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ORIGINAL ARTICLE

Miswak mediated green synthesized palladium nanoparticles as effective catalysts for the Suzuki coupling reactions in aqueous media

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KEYWORDS

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Abstract Green and eco-friendly synthesis of palladium nanoparticles NPs is carried out under facile and eco-friendly conditions using an aqueous solution of *Salvadora persica* L. (SP) root extract (RE) as a bioreductant, which is commonly known as Miswak. The as-synthesized Pd NPs were characterized using various spectroscopic and microscopic techniques, including, UV–Vis spectroscopy, FT-IR spectroscopy, XRD, ICP-MS and TEM. Detailed investigations of the Pd NPs have confirmed that the polyphenolic phytomolecules present in the RE of Miswak not only act as a bioreductant by facilitating the reduction and growth of Pd NPs, but they also functionalize the surface of Pd NPs and stabilized them in various solvents. Furthermore, the catalytic activity of the green synthesized Pd NPs was also tested toward the Suzuki coupling reactions of various aryl halides in aqueous media. The as-prepared Pd NPs exhibited superior catalytic activity and reusability for the Suzuki coupling reaction in aqueous and aerobic conditions. The kinetics of the reaction studied by GC revealed that the conversion of various aryl halides to biphenyl takes place in a short time.

1. Introduction

Nanotechnology has emerged as the most promising field of multidisciplinary science [1,2]. Due to their small size, nanoparticles (NPs) possess excellent physicochemical properties, which are completely different from their bulk counterparts [3]. These properties have been extensively exploited in several technological fields, including catalysis [4,5]. Among various nanomaterials, metallic NPs have a significant importance in human life

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[6]. Therefore, metallic NPs, including, Ag, Au, Pd, Pt, etc. have been extensively studied for several decades [2,7]. A number of studies have been reported involving the synthesis, characterization and applications of metallic NPs with particular focus on the size and morphology of the NPs [8–10]. So far, several methods have been applied to prepare metallic NPs, and these methods are mainly classified into two different categories that include physical and chemical methods. The preparation methods are usually selected according to the feasibility and accessibility of the protocols to achieve the targeted applications [11,12]. The physical methods, such as, ball milling, laser ablation, flame pyrolysis, etc. often require expensive instruments, high temperature and pressure.

Chemical methods are largely used for the preparation of metallic NPs, which are more facile and less expensive, when compared to the physical methods [8]. The chemical synthesis of metallic NPs involve the concepts of wet chemistry, where the reduction/decomposition of metal complexes is carried out in solutions using various chemical reductants, such as sodium borohydride, hydrazine or at elevated temperature [13,14]. Although, the chemical methods have been extensively used for the preparation of metallic NPs, the reactants, reductants, stabilizers and various organic solvents used in these methods are toxic and potentially hazardous to the environment [15,16]. Due to the growing environmental concerns,

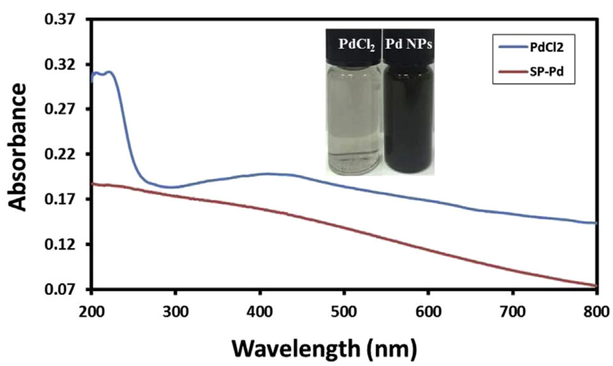

Figure 1 Ultraviolet–visible (UV–Vis) absorption spectra of the corresponding solution depicting the reduction of $PdCl_2$ to metallic Pd.

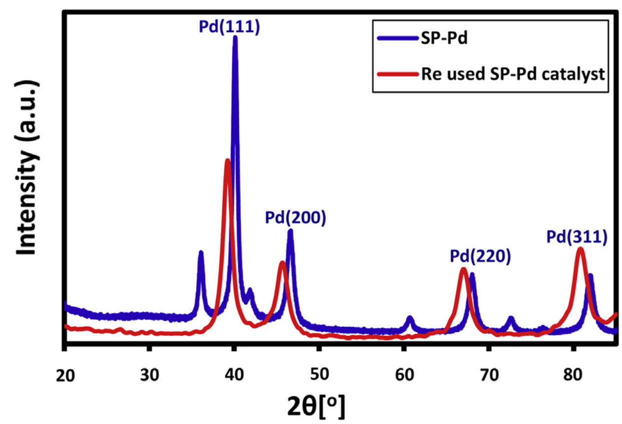

Figure 2 XRD diffraction pattern of as-synthesized palladium nanoparticles (Pd NPs).

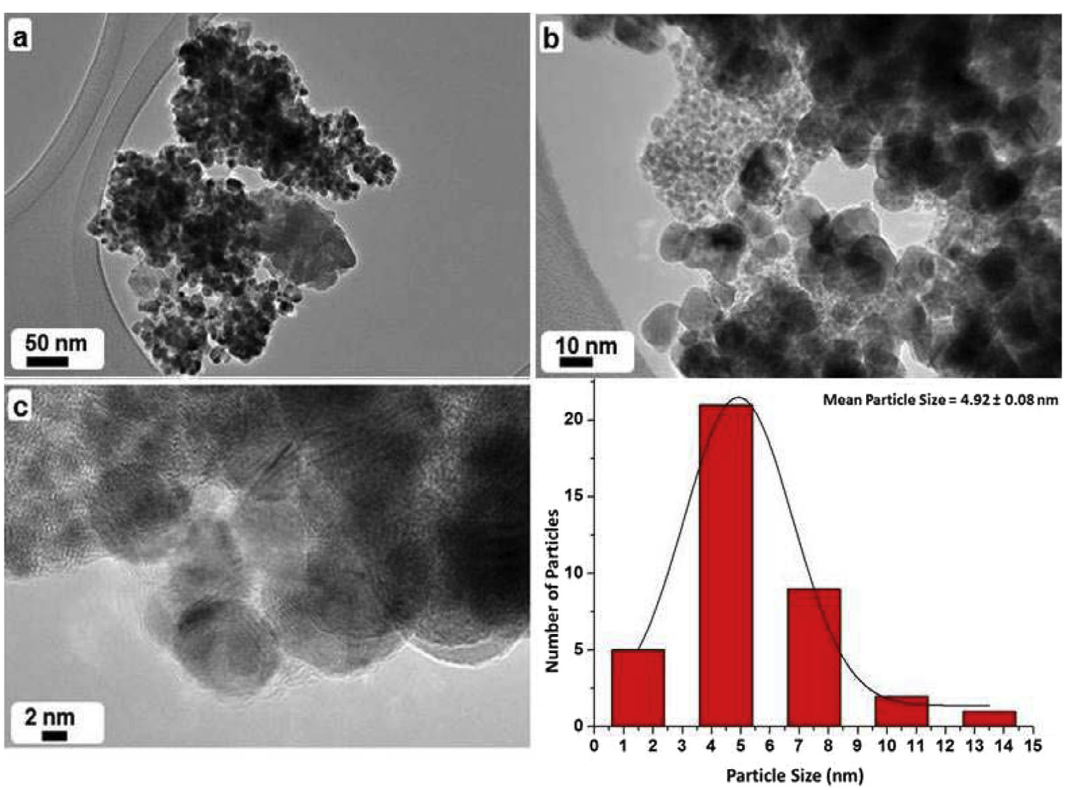

Figure 3 Transmission electron microscope (TEM) and high resolution (HRTEM) images of the Pd NPs (a) overview, (b) and (c) magnified HRTEM image (d) particle size distribution graph.