 64.7 | 52.6 |
| W10HT-02 | 39.4 | 97.6 | 40.4 | |
| W10HT-03 | 48.0 | 91.4 | 52.55 | |



Appendix C

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Table C1 Catalyst activity from catalyst for producing low molecular weight HDPE

| Sample | Weight of HDPE (g) | | | Catalyst activity (g PE×g ⁻¹ Ti×h ⁻¹) | | | Average catalyst activity (g PE×g ⁻¹ Ti×h ⁻¹) |
|--------|-----------------------|-----------------|-----------------|---|-----------------|-----------------|--|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| R1-01 | 131.9 | 112.3 | 120.3 | 63.2 | 53.8 | 57.6 | 58.2 |
| R1-02 | 119.4 | 145.1 | 137.6 | 57.2 | 69.5 | 65.9 | 64.2 |
| R1-03 | 132.4 | 113.2 | 137.8 | 63.4 | 54.2 | 66.0 | 61.2 |
| R2-01 | 64.7 | 69.5 | 68.6 | 154.9 | 166.5 | 164.3 | 161.9 |
| R2-02 | 62.0 | 60.7 | 57.0 | 148.4 | 145.4 | 136.4 | 143.4 |
| R2-03 | 64.6 | 65.9 | 60.9 | 154.8 | 157.8 | 145.8 | 152.8 |
| R3-01 | 144.1 | 143.1 | 138.8 | 345.1 | 342.7 | 332.5 | 340.1 |
| R3-02 | 157.2 | 158.1 | 152.7 | 376.6 | 378.6 | 365.6 | 373.6 |
| R3-03 | 149.2 | 146.8 | 151.1 | 357.4 | 351.6 | 362.0 | 357.0 |
| R4-01 | 262.1 | 221.1 | 173.8 | 416.2 | 529.5 | 627.8 | 524.5 |
| R4-02 | 231.6 | 193.2 | 263.8 | 462.7 | 554.7 | 631.7 | 549.7 |
| R4-03 | 186.3 | 226.3 | 260.1 | 446.2 | 542.1 | 623.0 | 537.1 |
| R5-01 | 272.6 | 339.8 | 199.1 | 652.8 | 813.8 | 476.8 | 647.8 |
| R5-02 | 338.5 | 296.1 | 247.3 | 810.8 | 709.1 | 592.4 | 704.1 |
| R5-03 | 293.3 | 284.4 | 269.2 | 681.1 | 702.5 | 644.7 | 676.1 |

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Table C2 Melt flow index at 5 kg load of HDPE from catalyst for producing low molecular weight HDPE

| Sample | MFI ₅ (g×10 min ⁻¹) | | | Average MFI ₅ (g×10 min ⁻¹) |
|--------|---|-----------------|-----------------|---|
| | 1 st | 2 nd | 3 rd | |
| R1-01 | 20.5 | 20.2 | 19.3 | 20.0 |
| R1-02 | 19.9 | 21.1 | 20.8 | 20.6 |
| R1-03 | 20.5 | 19.6 | 20.8 | 20.3 |
| R2-01 | 18.5 | 19.7 | 19.4 | 19.2 |
| R2-02 | 18.8 | 18.5 | 17.6 | 18.3 |
| R2-03 | 22.1 | 20.9 | 21.8 | 21.6 |
| R3-01 | 20.3 | 20.0 | 19.1 | 19.8 |
| R3-02 | 17.5 | 18.7 | 18.4 | 18.2 |
| R3-03 | 19.5 | 19.2 | 18.3 | 19.0 |
| R4-01 | 18.1 | 19.3 | 19.0 | 18.8 |
| R4-02 | 19.4 | 19.1 | 18.2 | 18.9 |
| R4-03 | 18.3 | 19.5 | 19.2 | 19.0 |
| R5-01 | 16.0 | 15.7 | 14.8 | 15.5 |
| R5-02 | 13.8 | 15.0 | 14.7 | 14.5 |
| R5-03 | 15.5 | 15.2 | 14.3 | 15.0 |

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Table C3 Melt flow index at 21.6 kg load of HDPE from catalyst for producing low molecular weight HDPE

| Sample | MFI _{21.6} (g×10 min ⁻¹) | | | Average MFI _{21.6} (g×10 min ⁻¹) |
|--------|--|-----------------|-----------------|--|
| | 1 st | 2 nd | 3 rd | |
| R1-01 | 193.4 | 199.3 | 195.3 | 196.0 |
| R1-02 | 203.2 | 200.5 | 208.1 | 203.9 |
| R1-03 | 204.1 | 199.3 | 196.5 | 200.0 |
| R2-01 | 189.4 | 185.0 | 195.9 | 190.1 |
| R2-02 | 176.2 | 188.3 | 181.2 | 181.9 |
| R2-03 | 244.6 | 247.9 | 253.3 | 248.6 |
| R3-01 | 201.3 | 215.2 | 207.2 | 207.9 |
| R3-02 | 188.6 | 185.2 | 194.1 | 189.3 |
| R3-03 | 194.7 | 203.1 | 197.9 | 198.6 |
| R4-01 | 198.6 | 192.9 | 206.4 | 199.3 |
| R4-02 | 196.8 | 193.2 | 194.0 | 194.7 |
| R4-03 | 197.9 | 200.6 | 197.2 | 198.6 |
| R5-01 | 161.6 | 158.5 | 159.0 | 159.7 |
| R5-02 | 160.3 | 165.8 | 156.8 | 161.0 |
| R5-03 | 167.1 | 154.6 | 159.8 | 160.5 |

Table C4 Melt flow index ratio of HDPE from catalyst for producing low molecular weight HDPE

| Sample | MFI ₅ (g×10 min ⁻¹) | MFI _{21.6} (g×10 min ⁻¹) | MFR | Average MFR |
|--------|---|--|------|-------------|
| R1-01 | 20.0 | 196.0 | 9.8 | 9.9 |
| R1-02 | 20.6 | 203.9 | 9.9 | |
| R1-03 | 20.3 | 200.0 | 9.8 | |
| R2-01 | 19.2 | 190.1 | 9.9 | 10.5 |
| R2-02 | 18.3 | 181.9 | 9.9 | |
| R2-03 | 21.6 | 248.6 | 11.5 | |
| R3-01 | 19.8 | 207.9 | 10.5 | 10.5 |
| R3-02 | 18.2 | 189.3 | 10.4 | |
| R3-03 | 19.0 | 198.6 | 10.5 | |
| R4-01 | 18.8 | 199.3 | 10.6 | 10.5 |
| R4-02 | 18.9 | 194.7 | 10.3 | |
| R4-03 | 19.0 | 198.6 | 10.5 | |
| R5-01 | 15.5 | 159.7 | 10.3 | 10.7 |
| R5-02 | 14.5 | 161.0 | 11.1 | |
| R5-03 | 15.0 | 160.5 | 10.7 | |

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Table C5 Catalyst activity from catalyst for producing high molecular weight HDPE
after redox reaction at 25 °C

| Sample | Weight of HDPE (g) | | | Catalyst activity (g PE×g ⁻¹ Ti×h ⁻¹) | | | Average catalyst activity (g PE×g ⁻¹ Ti×h ⁻¹) |
|----------|-----------------------|-----------------|-----------------|---|-----------------|-----------------|--|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0RT-01 | 143.4 | 139.1 | 137.5 | 68.7 | 66.6 | 65.9 | 67.1 |
| W0RT-02 | 117.5 | 123.4 | 119.1 | 56.3 | 59.1 | 57.0 | 57.5 |
| W0RT-03 | 129.2 | 127.7 | 133.6 | 61.9 | 61.2 | 64.0 | 62.4 |
| W1RT-01 | 123.7 | 129.6 | 125.3 | 59.2 | 62.1 | 60.0 | 60.4 |
| W1RT-02 | 106.7 | 102.4 | 100.8 | 51.1 | 49.0 | 48.3 | 49.5 |
| W1RT-03 | 112.5 | 114.0 | 118.4 | 53.9 | 54.6 | 56.7 | 55.1 |
| W2RT-01 | 173.6 | 169.2 | 167.6 | 83.2 | 81.1 | 80.3 | 81.5 |
| W2RT-02 | 231.6 | 233.1 | 237.5 | 110.9 | 111.7 | 113.8 | 112.1 |
| W2RT-03 | 201.1 | 199.5 | 205.5 | 96.3 | 95.6 | 98.4 | 96.8 |
| W3RT-01 | 172.5 | 176.9 | 170.9 | 82.6 | 84.7 | 81.9 | 83.1 |
| W3RT-02 | 236.0 | 230.1 | 231.7 | 113.1 | 110.2 | 111.0 | 111.4 |
| W3RT-03 | 200.2 | 206.2 | 201.8 | 95.9 | 98.8 | 96.7 | 97.1 |
| W4RT-01 | 266.6 | 262.3 | 260.7 | 127.7 | 125.6 | 124.9 | 126.1 |
| W4RT-02 | 208.7 | 210.3 | 214.7 | 100.0 | 100.7 | 102.8 | 101.2 |
| W4RT-03 | 234.6 | 240.5 | 236.1 | 112.4 | 115.2 | 113.1 | 113.6 |
| W10RT-01 | 164.6 | 164.0 | 166.4 | 197.1 | 196.4 | 199.2 | 197.6 |
| W10RT-02 | 191.6 | 192.2 | 194.0 | 229.4 | 230.2 | 232.3 | 230.6 |
| W10RT-03 | 177.8 | 178.4 | 180.1 | 212.9 | 213.6 | 215.7 | 214.1 |

Table C6 Melt flow index at 5 kg load of HDPE from catalyst for producing high molecular weight HDPE

| Sample | MFI ₅ (g×10 min ⁻¹) | | | Average MFI ₅ (g×10 min ⁻¹) |
|----------|---|------|------|---|
| | | | | |
| W0RT-01 | 14.1 | 13.8 | 12.9 | 13.6 |
| W0RT-02 | 10.9 | 12.1 | 11.8 | 11.6 |
| W0RT-03 | 12.8 | 11.9 | 13.1 | 12.6 |
| W1RT-01 | 12.9 | 14.1 | 13.8 | 13.6 |
| W1RT-02 | 14.0 | 13.7 | 12.8 | 13.5 |
| W1RT-03 | 13.9 | 12.7 | 13.6 | 13.4 |
| W2RT-01 | 15.5 | 15.2 | 14.3 | 15.0 |
| W2RT-02 | 15.3 | 16.5 | 16.2 | 16.0 |
| W2RT-03 | 16.0 | 15.7 | 14.8 | 15.5 |
| W3RT-01 | 14.8 | 16.0 | 15.7 | 15.5 |
| W3RT-02 | 13.8 | 13.5 | 12.6 | 13.3 |
| W3RT-03 | 13.7 | 14.9 | 14.6 | 14.4 |
| W4RT-01 | 16.6 | 16.3 | 15.4 | 16.1 |
| W4RT-02 | 14.9 | 16.1 | 15.8 | 15.6 |
| W4RT-03 | 16.5 | 16.2 | 15.3 | 16.0 |
| W10RT-01 | 18.5 | 19.7 | 19.4 | 19.2 |
| W10RT-02 | 16.0 | 15.7 | 14.8 | 15.5 |
| W10RT-03 | 16.5 | 17.7 | 17.4 | 17.2 |

Table C7 Melt flow index at 21.6 kg load of HDPE from catalyst for producing high molecular weight HDPE

| Sample | MFI _{21.6} (g×10 min ⁻¹) | | | Average MFI _{21.6} (g×10 min ⁻¹) |
|----------|--|-------|-------|--|
| | | | | |
| W0RT-01 | 135.9 | 134.0 | 133.9 | 134.6 |
| W0RT-02 | 115.3 | 117.3 | 115.4 | 116.0 |
| W0RT-03 | 124.8 | 124.7 | 126.7 | 125.4 |
| W1RT-01 | 124.4 | 126.4 | 124.5 | 125.1 |
| W1RT-02 | 132.3 | 130.4 | 130.3 | 131.0 |
| W1RT-03 | 127.1 | 125.1 | 125.2 | 125.8 |
| W2RT-01 | 148.3 | 146.4 | 146.3 | 147.0 |
| W2RT-02 | 157.7 | 159.7 | 157.8 | 158.4 |
| W2RT-03 | 153.0 | 151.1 | 151.0 | 151.7 |
| W3RT-01 | 148.1 | 150.1 | 148.2 | 148.8 |
| W3RT-02 | 133.0 | 131.1 | 131.0 | 131.7 |
| W3RT-03 | 140.6 | 142.6 | 140.7 | 141.3 |
| W4RT-01 | 165.5 | 163.6 | 163.5 | 164.2 |
| W4RT-02 | 153.7 | 155.7 | 153.8 | 154.4 |
| W4RT-03 | 162.1 | 160.2 | 160.1 | 160.8 |
| W10RT-01 | 204.7 | 206.7 | 204.8 | 205.4 |
| W10RT-02 | 164.1 | 162.2 | 162.1 | 162.8 |
| W10RT-03 | 181.6 | 183.6 | 181.7 | 182.3 |

Table C8 Melt flow index ratio of HDPE from catalyst for producing high molecular weight HDPE

| Sample | MFI ₅ (g×10 min ⁻¹) | MFI _{21.6} (g×10 min ⁻¹) | MFR | Average MFR |
|----------|---|--|------|-------------|
| W0RT-01 | 13.6 | 134.6 | 9.9 | 10.0 |
| W0RT-02 | 11.6 | 116.0 | 10 | |
| W0RT-03 | 12.6 | 125.4 | 10.0 | |
| W1RT-01 | 13.6 | 125.1 | 9.2 | 9.4 |
| W1RT-02 | 13.5 | 131.0 | 9.7 | |
| W1RT-03 | 13.4 | 125.8 | 9.4 | |
| W2RT-01 | 15.0 | 147.0 | 9.8 | 9.8 |
| W2RT-02 | 16.0 | 158.4 | 9.9 | |
| W2RT-03 | 15.5 | 151.7 | 9.8 | |
| W3RT-01 | 15.5 | 148.8 | 9.6 | 9.8 |
| W3RT-02 | 13.3 | 131.7 | 9.9 | |
| W3RT-03 | 14.4 | 141.3 | 9.8 | |
| W4RT-01 | 16.1 | 164.2 | 10.2 | 10.1 |
| W4RT-02 | 15.6 | 154.4 | 9.9 | |
| W4RT-03 | 16.0 | 160.8 | 10.1 | |
| W10RT-01 | 19.2 | 205.4 | 10.7 | 10.6 |
| W10RT-02 | 15.5 | 162.8 | 10.5 | |
| W10RT-03 | 17.2 | 182.3 | 10.6 | |

Table C9 Catalyst activity from catalyst for producing high molecular weight HDPE
after redox reaction at 120 °C

| Sample | Weight of HDPE (g) | | | Catalyst activity (g PE×g ⁻¹ Ti×h ⁻¹) | | | Average catalyst activity (g PE×g ⁻¹ Ti×h ⁻¹) |
|----------|-----------------------|-----------------|-----------------|---|-----------------|-----------------|--|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| W0HT-01 | 178.4 | 174.1 | 172.5 | 85.5 | 83.4 | 82.6 | 83.8 |
| W0HT-02 | 167.5 | 173.4 | 169.1 | 80.2 | 83.1 | 81.0 | 81.4 |
| W0HT-03 | 171.4 | 169.8 | 175.8 | 82.1 | 81.3 | 84.2 | 82.5 |
| W1HT-01 | 122.8 | 128.8 | 124.4 | 58.8 | 61.7 | 59.6 | 60.0 |
| W1HT-02 | 122.9 | 118.6 | 117.0 | 58.9 | 56.8 | 56.0 | 57.2 |
| W1HT-03 | 121.2 | 125.6 | 119.7 | 58.1 | 60.2 | 57.3 | 58.5 |
| W2HT-01 | 151.6 | 147.2 | 145.6 | 72.6 | 70.5 | 69.8 | 71.0 |
| W2HT-02 | 211.4 | 215.8 | 209.8 | 101.3 | 103.4 | 100.5 | 101.7 |
| W2HT-03 | 179.1 | 177.5 | 183.5 | 85.8 | 85.0 | 87.9 | 86.2 |
| W3HT-01 | 126.8 | 128.4 | 132.8 | 60.8 | 61.5 | 63.6 | 62.0 |
| W3HT-02 | 211.0 | 205.1 | 206.7 | 101.1 | 98.2 | 99.0 | 99.4 |
| W3HT-03 | 166.0 | 171.9 | 167.5 | 79.5 | 82.4 | 80.3 | 80.7 |
| W4HT-01 | 267.1 | 262.8 | 261.2 | 128.0 | 125.9 | 125.1 | 126.3 |
| W4HT-02 | 193.1 | 197.5 | 191.5 | 92.5 | 94.6 | 91.7 | 92.9 |
| W4HT-03 | 226.2 | 232.1 | 227.7 | 108.3 | 111.2 | 109.1 | 109.5 |
| W10HT-01 | 146.7 | 146.1 | 148.5 | 175.7 | 174.9 | 177.8 | 176.1 |
| W10HT-02 | 204.6 | 206.4 | 204.0 | 245.0 | 247.1 | 244.3 | 245.5 |
| W10HT-03 | 175.6 | 177.4 | 175.0 | 210.3 | 212.4 | 209.6 | 210.8 |

Table C10 Melt flow index at 5 kg load of HDPE from catalyst for producing high molecular weight HDPE after redox reaction at 120 °C

| Sample | MFI ₅ (g×10 min ⁻¹) | | | Average MFI ₅ (g×10 min ⁻¹) |
|----------|---|------|------|---|
| | | | | |
| W0HT-01 | 13.9 | 13.6 | 12.7 | 13.4 |
| W0HT-02 | 12.0 | 13.2 | 12.9 | 12.7 |
| W0HT-03 | 13.4 | 12.5 | 13.7 | 13.2 |
| W1HT-01 | 7.8 | 9.0 | 8.7 | 8.5 |
| W1HT-02 | 15.3 | 15.0 | 14.1 | 14.8 |
| W1HT-03 | 12.3 | 11.1 | 12.0 | 11.8 |
| W2HT-01 | 8.9 | 8.6 | 7.7 | 8.4 |
| W2HT-02 | 11.8 | 13.0 | 12.7 | 12.5 |
| W2HT-03 | 11.1 | 10.8 | 9.9 | 10.6 |
| W3HT-01 | 11.5 | 12.7 | 12.4 | 12.2 |
| W3HT-02 | 14.1 | 13.8 | 12.9 | 13.6 |
| W3HT-03 | 12.2 | 13.4 | 13.1 | 12.9 |
| W4HT-01 | 15.2 | 14.9 | 14.0 | 14.7 |
| W4HT-02 | 12.5 | 13.7 | 13.4 | 13.2 |
| W4HT-03 | 14.6 | 14.3 | 13.4 | 14.1 |
| W10HT-01 | 13.5 | 14.7 | 14.4 | 14.2 |
| W10HT-02 | 20.8 | 20.5 | 19.6 | 20.3 |
| W10HT-03 | 16.7 | 17.9 | 17.6 | 17.4 |

Table C11 Melt flow index at 21.6 kg load of HDPE from catalyst for producing high molecular weight HDPE after redox reaction at 120 °C

| Sample | MFI _{21.6} (g×10 min ⁻¹) | | | Average MFI _{21.6} (g×10 min ⁻¹) |
|----------|--|-------|-------|--|
| | | | | |
| W0HT-01 | 135.3 | 133.4 | 133.3 | 134.0 |
| W0HT-02 | 128.8 | 130.8 | 128.9 | 129.5 |
| W0HT-03 | 132.7 | 132.6 | 134.6 | 133.3 |
| W1HT-01 | 76.7 | 78.7 | 76.8 | 77.4 |
| W1HT-02 | 184.8 | 182.9 | 182.8 | 183.5 |
| W1HT-03 | 129.9 | 127.9 | 128.0 | 128.6 |
| W2HT-01 | 77.8 | 75.9 | 75.8 | 76.5 |
| W2HT-02 | 118.6 | 120.6 | 118.7 | 119.3 |
| W2HT-03 | 99.3 | 97.4 | 97.3 | 98.0 |
| W3HT-01 | 118.9 | 120.9 | 119.0 | 119.6 |
| W3HT-02 | 137.3 | 135.4 | 135.3 | 136.0 |
| W3HT-03 | 127.0 | 129.0 | 127.1 | 127.7 |
| W4HT-01 | 148.3 | 146.4 | 146.3 | 147.0 |
| W4HT-02 | 126.0 | 128.0 | 126.1 | 126.7 |
| W4HT-03 | 139.5 | 137.6 | 137.5 | 138.2 |
| W10HT-01 | 141.3 | 143.3 | 141.4 | 142.0 |
| W10HT-02 | 220.5 | 218.6 | 218.5 | 219.2 |
| W10HT-03 | 180.3 | 182.3 | 180.4 | 181.0 |

Table C12 Melt flow index ratio of HDPE from catalyst for producing high molecular weight HDPE after redox reaction at 120 °C

| Sample | MFI ₅ (g×10 min ⁻¹) | MFI _{21.6} (g×10 min ⁻¹) | MFR | Average MFR |
|----------|---|--|------|-------------|
| W0HT-01 | 13.4 | 134.0 | 10.0 | 10.1 |
| W0HT-02 | 12.7 | 129.5 | 10.2 | |
| W0HT-03 | 13.2 | 133.3 | 10.1 | |
| W1HT-01 | 8.5 | 77.4 | 9.1 | 10.8 |
| W1HT-02 | 14.8 | 183.5 | 12.4 | |
| W1HT-03 | 11.8 | 128.6 | 10.9 | |
| W2HT-01 | 8.4 | 76.5 | 9.1 | 9.3 |
| W2HT-02 | 12.5 | 119.3 | 9.5 | |
| W2HT-03 | 10.6 | 98.0 | 9.3 | |
| W3HT-01 | 12.2 | 119.6 | 9.8 | 9.9 |
| W3HT-02 | 13.6 | 136.0 | 10.0 | |
| W3HT-03 | 12.9 | 127.7 | 9.9 | |
| W4HT-01 | 14.7 | 147.0 | 10.0 | 9.8 |
| W4HT-02 | 13.2 | 126.7 | 9.6 | |
| W4HT-03 | 14.1 | 138.2 | 9.8 | |
| W10HT-01 | 14.2 | 142.0 | 10.0 | 10.4 |
| W10HT-02 | 20.3 | 219.2 | 10.8 | |
| W10HT-03 | 17.4 | 181.0 | 10.4 | |



Appendix D

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Table D1 Catalyst efficiency from mixed catalyst for producing broad molecular weight distribution HDPE

| R3:W2HT | Weight of HDPE (g) | | | Catalyst efficiency (g PE×g ⁻¹ Ti×h ⁻¹) | | | Average catalyst efficiency (g PE×g ⁻¹ Ti×h ⁻¹) |
|---------|-----------------------|-----------------|-----------------|---|-----------------|-----------------|--|
| | 1 st | 2 nd | 3 rd | 1 st | 2 nd | 3 rd | |
| 1:9 | 79.3 | 78.4 | 67.6 | 94.9 | 93.9 | 80.9 | 89.9 |
| 3:7 | 83.3 | 96.7 | 95.0 | 99.8 | 115.8 | 113.8 | 109.8 |
| 5:5 | 146.2 | 117.8 | 147.1 | 175.1 | 141.1 | 176.1 | 164.1 |
| 7:3 | 136.1 | 165.3 | 164.4 | 162.9 | 197.9 | 196.9 | 185.9 |
| 9:1 | 180.0 | 179.2 | 150.8 | 215.5 | 214.5 | 180.5 | 203.5 |

Table D2 Molecular weight by number of HDPE from mixed catalyst for producing broad molecular weight distribution HDPE

| R3:W2HT | Mn | | | Average Mn |
|---------|--------|--------|--------|------------|
| | 1st | 2nd | 3rd | |
| 1:9 | 23,450 | 23,350 | 23,100 | 23,300 |
| 3:7 | 16,900 | 17,250 | 17,150 | 17,100 |
| 5:5 | 15,250 | 15,000 | 15,350 | 15,200 |
| 7:3 | 25,500 | 25,850 | 25,750 | 25,700 |
| 9:1 | 9,550 | 9,450 | 9,200 | 9,400 |

Table D3 Molecular weight by weight of HDPE from mixed catalyst for producing broad molecular weight distribution HDPE

| R3:W2HT | Mw | | | Average Mw |
|---------|---------|---------|---------|------------|
| | 1st | 2nd | 3rd | |
| 1:9 | 118,000 | 118,000 | 117,700 | 117,900 |
| 3:7 | 76,100 | 76,400 | 76,400 | 76,300 |
| 5:5 | 88,500 | 88,200 | 88,500 | 88,400 |
| 7:3 | 94,100 | 94,400 | 94,400 | 94,300 |
| 9:1 | 66,900 | 66,900 | 66,600 | 66,800 |

Table D4 Molecular weight distribution of HDPE from mixed catalyst for producing broad molecular weight distribution HDPE

| R3:W2HT | Average Mn | Average Mw | Average MWD |
|---------|------------|------------|-------------|
| 1:9 | 23,300 | 117,900 | 5.1 |
| 3:7 | 17,100 | 76,300 | 4.5 |
| 5:5 | 15,200 | 88,400 | 5.8 |
| 7:3 | 25,700 | 94,300 | 3.7 |
| 9:1 | 9,400 | 66,800 | 7.1 |

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Appendix E

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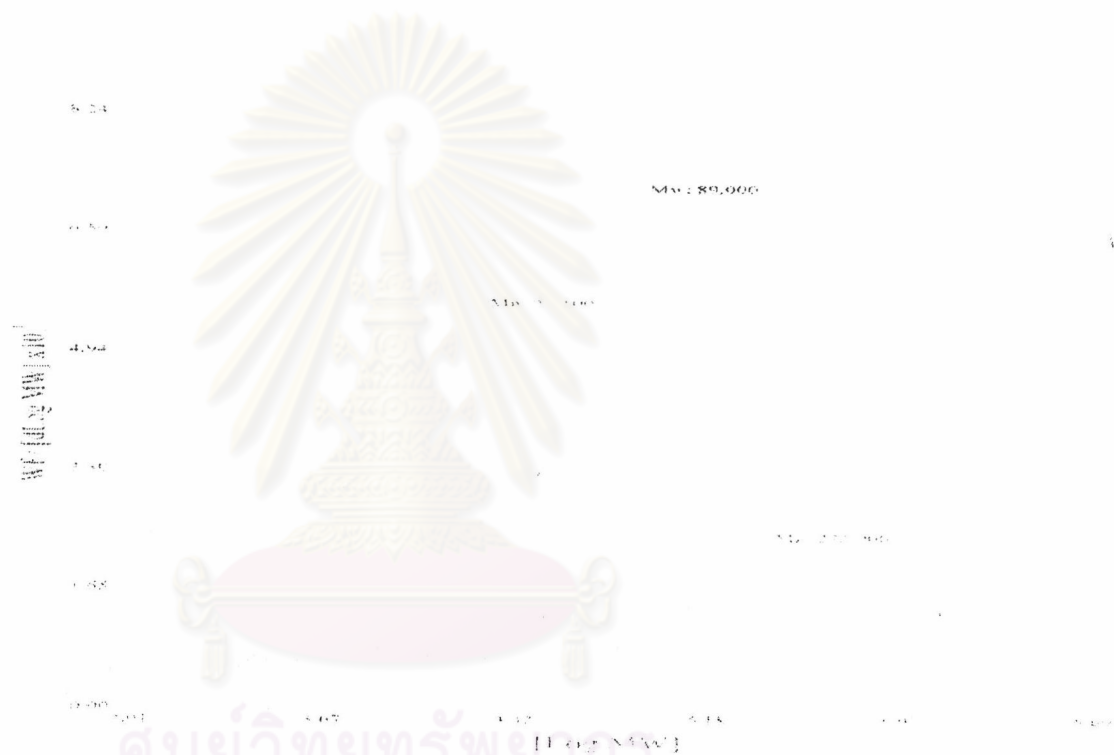


Figure E1 Gel permeation chromatography of HDPE that was polymerized by mixed catalyst of R3 with W2HT in 1 per 9 ratio

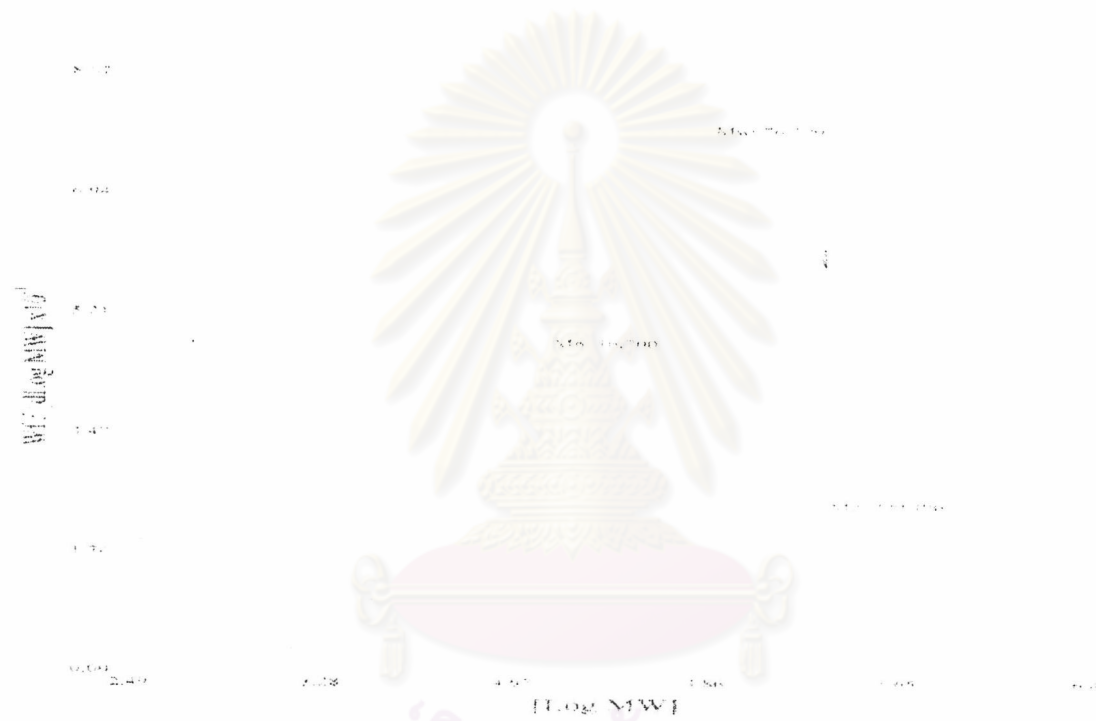


Figure E2 Gel permeation chromatography of HDPE that was polymerized by mixed catalyst of R3 with W2HT in 3 per 7 ratio

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Figure E3 Gel permeation chromatography of HDPE that was polymerization by mixed catalyst of R3 with W2H11 in 5 per 5 ratio

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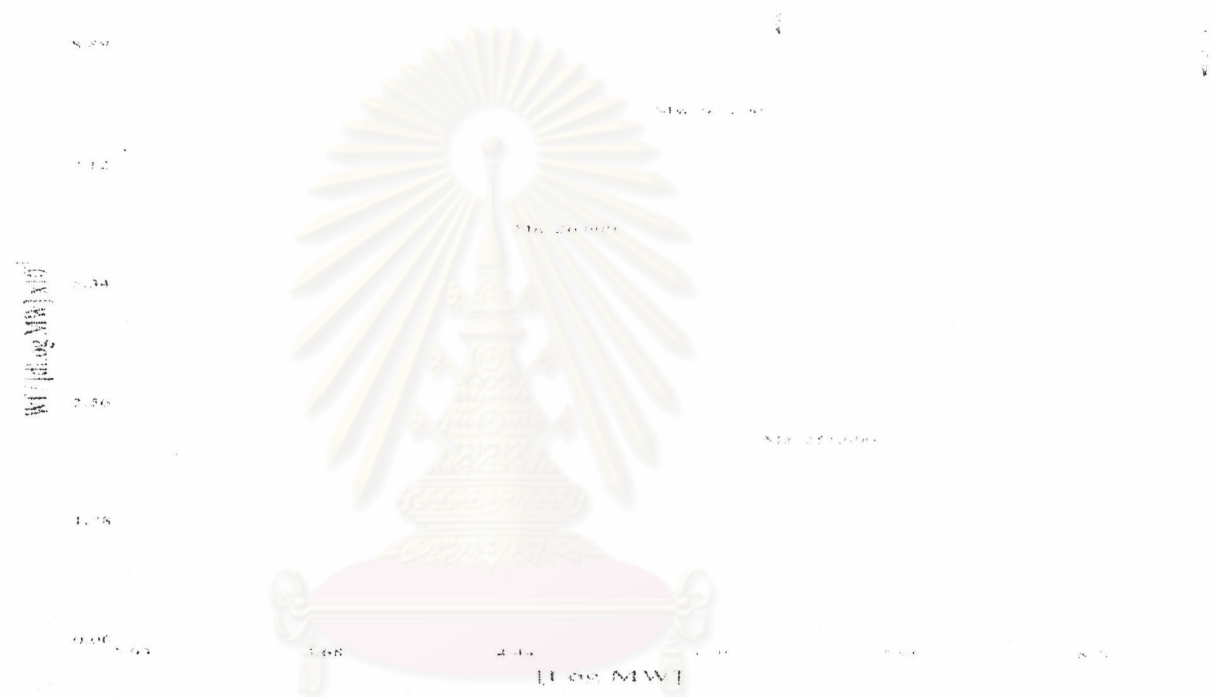


Figure E4 Gel permeation chromatography of HDPE that was polymerization by mixed catalyst of R3 with W2HT in 7 per 3 ratio

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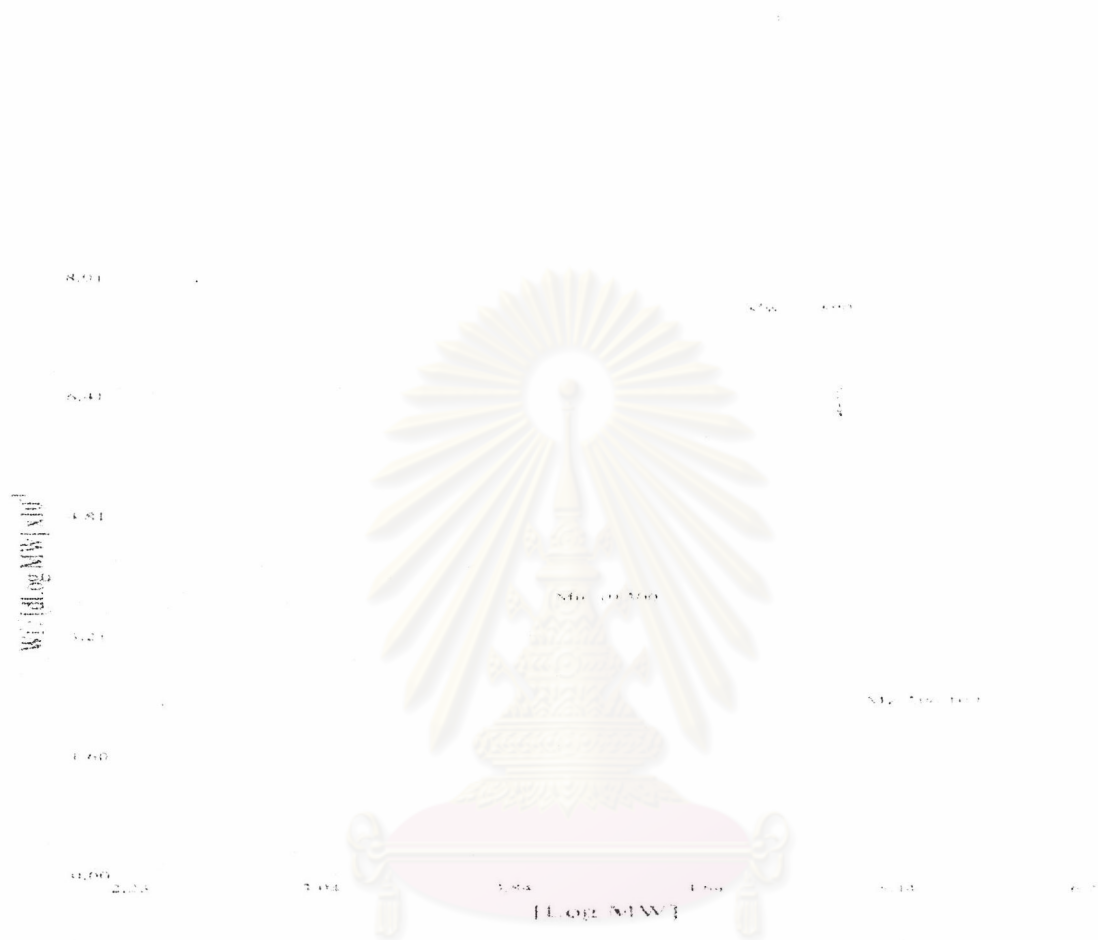


Figure E5 Gel permeation chromatography of HDPE that was polymerization by mixed catalyst of R3 with W2/IT in 9 per 1 ratio

ศูนย์วิจัยหัตถศึกษา
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