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# Investigation of the stability of Platinum nanoparticles incorporated in mesoporous silica with different pore sizes

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ABSTRACT

The effect of the pore size of mesoporous silica on the stability of Pt nanoparticles (NPs) has been investigated. TEM observation and XRD measurement were conducted *in situ* for Pt loaded mesoporous silica with different mesopore sizes. It turns out that smaller pores are more effective to stabilize Pt NPs below 600 °C. However, aggregation of Pt NPs on the surface of particles is not fully suppressed more than 1000 °C in ambient atmosphere even though smaller mesopore size is applied. The type of precursor does not affect the stability of Pt NPs.



## 1. Introduction

Precious metal nanoparticles (NPs) have been used as catalysts for various reactions due to their high catalytic activity. Among them, Platinum NPs are the most industrialized and used in a broad range of reactions, such as hydrogenation, oxidation, reforming, $NO_X$ abatement, and direct decomposition of alcohols for hydrogen production [1–7].

Although Pt NPs are practically realized in various applications, it is highly common that catalytic performance decreases gradually during operation because of the aggregation [8–12]. In case the aggregation is suppressed, the amount of Pt in an automotive catalytic converter for example could be reduced by a large amount.

Thermal resistance of NPs is much lower than that of bulk materials [13,14]. The melting point of Pt is 1768 °C. However, the decrease in the catalytic activity occurs when NPs are used even less than 1000 °C. One of the indices of thermal resistance is Tamman temperature (Tm), briefly expressed by Tm = 0.5 $T_{\text{melting point}}$ [15]. The Tamman temperature of Pt is calculated to be ca. 750 °C.

Mesoporous silica has ordered nano-sized pores with very narrow size distribution [16]. The introduction of various types of nanoparticles into pores of mesoporous silica has been reported by many researchers. High uniformity in size for NPs is expected since pore size of mesoporous silica is uniform. The size of NPs can be tuned depending on the pore size of mesoporous silica. Since NPs are confined in mesopores, it can be possible to suppress aggregation, leading to high thermal stability. The composites of NPs/mesoporous silica are extended in various applications such as catalysis [17–20], drug delivery [21–24], and optics [25,26].

In this report, we have systematically investigated the effect of the pore size of mesoporous silica on the stability of Pt NPs. Monodispersed mesoporous silica spheres (MMSS) are used as a host to support Pt NPs [27–30]. It is very easy to find aggregated NPs outside MMSS because the particles size of MMSS is uniform and in the range of several hundred nanometers. Nanoparticles in the same area are traced by using *in situ* TEM observation and XRD measurement.

## 2. Experimental

### 2.1. Materials

Hexadecyltrimethylammonium chloride ($C_{16}$TMACl) and tetramethylorthosilicate (TMOS) were purchased from Tokyo Kasei Co. (Japan). Methanol, 1 N NaOH, and 2 N HCl were purchased from Wako Pure Chemical Co. (Japan). Tetraammineplatinum (II) nitrate and hydrogen hexachloroplatinate hexahydrate were purchased from Aldrich. All materials were used as received. The synthesis for monodispersed mesoporous silica spheres (MMSS) and

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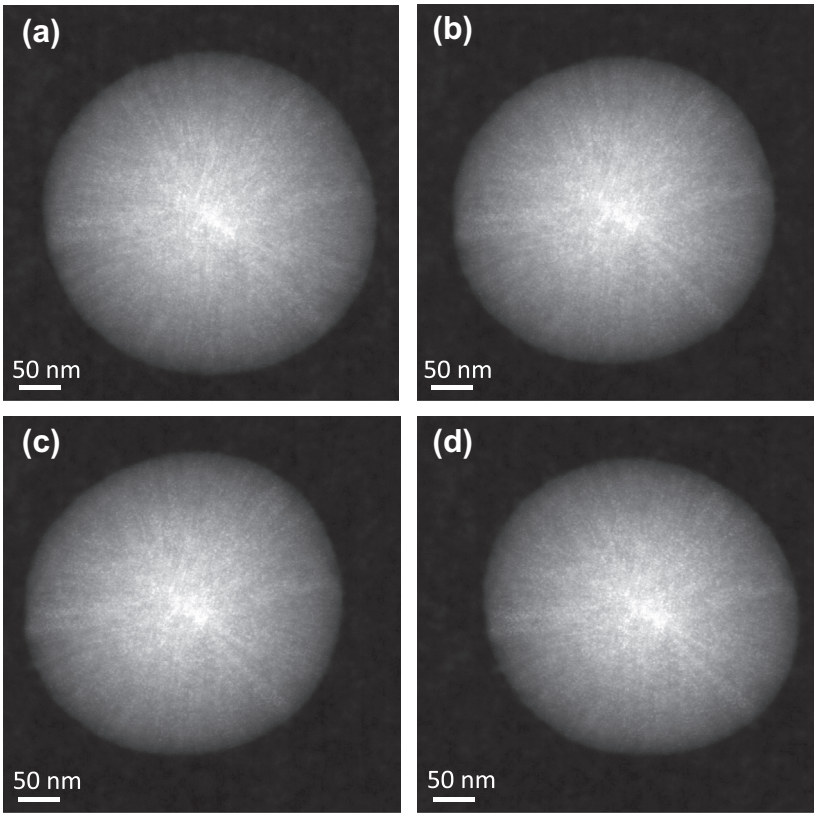


**Fig. 1.** TEM images of Pt/MMSS heated *in situ* at (a) 400, (b) 600, (c) 800, and (d) 1000 °C.

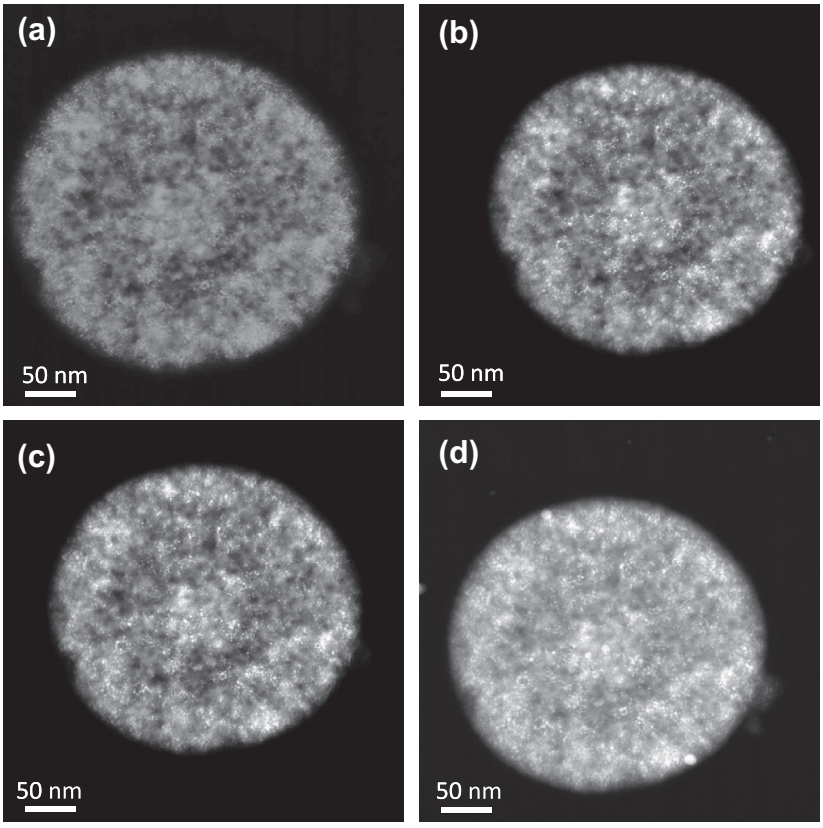


**Fig. 2.** TEM images of Pt/HT-MMSS heated *in situ* at (a) 400, (b) 600, (c) 800, and (d) 1000 °C. Pt NPs (bright spots) become larger with increasing temperature and bigger particles are observed at the surface at 1000 °C (d).