

Boron nitride: A support to synthesize stable Pt-based catalysts for high-temperature oxidative reactions

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Introduction

Platinum is one of the most active and widely used catalysts for various chemical reactions over a wide range of temperatures [1] but, the stability of Pt-nanoparticles for high-temperature oxidative reactions is still a challenge for many chemical processes [2]. Sulfur-based thermochemical cycle for water splitting (usually used for H₂ production from water), using solar energy input, is one of the examples of such high-temperature processes where H₂SO₄ is decomposed to form SO₂ and O₂ at temperatures $\geq 750^{\circ}\text{C}$ over the Pt-catalyst, with Pt being the most active [3]. In most of the recent works, titania (TiO₂) supported nanoparticles of platinum group metals have been considered as very effective catalysts for high-temperature oxidative reactions [4]–[6]. However, Pt sinters and forms larger particles on TiO₂ at high temperature, which deactivate the catalysts, highlighting the need for a very support that can significantly reduce metal sintering [2].

Boron nitride (BN) was used as support in this study which exhibits higher thermal stability and oxidation resistance, and greater mechanical strength that leads to minimize Pt sintering on support. A series of Pt-based catalysts (both monometallic and bimetallic) supported on BN were prepared and characterized for stability under high-temperature oxidative conditions. Investigations found that bimetallic catalysts composed of Pt and Ir were effectively limiting the sintering of platinum on BN at high-temperature oxidative conditions.

Materials and Methods

Tetramineplatinum (II) hydroxide hydrate and hydrogen hexachloroiridate (IV) hydrate supplied by Sigma-Aldrich and BN supplied by Alfa-Aesar were used for catalyst preparation. Prior to the preparation of catalysts, BN support was calcined at 800°C in static air for 8 hours to minimize support collapse during high-temperature treatment. Dry impregnation (DI) method was used for the synthesis of monometallic Pt and Ir catalysts. Employing surface free energy (SFE) differences for enhancing stabilization, the lower SFE Pt was anchored on higher SFE Ir using electroless deposition (ED) technique. All these catalysts were calcined at 800°C in static air condition for 8 hours and characterized them after each reduction and calcination treatment using X-ray diffraction (XRD), pulse chemisorption, and screening transmission electron microscopy (STEM).

Results and Discussion

XRD patterns of BN supported Pt-catalysts after reduction at 300°C in hydrogen flow for 2h, and calcination treatment at 800°C in static air for 8h are shown in Figure-1. The width of Pt peaks increases for bimetallic catalyst compared to the monometallic catalyst,

which describes the formation of smaller Pt particles for bimetallic catalysts than monometallic catalysts. Also, the Pt-peak width increase with increasing weight loading of Ir. Table-1 compares the size of Pt particles after calcination treatment for both NS and TiO₂ supported Pt-catalysts.

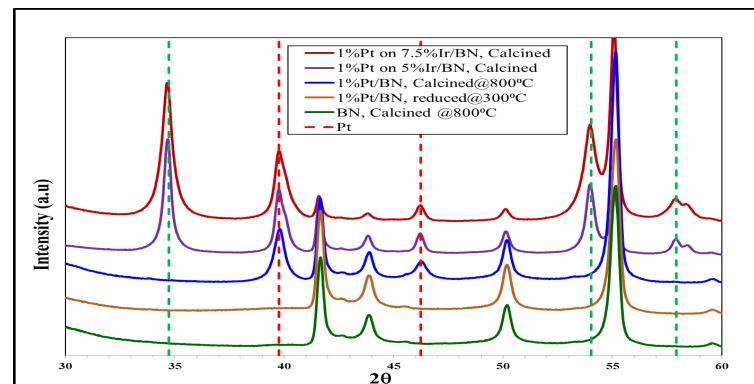


Figure 1. XRD patterns of BN supported Pt-catalysts after reduction and calcination treatment. The red and green dotted lines represent the peaks of Pt and IrO₂ respectively.

Table 1. Size of Pt particles after calcination for both NS and TiO₂ supported catalysts

	BN	TiO ₂
1%Pt	13.2 nm	34.0 nm
1%Pt on 5%Ir,	12.3 nm	23.4 nm
1%Pt on 7.5%Ir	10.5 nm	21.6 nm

Significance

The development of highly active and thermally stable Pt-based catalysts will not only increase the catalyst lifetime but also maintains the long-term stability, which leads to a reduction in the plant investment cost and an increase in the overall process efficiency.

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