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Palladium particle recovery from nitrile butadiene rubber dissolved in acetone through precipitation of poly(2-(dimethylamino)ethyl methacrylate)

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ABSTRACT

Acrylonitrile butadiene rubber (NBR) has been used in the automotive industry. To change the strength of NBR, the double bond in NBR can be converted to a single bond using palladium particles immobilized on a support as a catalyst. During this catalytic reaction, palladium particles might leak into the solution. In this study, to recover palladium particles from highly concentrated NBR acetone solution, poly(2-(dimethylamino)ethyl methacrylate) (poly(DMAEMA)) solution was added to the palladium-containing solution. The amino group of poly (DMAEMA) captured palladium particles and poly(DMAEMA) shrunk by dehydration in acetone, resulting in rapid precipitation of poly(DMAEMA) complexed with palladium particles. The percentage of recovered palladium particles after 1 h was 60%. By immersing the complex in HNO_3 solution including thiourea, 90% of the recovered palladium was eluted from the precipitated poly(DMAEMA).

1. Introduction

Palladium particles immobilized on silica and carbon have been used as a catalyst in Suzuki–Miyaura coupling (Corma et al., 2005) and hydrogenation reactions of polymers (Bhattacharjee et al., 1990). Acrylonitrile butadiene rubber (NBR) has been used in the automotive and aerospace industries (Schultz et al., 2007). The double bond in NBR can be converted to a single bond via hydrogenation to prevent its cross-linking reaction as well as to improve its mechanical characteristics; for instance, to control the gas permeability through the rubber (Zhang et al., 2010). However, some immobilized palladium particles leak into reaction media containing NBR (Crudden et al., 2005). The leaked palladium particles are observed as a black precipitate at the bottom of the reaction media.

Dissolved or dispersed NBR in acetone displays a high viscosity of 1000 mPa·s. When NBR is reacted with immobilized palladium particles, palladium particles can possibly leak into the highly viscous NBR solution. Palladium is a precious metal and thus its recovery is desirable. Several methods to recover palladium particles dissolved in water solution have been proposed. For example, palladium ions leached from waste electrical and electronic devices have been recovered selectively using solvent extraction (Ohto et al., 2017; Swain et al., 2010), adsorption (Yoshimura et al., 2012; Nikoloski et al., 2015), and membranes (Yoshikawa et al., 2008). Each of these methods recovers palladium ions as $PdCl_4^{2-}$, which forms in HCl through electrostatic interaction with protonated amino groups. However, the recovery of palladium particles dispersed in highly viscous polymer solutions, such as NBR in acetone, faces the following problems. Adsorption mass transfer of palladium particles onto an adsorbent requires a long time. Membrane permeation of solutions containing palladium particles and NBR results in NBR fouling the membrane pore surface, which lowers the permeation flux. In solvent extraction, solvents such as acetone that can dissolve NBR do not readily form a separable phase with water. Therefore, a novel method to recover palladium particles from highly viscous NBR solution is still required.

In this study, the rapid recovery of palladium particles from highly viscous NBR solution through the precipitation of an amino group-containing polymer is proposed, as shown in Fig. 1. Amino groups are known to form complexes with palladium particles (Du and Chen, 2015). The amino group-containing monomer 2-(dimethylamino)ethyl methacrylate (DMAEMA), is polymerized to give poly(DMAEMA) with high molecular weight. A solution of poly(DMAEMA) dissolved in water added to a solution of palladium particles and NBR in acetone, forming a precipitate of poly(DMAEMA) via dehydration. During the dehydration of poly(DMAEMA), the dispersed palladium particles form complexes with the amino groups of the precipitating poly(DMAEMA).

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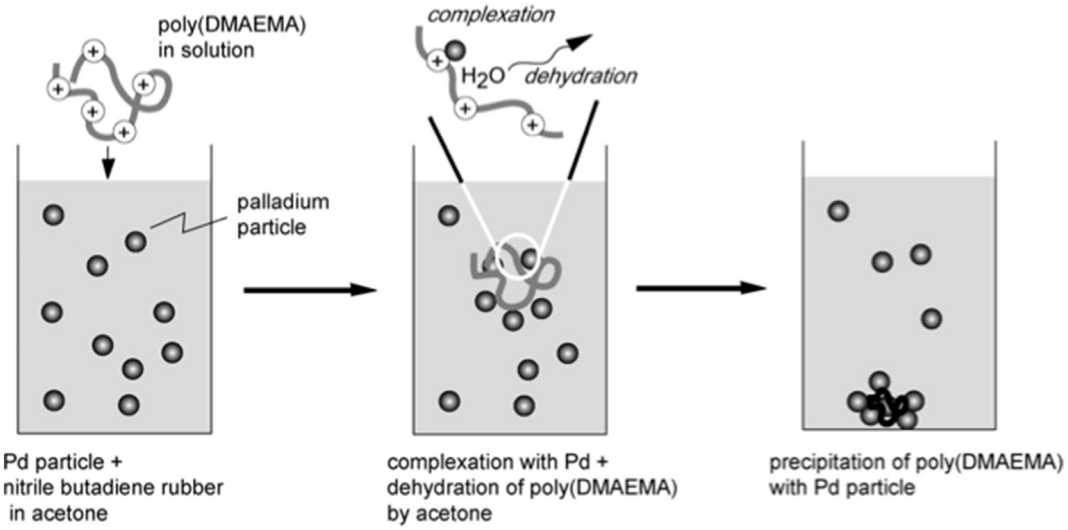

Fig. 1. Outline of palladium particle recovery from nitrile butadiene rubber in acetone solution through precipitation of poly(DMAEMA).

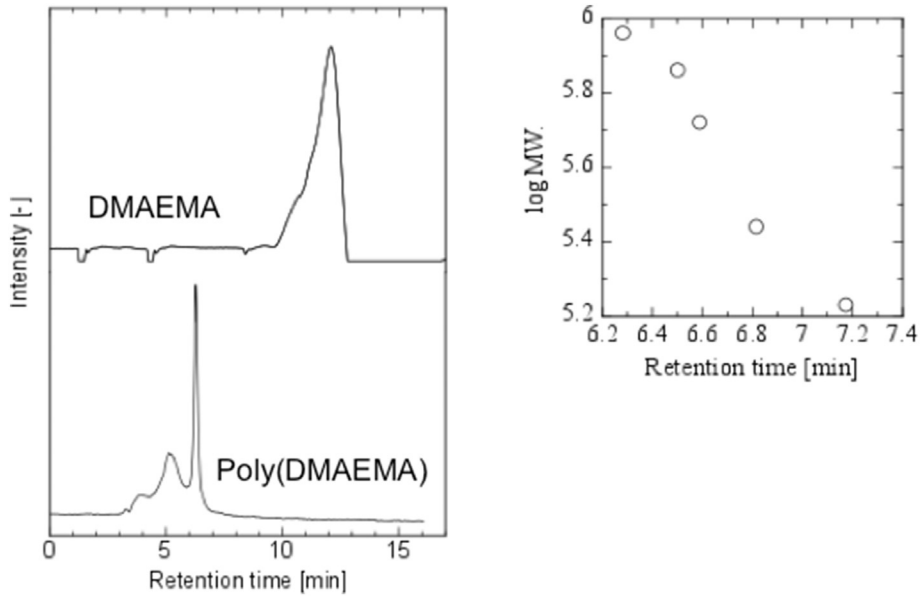

Fig. 2. Chromatography results for the obtained poly(DMAEMA).

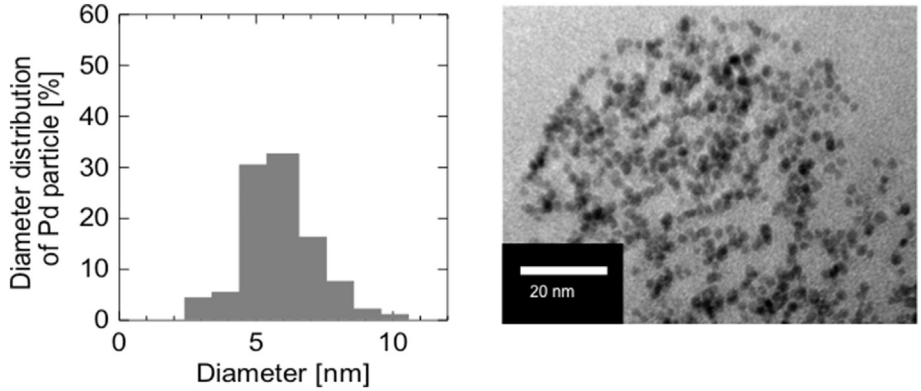

Fig. 3. TEM image (right) and size distribution (left)of the palladium particles.