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# SURFACE FUNCTIONALIZATION OF GRAPHENE PRIOR TO NANOPARTICLES TETHERING FOR TRI-FUNCTIONALITY IN BOTH ACIDIC AND ALKALINE MEDIA

**Abstract**

NASA's aerospace vehicles often use regenerative fuel cells (RFC) that require tri-functionality to decrease weight, thereby cost, for space exploration purposes. Tri-functionality requires three reactions to supply energy: oxygen reduction reaction (ORR), oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) thereby allowing water splitting and formation. Many RFC based technologies have been centered on its use of noble based metals such as Pt and its alloys (Pt/Ir or Pt/Ru) due to their efficient catalytic surface area, selectivity towards hydrogen and oxygen and stability in harsh environments. However, their susceptibility to fast degradation in durability tests, agglomeration, and methanol poisoning has driven research to find alternatives.[1]. Non-precious transition metal oxides (TMO) including Fe3O4, MnOx and Co3O4 have attracted significant attention as they maximize catalytically active sites per volume and mass [2].

We utilized a composite structure where CeO2, ZrO2 or TiO2 is deposited onto conductive 3D carbon structure, such as graphene oxide (GO),whose merits include high surface area and excellent electronic conductivity. However, GO contains oxygen based functional groups on the edges and wrinkles that provides an anchor for nanoparticles binding, while its basal plane stays relatively non-reactive. To more fully utilized GO, we leverage acid treatment to functionalize the basal surface using phosphoric, hydrobromic and/or oxalic acid. After such treatment, various types of GO were hydrothermally reacted with precursors (Ce(NO3)3 or ZrOCl2) or nanoparticles (P25).

The hydroxylated CeO2/GO hybrids showed the best ORR and OER performance in both 0.1 M HClO2 and 0.1 M KOH, in terms of onset/half-wave potential, electron transfer number, and current density when comparing to the performance of IrO2 or Pt/C. From a series of material/experimental analyses, a strong tethering of metal oxides upon the basal plane of GO prohibits restacking, and that the particle-GO interfaces (as oppose to the particle or GO itself) dictates the performance and reaction route, as indicated in density functional theory calculations.

However, further analysis was needed to see if an additive such as PdO2 via hydrothermal reaction could be used to increase HER capabilities [3]. Results have indicated an increase in HER capabilities of the CeO2/GO/PdO2 hybrid.

## References

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