Introduction:
This invention describes two new classes of electrocatalyst materials for application in alkaline fuel cells. The first can facilitate both hydrogen oxidation and hydrogen evolution reactions, while the second can catalyze oxygen reduction and oxygen evolution reactions. All of these processes are essential for high-performing fuel cells and electrolyzers. These novel catalyst materials are significantly less expensive than currently available commercial fuel cell catalysts and could also have applications in oxygen sensors, catalytic converters and lithium-air batteries.

**IrPdRu Catalysts**

**Synthesis of IrRu/C, IrPd/C and IrPdRu/C catalysts**

**Wet Impregnation Method**

**TEM Characterization**

**XRD Patterns of IrPdRu/C catalysts**

**Mn,Ru_{1-x}O_2 Catalysts**

**Thin Film Binary Oxides - Mn,Ru_{1-x}O_2**

**Thin Film Ternary Oxides - (Mn+Co/Fe)_Ru_{1-x}O_2**

**H2 Oxidation and Evolution on IrPdRu/C catalysts**

**Synthesis of Mn,Ru_{1-x}O_2 Particles**

1. RuCl_3•3H_2O (80 parts) and MnSO_4 (12 parts) were mixed in 5 mL water, and stirred for approx. 30 min.
2. MnO_2 (8 parts equivalent, 4 mL aq. solution) was added and stirred for 10 min. A brown solid precipitated.
3. The solid-liquid suspension was transferred to a Teflon bomb autoclave and was heated at 160 °C for 6 hours.
4. The black precipitate was filtered, and washed with water, and was annealed in air at 450 °C for 6 hours.

**O2 Reduction and Evolution on Mn,Ru_{1-x}O_2 Particles**

**Conclusions**

- IrRu/C, IrPd/C and IrPdRu/C catalysts are more active than individual element catalysts, even Pt/C, for HOR and HER. High Ru-content catalysts - IrRu/C and IrPdRu/C are much less expensive than Pt/C and Ir/C, while being more active than Pt/C and Ir/C.
- Mn,Ru_{1-x}O_2 is comparable to Pt in its activity/efficiency for ORR and OER, but is significantly less expensive. Manufacturing processes are well-known methods and are easily scalable.

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