Effect of Cobalt-Platinum Nanoalloy Combination with Non-Metallic Catalyst Fe-N-C on Anti-Poisoning Performance of Hydrogen Fuel Cell Catalyst

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Abstract: Due to the growing global demand for sustainable energy sources, the advent of hydrogen energy reduces dependence on fossil fuels. Hydrogen possesses a high calorific value and emits non-polluting substances in comparison to traditional fossil fuels. As a result, hydrogen energy exhibits significant potential for development. Hydrogen fuel cells are a major technology for the realization of multi-directional hydrogen energy applications. Changes in catalyst activity during battery use will affect battery life. Catalyst poisoning is a major difficulty affecting battery life. Combining cobalt-platinum nanoprecious metals with non-metallic catalysts Fe-N-C. This paper combined with a number of current research results explores the effect of combining cobalt-platinum nanoprecious metals with non-metallic catalysts Fe-N-C on the catalyst's antitoxicizing effect. The catalyst was investigated for battery performance studies. Cost of catalyst manufacturing is evaluated into battery use. The feasibility of using batteries for manufacturing is analyzed. Under a multi-faceted inspection, combining nanoprecious metals with non-precious metal catalysts plays an important role in the anti-toxicity effect and performance enhancement of batteries. Under conditions of catalyst poisoning, Exploiting the anomalous infrared absorption effect of cobalt-platinum on carbon monoxide, Improved catalyst resistance to toxicity. Significantly extends battery life. For the distribution of metals over spatial locations. The combination of precious metals and catalysts is particularly important. In this paper, we mainly consider metal-nanometal bonding, graphene encapsulation and graphene tessellation. Comparison of graphene mosaicing method for battery performance has a large improvement through the study. The method also reduces the use of precious metal catalysts. In addition, compared with the conventional nickel-cobalt alloy. The advantages of cobalt-platinum nano-alloys are not only reflected in their antitoxicity effect. The performance of the catalyst is further enhanced.

1 INTRODUCTION

With utilization of fossil fuel increasingly intensifying, the environment problem created behind it cannot be ignored it becomes the centre of global attention. The development of hydrogen fuel cells meets the demand of non-pollution and zero-emission. The advent of this technology favourale to the continue advancement of global carbon emissions and carbon neutrality. Nowadays, alkaline fuel cell (AFC), acidic fuel cell (PAFC), proton exchange membrane fuel cell (PEMFC) etc. are widely used. Among the cells, PEMFC is the one most widely used especially in the new energy electric vehicle with good prospects for development (Xu, Zhu and Xu, 2023). The ability to convert chemical energy directly into electrical energy with the advantage of no pollution, and enables hydrogen fuel cells to generate electricity with much greater efficiency than generator (Xu, Zhu and Xu, 2023). Although the hydrogen fuel cells have such superior performance, the problem behind the battery is still non-negligible. The issue arises from the trade-off between the battery’s performance and construction cost. It is not feasible to optimize both factors simultaneously. The precious metal catalyst exhibits excellent catalytic properties. However, its high price becomes a limiting factor as demand for its application increases and resources become increasingly scarce (Zhang et al., 2023). Non-precious mental catalyst has low price, but compared with precious one, the catalytic properties are not outstanding. The other problem is catalyst poisoning. Nowadays, the most mature non-metallic catalyst is Fe-N-C, with the increase in the temperature carbon contain in it. Porous structures are characteristic of hydrogen

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energy fuel cells, where the oxidation of the carbon reacts with oxygen, carbon monoxide will be generated. The production of carbon monoxide by the electrode, its attachment to the catalyst surface, and occupation of the active site can lead to catalyst poisoning, which is a primary factor in decreasing battery life (Huang, Wang and Pei, 2023). Pt-Co-N-C catalysts exhibit excellent stability and catalytic effectiveness under both acidic and alkaline conditions, thereby exerting a positive impact on delaying the process of catalyst poisoning (Deng et al., 2023).

By employing the co-reduction method to produce nanopolyhedral-type metals of Pt and Co, the catalyst reaction contact area is increased and its stability is enhanced compared to using a single metal (Cao et al., 2023). It exhibits superior catalytic activity, particularly when using Pt and Co for absorption compared to a single metal catalyst. Additionally, the nickel-cobalt alloy shows an anomalous infrared effect in the nanometer range. The addition of cobalt strengthens the ability of platinum to absorb carbon monoxide, in addition, making use of co-reduction method increases the degree of alloying of two metals. For the structural performance, this method provides certain guarantee for the stability of catalyst by reduction- deposition method (Dey and Dhal, 2020 & Chen et al., 2023). This method compared with other preparation method simplifies the manufacturing process, furthermore, applying this approach catalyst usually have high catalystic activity within a relatively wide temperature range. The proposal of such catalyst will contribute to the mitigation of catalyst poisoning resulting from carbon monoxide and improve battery performance. The aim of this article is to investigate the antitoxicity ability of catalysts in hydrogen energy batteries, and discuss the impact of the use of the catalyst on the performance of the battery and analyze its feasibility.

2 PLATINUM-COBALT INFRARED ANOMALOUS ABSORPTION

Electrochemical deposition to manufacture the catalyst and primary potentiometric infrared spectroscopy is used to detected abnormal infrared absorption effect of cobalt platinum alloy, quantification of infrared anomalous absorption intensity using infrared absorption factors at different wavelengths of light (according to the formula), as shown in figure1. According to the figure, compared with the native platinum and cobalt electrodes, the infrared absorption of the nano-platinum and cobalt film electrode is significantly enhanced. Even if the infrared absorption intensity of platinum-cobalt monometallics is increased by a factor of five, the value is still lower than that of platinum-cobalt alloys (Chen, Guo and Sun, 2014). In a researcher conducted in University of California a graphene-nanosphere encapsulated platinum-cobalt nanocatalyst was developed. The catalyst has excellent durability after endurance testing mass activity remains 78% (Zhao et al., 2022). Besides, the team UCLA embeds tiny crystals of platinum cobalt in rice-resistant bags made of graphene. The catalyst maintains the advantages of high efficiency and high toxicity resistance. Reduced the use of platinum 40% (Zhao et al., 2022).

Generally, Infrared anomalous absorption effects in platinum-cobalt nano-alloys provide the new idea in the study of battery antitoxicity. In catalyst manufacture, different process methods lead to various effect of resistance to poisoning. Among these manufacture methods, the catalyst made by the team UCLC is most reliable. Although electrochemical deposition has the shortest preparation cycle among several methods and the mild manufacture conditions, the compactness of its internal structure greatly reduces the effective utilisation of the catalyst. This technology is an extension of the use of thin metal films, and provided a theoretical basis for further research that followed. The research team in Los Angeles and UCLA used the more precise graphene wrapping and embedding methods. The difference between the two lies in the different spatial position relationship between cobalt platinum alloy and graphene, which leads to the difference in the consumption of nano alloys and effective contact area during reaction. Using cobalt platinum alloys of the same quality, graphene embedding method has a larger effective reaction area compared to encapsulation method, and the catalyst prepared by embedding method requires less platinum cobalt material. Achieved the goal of reducing resource consumption. Compared to graphene encapsulated catalysis, embedded catalysts have weaker resistance to poisoning. But using multi-layer graphene to increase surface area can solve this problem.

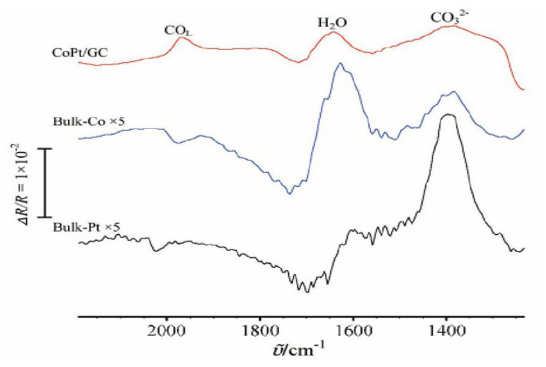

Figure 1: MSFTIR spectra of saturated adsorption of CO on C and Co, Pt electrodes (Chen, Guo and Sun, 2014)

3 EFFECT OF IRON AND COBALT IN CATALYSTS ON BATTERY PERFORMANCE

The greatest impact of PtCo-Fe-N-C catalyst on battery performance is the interaction of cobalt and iron. The catalytic mechanism of iron and cobalt is the reaction of both with oxygen and form coordination bonds. The addition of water reacts to form $Fe(OH)_2$ and $Co(OH)_2$, afterwards OH- disengage the catalyst (Jiang et al., 2021). Use of cobalt and iron to enhance battery performance provides new ideas. Bimetallic interdoping is used in manufacture of bimetallic catalysts. Later, EIS was utilized to detect catalyst double layer capacitor. Utilizing different ratios of cobalt to iron to quantitative cell performance figure 2. The larger capacitance represents that in ORR process, the catalyst has a greater catalytic surface area. And when the ratio of cobalt to iron reaches 14:1, catalyst has higher catalytic performance relatively. And the durability of the cell's catalytic have better performance under acidic conditions compared to the alkaline environment (Lei et al., 2023). Based on the chart half-wave potential and limiting current are the basis for judging the catalytic oxidizing ability of the catalyst. Platinum has a better catalytic oxidizing ability than nickel and catalytic effects of iron and cobalt oxidation much lower than the catalytic effect of iron, cobalt and nickel ternary metal catalysts (Li, 2023). This demonstrates the limitations of bimetallic catalysts. However, it is affirmed that ternary metals have a significant role in enhancing catalyst performance. And a ternary metal catalyst for platinum instead of nickel Provides some basis. Previous scientists have used DFT calculation. Based on the binding energy of ORR activity to free radicals on metals. The table1 was plotted. In Table 1 the ORR catalytic performance of Pt is much better than that of Ni in the most suitable potential energy. Based on the trend line on the way, platinum has higher catalytic activity than nickel (Guo, 2024). This is better illustrated by the catalytic activity of the different metals in figure 3, where platinum has a higher upper limit of catalytic performance compared to nickel.

In generally, the performance enhancement of catalysts is closely related to the use of multiple metals. Compared to a single metal, the anti-poisoning ability and catalytic efficiency are greatly enhanced. Although in terms of manufacturing costs, with the addition of multiple metals, the manufacturing cost of catalysts will also increase. The prolonged service life of the catalyst and the increased reaction efficiency cannot be ignored. In the balance between catalyst performance and manufacturing cost. The iron cobalt platinum ternary nano alloy catalysts have the highest cost-effectiveness.

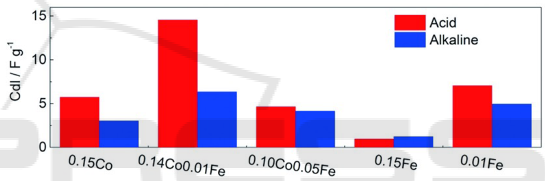

Figure 2: The comparison of double layer capacitance (Cdl) values (Li, 2023)

Table 1: Summary of ORR performance of catalysts and pt/c at 0.1M KOH (Guo, 2024)

Catalyst name	Half-wave potential（V）	Limiting current（ mA/cm^2)	Tafel slope（ mV/dec ）
Ni@NDC	0.793	4.98	109
Fe-Co-Ni@NDC	+0.109	+0.38	-39
Co-Ni@NDC	+0.051	+0.36	-2
Fe-Co@NDC	+0.053	-2.23	+16
Pt/C	+0.040	+0.33	-20

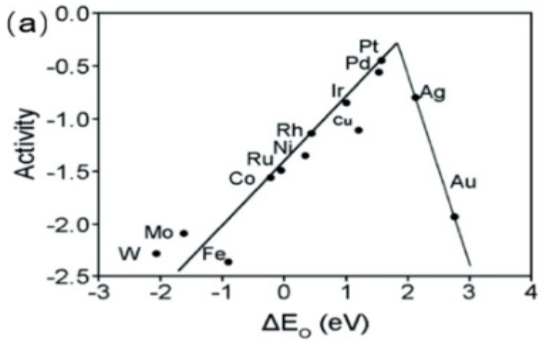

Figure 3: Transition metals and precious metals ORR oxygen active adsorption energy △E0

4 CONCLUSION

With collation of the literature reveals that even though the catalyst has good catalytic properties as well as resistance to toxification. The scope of use of this technology is limited. The use of ternary metal catalysts has a tremendous amount of voltage and energy within them. Mismatched original materials may cause structural damage inside the battery. Accelerates battery aging and can even be potentially dangerous. Even if this technology incorporates precious metals into non-metallic catalysts enhance the performance of non-metallic catalysts. But compared to catalysts made directly from precious metals there may still be some gaps. For battery manufacturing costs, this catalyst uses two types of precious metal ctalysts will undoubtedly lead to an increase in battery manufacturing prices. In order to pursue the good anti-poisoning properties of catalysts. Using Platinum to replace metals such as Nickel would lead further increase the manufacturing cost of catalysts. In addition, the manufacturing of nanometals compared to the direct use of large-diameter particle metals. The technical costs contained within it cannot be ignored in catalyst process manufacturing. Fabrication techniques for nanometers have process drawbacks. When battery life runs out battery aftercare is unavoidable. Leakage of cobalt from the catalyst in this battery can cause some ecological damage. In future research on hydrogen energy cells, multi-component nanometal catalyst technology could provide new idea and solve the catalyst poisoning in the field of hydrogen fuel cells, and in subsequent studies, it is not limited to the effect of carbon monoxide on battery catalysts. It is possible to advance the study of the catalyst's antitoxicity to other gases. In future studies, compared to mitigating cell catalyst poisoning tackling catalyst poisoning at its source is even more important. In catalyst material selection, it is hoped that a catalyst will be created that will be able to absorb and convert carbon monoxide. Formation of a new energy source through internal conversion of carbon monoxide. Achieving the goal of sustainable recycling of hydrogen energy cells. Researching high performance and anti-toxicity catalysts while pursuing simpler manufacturing processes. Striving for a better balance between performance and manufacturing costs. In the field of responding to hydrogen energy fuel cell catalyst poisoning still has a bright future.

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