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Porous wood decorated with gold nanoparticles as flow-through membrane
reactor for catalytic hydrogenation of methylene blue and 4-nitrophenol

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Abstract: In this study, gold nanoparticles (Au NPs) were decorated into *Paulownia Sieb. et Zucc.* chip. Lignin, as one main component of wood, contains the reducing groups *e.g.* hydroxyl, carbonyl and aldehyde groups. Under sunlight irradiation, Au (III) diffused into wood was *in situ* reduced by lignin to form gold nanoparticles. Therefore, the Au NPs/Wood was successfully fabricated by this facile and green procedure. Meanwhile, the three-dimensional interpenetrating network of wood prevented the aggregation of Au NPs which retained its catalytic activity. Methylene blue and 4-nitrophenol were adopted as model organic contaminants to evaluate the catalytic hydrogenation ability of the Au NPs/Wood. The analyses of XRD, SEM, ICP-MS and XPS indicated that Au NPs were successfully immobilized in wood chip. The degradation results revealed that the Au NPs/Wood has excellent catalytic activity for methylene blue and 4-nitrophenol hydrogenation under batchwise and continuous flow process. Meanwhile, the Au NPs/Wood also exhibited excellent recyclability. The hydrogenation efficiency of MB and 4-NP still reaches more than 90% after 8 cycles. This study provides a new solution for green and low-cost fabrication of Au NPs/Wood which has broad application prospects in wastewater treatment.

Keywords: Wood; Lignin; Gold nanoparticle; Catalytic degradation; Wastewater treatment

1 Introduction

At present, nanostructured catalysts with high specific surface area and surface energy have been widely studied by researchers (Sharma et al., 2015). Among them, noble metal nanoparticles have high activity as heterogeneous catalysts in many liquid-phase reactions (Ji et al., 2015; Zahmakiran and Ozkar, 2011), especially in the catalytic conversion or decomposition of organic pollutants such as nitro-group compounds and dyes (Shultz et al., 2019). Gold nanoparticle (Au NPs) with high specific surface area and characteristics of less likelihood of metal leaching and self-poisoning has attracted much attention due to its desirable chemical catalytic ability (Alba-Molina et al., 2019; Hassinen et al., 2015).

Nevertheless, there are still two major challenges limiting the application of Au NPs. First challenge is related to the easy agglomeration of Au NPs in aqueous solution, which reduces the contact area between Au NPs and target pollutants, therefore the catalytic performance of Au NPs will be seriously inhibited (Massaro et al., 2019; Zhang et al., 2020). In order to maintain the dispersibility of Au NPs, it is usually fixed on solid support (such as silica, metal oxides and polymers), which can prevent Au NPs from aggregation and ensure high catalytic activity (Gualteros et al., 2018; Kong et al., 2020; Singh et al., 2019; Wang et al., 2019). However, in some chemical environments with high or low pH, the stability of the above solid carrier will be affected, resulting in problems such as the dissolution of the carrier or the inability to obtain uniform distribution of Au NPs (Quast et al., 2016; Saini et al., 2010). Another challenge comes from the chemical reduction reaction adopted for Au NPs preparation. During this process, the reducing agents and the stabilizing agents are extensively used (Al-Johani et al., 2017; Alba-Molina et al., 2019). From the perspective of the environment and human health, these chemical reagents are toxic and harmful, and the synthesis process has many steps and low efficiency. In addition, the complete separation of Au NPs from the reaction system is also a huge challenge. All of these have brought difficulties to the extensive application of Au NPs (Raveendran et al., 2003).

Therefore, it is the main research of basic application of Au NPs to find high

stability carrier and realize green synthesis method. Wood is a natural three-dimensional porous material with unique microstructure (Liu et al., 2019), which can be used as a carrier to construct functional composite materials. Lignin, one of the main components of wood, contains many functional groups, such as hydroxyl group, carbonyl group and aldehyde group (Chen et al., 2020). These functional groups can be used as reducing functional groups to synthesize metal nanoparticles (Luo et al., 2017; Wang et al., 2016). Furthermore, the orderly channel structure of wood can pump water and nutrients from the root to the crown under the sunlight irradiation (Liu et al., 2019; Zhu et al., 2018). Therefore, when the wood comes into contact with the metal salt solution under sunlight irradiation, the metal ions will be pumped out from the bottom of the solution and diffused in the middle channel, and reduced to metal nanoparticles by lignin. Paulownia is a kind of fast-growing wood, which is distributed in various regions of China (Ates et al., 2008). It is a natural material with honeycomb units, high strength/stiffness weight ratio and high grade value (Janjić and Janjić, 2019). Therefore, Paulownia decorated with gold nanoparticles can be used as the membrane for wastewater treatment.

In this work, the Au NPs/Wood was fabricated by a green and simple method, and its catalytic activity was respectively tested by batchwise and continuous flow reaction. The Au NPs were *in situ* reduced and immobilized in the cavity structure of Paulownia by one-step irradiation of wood immersing in Au (III) solution. Under the conditions of batchwise and continuous flow reaction, the catalytic performance of gold nanoparticles immobilized in the wood chip was investigated with MB and 4-NP as the organic pollutant models.

2. Experimental section

2.1 Materials and chemical reagents

The wood (Paulownia *Sieb. et Zucc.*) used in this study was obtained from the local timber market (Nanning China). Gold chloride acid ($\text{AuCl}_3 \cdot \text{HCl} \cdot 4\text{H}_2\text{O}$, HAuCl_4 , $\geq 99\%$) and 4-nitrophenol (4-NP, $\geq 99\%$) were purchased from Shanghai McLean Biochemical Technology Co., Ltd (Shanghai, China). Anhydrous ethanol ($\text{CH}_3\text{CH}_2\text{OH}$,

≥99%) and methylene blue (MB) and were purchased from Tianjin Zhiyuan Chemical Reagent Co., LTD (Tianjin China). Sodium borohydride (NaBH_4 , ≥99%) was purchased from Sigma Aldrich Chemical Company (Shanghai China). The ultrapure water was used for all experiments (Milli-Q purification system, Darmstadt Merck Company, Germany).

2.2 Preparation of Au NPs/Wood

The wood was cut perpendicular to the growth direction into slices ($25 \times 25 \times 1 \text{ mm}^3$). The wood slices were extracted with water at 85 °C for 18 h (water was replaced at an interval of 3 h) to remove soluble impurities and then the samples were air dried overnight. Thereafter, the slice was immersed into 20 mL HAuCl_4 solution (1 mM) for 3 h under the sunlight irradiation (CEAULIGHT, CEL-WLAX500). The products were ultrasonic washed with ultrapure water for 30 min several times to remove the unreacted chemicals and unfixed Au NPs. Eventually, the Au NPs/Wood was obtained after 8 h vacuum drying.

2.3 Characterization

The surface morphology of the wood and Au NPs/Wood were characterized by scanning electron microscope (SEM, Hitachi SU8000 Series). The surface components of the samples were determined by X-ray electron spectroscopy (XPS, ESCALAB 250 XI+, Thermo Fisher Scientific, U.S.A.). The gold nanoparticles in the wood were characterized by solid ultraviolet visible spectrophotometer (UV-Vis, Specond plus 50, Analytikjena, Germany) at the spectrum of 400-900 nm. The crystal nanostructure of Au loaded on the wood was revealed by 2200 X-ray diffraction (XRD, SMARTLAB3KW, Rigaku, Japan), operating with a $\text{Cu-K}\alpha$ radiation ($\lambda = 1.54 \text{ \AA}$). The Au content of the Au NPs/Wood was quantified by inductively coupled plasma mass spectrometry (Agilent ICP-MS7800, U.S.A.).

2.4 Catalytic performance of Au NPs/Wood

The MB (30 mg/L), 4-NP (0.2 mM) and NaBH_4 (50 mM) solutions were prepared in ice water bath, respectively. The mixture prepared with equal volume proportion of the MB and NaBH_4 solutions was used for the catalytic degradation of MB (Qin, L. et

al., 2019). Subsequently, the wood and Au NPs/Wood were immersed in 30 mL mixture at room temperature with magnetic stirring. The liquor was collected at the desired time intervals and its absorbance from 400-800 nm was characterized by UV-Vis spectroscopy. The absorbance changes according to the reaction time were quantified by UV-Vis at 665 nm. As a comparison, the Au NPs isolated from the Au NPs/Wood by ultrasonic treatment for 2 h was also applied to catalytically degrade the mixture. The Au NPs/Wood, wood and Au NPs were respectively used as the catalyst to complete the reaction. The mixture prepared with equal volume proportion of the 4-NP and NaBH₄ solutions was used for the catalytic degradation of 4-NP. The absorbance in the range of 200-600 nm was characterized by UV-Vis spectroscopy, and the hydrogenation efficiency of 4-NP was evaluated by the change of absorbance at 400 nm. The reduction efficiency of MB and 4-NP was calculated using the following equation:

$$Conversion(\%) = (C_0 - C_t)/C_0 * 100\% = (A_0 - A_t)/A_0 * 100\% \quad (1)$$

Where C_0 and C_t are the concentration of the mixture before and after the reaction respectively, and A_0 and A_t are the corresponding absorbance (Guo et al., 2019).

The Au NPs/Wood placed on the sand core filter was used for the continuous flow degradation which was conducted at 0.015 MPa. Before the reaction, the Au NPs/Wood was immersed in the MB solution to reach the equilibrium to eliminate the adsorption interference (Liu et al., 2017). Thereafter, the mixture of MB and NaBH₄ was filtered through the Au NPs/Wood to complete the continuous flow degradation. The flow degradation of 4-NP was conducted with the same procedure. As a comparison, the wood chip was also used to conduct the continuous flow degradation. The factors including the Au NPs/Wood layers, the concentration of contaminants, and the water flux were evaluated. As for the evaluation of recyclability, the Au NPs/Wood was recovered by washing with deionized water followed with ethanol for the subsequent reaction.

3. Results and Discussion

3.1 Characterizations

Under the sunlight irradiation, Au (III) was diffused into the wood and reduced *in*

situ by lignin to form Au NPs. Fig. 1a shows that the wood color changed from brown yellow to purple due to the surface plasmon effect of Au NPs depositing on the surface of wood cell wall (Amendola et al., 2017). Fig. 1b indicates that Au NPs was uniformly deposited throughout the wood slice. SEM-EDS characterization observed that the wood cell wall surface was uniformly loaded with Au NPs (Fig. 1c-f). The high resolution SEM image (Fig. 1g) confirmed that Au NPs immobilized uniformly on the wood cell wall surface without aggregation which retained their catalytic ability. Furthermore, the gold content of the sample was quantified as 1.4wt% by ICP-MS. The unique three-dimensional porous structure was maintained in the Au NPs/Wood. A large number of honeycomb like units and channels were connected with the perforated plates containing nano size pores (Fig. 1h). Fig. 1i confirms that nano size pores were identified in the perforated plates. Fig. 1j demonstrates that the vessels connected with the perforated plates can be used as channels for transferring water and nutrients in the wood. All of these characteristics of the wood ensured that the Au NPs/Wood can be used as an ideal catalytic membrane for wastewater treatment.

Fig. 1 Photos of (a) the wood and (b) the Au NPs/Wood. (c)-(f) C, O, Au elemental mapping of a transverse section of the Au NPs/Wood. (g) SEM image of Au NPs distributing on the wood. (h-j) SEM images of the Au NPs/Wood.

Compared to the wood, a new UV-Vis peak appearing at about 530 nm from the Au NPs/Wood (Fig. 2a) was attributed to the surface plasma resonance phenomenon of Au NPs (Cabreira and Camilo, 2020; Haiss et al., 2007; Luty-Błoch et al., 2011), which further proved that Au NPs was successfully decorated in the wood. As for the XRD characterization (Fig. 2b), the diffraction peaks at 21.6° and 34.3° were respectively assigned to the reflections from the (200) and (004) planes of cellulose. The XRD peaks of Au NPs/Wood were 38.1° , 44.3° , 64.7° and 77.6° , which were attributed to surface reflections of Au (110), (200), (220) and (311), respectively (JCPDS 04-0784) (Ju et al., 2015; Liu et al., 2018). The chemical composition of the Au NPs/Wood was characterized by XPS. Fig. 2c shows that the peaks assigned to Au 4f, Au 4d were identified from the Au NPs/Wood, while only the peaks assigned to C 1s and O 1s were identified in the wood. As shown in Fig. 2d, Au $4f_{5/2}$ and $4f_{7/2}$ peaks were observed at 87.6 eV and 83.8 eV, respectively, which confirmed the zero valence state of gold on the cell wall surface (Kong et al., 2009; Zhang et al., 2011).

Fig. 2 (a) UV-Vis spectrum of the wood and the Au NPs/Wood. (b) XRD patterns of the wood and the Au NPs/Wood. (c) XPS of the wood and the Au NPs/Wood, and (d) high-resolution XPS spectra of Au 4f in the Au NPs/Wood.

3.2 Catalytic activity of Au NPs/Wood

NaBH_4 ($E^\circ = -1.33$ V) is reported to be thermodynamically feasible to reduce 4-NP ($E^\circ_{4\text{-NP}/4\text{-AP}} = 0.76$ V) and MB ($E^\circ_{\text{MB}/\text{LMB}} = -0.21$ V) (Neal et al., 2019), but the reaction is not favored by the kinetics due to the large difference of their standard electrode potentials between NaBH_4 and the pollutant model (Yan et al., 2018). As an active electron transfer medium, Au NPs possesses an appropriate redox potential and plays a critical role in the reaction by helping to overcome the kinetic barrier by facilitating electron transfer from the donor (NaBH_4) to the recipient (MB/4-NP) (Gupta et al., 2011).

3.2.1 Batchwise catalytic degradation

The UV-Vis absorbance at 665 nm decreased slightly with the reaction time as the wood slice was immersed in the mixture (Fig. 3a), which was attributed to a little adsorption of MB by the wood. As a comparison, the absorbance at 665 nm was little detected after 21 min immersion (Fig. 3b), indicating that the Au NPs/Wood had an effective catalytic performance on the reduction of MB. According to the previous report, the reduction process can be described as a quasi-first-order kinetic process (Ramirez et al., 2017). Thus, the reaction rate constant (k) can be calculated to evaluate the catalyst's performance according to the following equation:

$$\ln(C_t/C_0) = \ln(A_t/A_0) = -kt \quad (2)$$

Where C_0 and C_t are the concentration of the contaminant at the initial stage and at the reaction time t (min), respectively, A_0 and A_t are the corresponding absorbance, k is the reaction rate constant.

Fig. 3c shows the quasi-first-order kinetics between the reactants, *i.e.* the reaction rate constant k was calculated from the linear relationship between $\ln(C_t/C_0)$ and reaction time. The catalytic reaction rate k of wood chips for MB and NaBH_4 was calculated to be 0.008 min^{-1} , and the k value for MB catalytic reduction using the Au NPs/Wood was calculated to be 0.162 min^{-1} . It can be seen from Table 1 that the

catalytic activity of Au NPS /Wood is comparable to some extent, or even higher than that of other materials supported gold nanoparticles in the catalytic reaction kinetics of MB.

As for the catalytic reduction of 4-NP, the characteristic absorbance at the wavelength of 400 nm displayed by UV-Vis decreased slightly with the reaction time (Fig. 3d), which was attributed to the small amount of adsorption of 4-NP by wood. When Au NPs/Wood was applied to the pollutants, the UV-Vis scanning spectrum showed that the characteristic peak at 400nm almost disappeared after 27min reaction, while a new peak appeared at 298nm, which was the characteristic peak of 4-aminophenol, indicating that 4-NP was reduced to 4-AP (Fig. 3e) (Aditya et al., 2015; Ma et al., 2018). The results show that Au NPS /Wood has a certain catalytic potential for the reduction of 4-NP. Based on the equation (1), the k values of the wood and the Au NPs/Wood for mixture were calculated as 0.011 min⁻¹ and 0.152 min⁻¹, respectively (Fig. 3f). It can be seen from Table 1 that Au NPS /Wood has good catalytic effect on 4-NP.

Table 1 Comparison of catalytic performance of different gold based catalysts

Catalysts	Contaminant	K value (min ⁻¹)	References
Au NPs	MB	0.0118	(Kumar et al., 2019)
Au / KNbO ₃	MB	0.0115	(Yan et al., 2014)
CEL_AuNPs_H ₂ O	4-NP	0.0363	(Cabreira and Camilo, 2020)
Au @ PZS@ CNTs	4-NP	0.1072	(Wang et al., 2014)
Au NCs/CNTs	4-NP	0.2	(Liu et al., 2017)

Fig. 3 The successive spectra of the mixture of MB and NaBH_4 from 400 to 800 nm of (a) the wood and (b) the Au NPs/Wood. (c) The curve of $\ln(C_t/C_0)$ with reaction time and the quasi-first-order kinetic fitting of wood and Au NPs/Wood. The successive spectra of the mixture of NaBH_4 and 4-NP from 200 to 600 nm of (d) the wood and (e) the Au NPs/Wood. (f) The curve of $\ln(C_t/C_0)$ with reaction time and the quasi-first-order kinetic fitting of wood and Au NPs/Wood.

The Au NPs were isolated from the Au NPs/Wood after 2 h ultrasound treatment at room temperature, and the characteristic color of Au NPs was observed from the solution (Unal et al., 2020) (Fig. S2a). As the suspension had stood for 2 h, the precipitant was observed at the bottom of the centrifuge tube, indicating that the solo Au NPs was inclined to precipitate (Fig. S2b). Therefore, the catalytic performance of

Au NPs was attenuated by the precipitation. For example, the UV absorbance in the range of 400-800 nm decreased little even after the mixture of MB and NaBH₄ had mixed with Au NPs for 19 min (Fig. S2c). This result verified that the decoration of Au NPs on the surface of wood cell wall prevented their precipitation, thereby retained their catalytic performance.

3.2.2 Continuous flow catalytic degradation

According to the phenomena and UV-Vis measurement results observed in Fig. S2, it can be inferred that the Au NPs/Wood has a promising application in continuous flow catalytic reaction. Taking MB as a model pollutant, the flow catalytic ability of Au NPs/Wood was evaluated under the vacuum filtration device shown in Fig. S4a. It can be clearly seen that the initial blue solution becomes colorless after the filtration (Fig. S4b). During the filtration process, the solution contacted the Au NPs in the wood, therefore, the MB was catalytically reduced to LMB. When the vacuum was maintained as 0.015 MPa, the impact of different layer of Au NPs/Wood on the reduction of MB (30 mg/L) was evaluated. The results showed that the catalytic degradation efficiency of the one-layer membrane was only 22%. As more layers of Au NPs/Wood were applied, the removal efficiency of pollutants and the filtration time were increased. For example, the removal efficiency was obtained as 98.9% as three layers of Au NPs/Wood were applied, however the filtration time increased to 12 min (Fig. 4a). This result was explained by the increase of the axial tracheid perforation plate, which retained the mixture in the wood cavity, slowing down the flow velocity by forcing the solution flow through more the perforated plates, and increased the contact between MB and Au NPs. Therefore, the membrane composing with three layers of Au NPs/Wood were selected for the next flow catalytic experiments (Thomas, 1977).

The impact of water fluxes on the catalytic efficiency of the Au NPs/Wood was evaluated, as well. Technically, the water flux was adjusted by the vacuum. The flux of water treatment can be calculated by following equation:

$$J = V/(T \times A) \quad (3)$$

Where V is the volume of solution (L), T is the required time for a specific volume

solution filtering through the membrane (h), A is the effective area of the membrane (m^2), and J is the treatment flux ($\text{L}/\text{m}^2 \cdot \text{h}$) (Cheng et al., 2018).

Even the flux was increased to $0.973 \times 10^3 \text{ L}/\text{m}^2 \cdot \text{h}$ (the corresponding vacuum was of 0.015 MPa), the removal efficiency was still more than 95% (Fig. 4b). This result was attributed to three explanations. Firstly, Au NPs, as the electron transfer between nucleophilic NaBH_4 and electrophilic contaminant, distribute uniformly in wood, which promotes the catalytic reduction process. Secondly, the porous structure and the perforated plates of the wood retain the effective contact between catalyst and reagent. Finally, the low bending and arraying microchannels have good hydrophilicity and can facilitate rapid sewage transport without sacrificing removal efficiency (Huang et al., 2016; Plaza, 2019). Moreover, the influence of MB concentrations on the catalytic efficiency of the Au NPs/Wood was further analyzed. It was shown in Fig. 4c that the removal of MB decreased with its concentration. It can be observed from Fig. 4c that Au NPs/Wood can still show excellent degradation performance of MB in a large concentration range. It should be noted that when the concentration of MB was 40 mg/L, the removal efficiency decreased, but still remained above 95%. However, when the concentration of MB increased to 60 mg/L, the removal efficiency decreased significantly.

Fig. 4 (a) The layer number of Au NPs/Wood impacting on the removal efficiency and filtration time. (b) The correlation between the removal efficiency and the water flux. (c) The relationship between the removal efficiency and MB concentration.

The continuous flow catalytic reaction of 4-NP reduced to aminophenol was conducted as follows. The mixture composed with 4-NP and NaBH_4 was filtered through the membrane fabricated with three layers of Au NPs/Wood under 0.015 MPa vacuum. The membrane composed with the wood was used as a blank for comparison.

The absorbance change during the filtration was analyzed by UV-Vis in the range of 200-600 nm. As shown in Fig. 5a, the peak strength at 400 nm after the wood filtration hardly decreased, which can be interpreted as the finite adsorption of 4-NP by the wood. However, After the Au NPs/Wood treatment, the characteristic peak at 400 nm almost disappeared, meanwhile the absorption peak of 4-AP at 298 nm appeared, indicating that 4-NP was effectively catalytically reduced to 4-AP (Fig. 5b).

Fig. 5 The UV-Vis absorption change of 4-NP during the filtration through the wood (a) and the Au NPs/Wood (b).

3.3 Recyclability of Au NPs/Wood

The recyclability is another important parameter of polyphase catalyst for the practical application. In order to investigate the recyclability of Au NPs/Wood, it was recycled eleven times for the catalytic reduction of MB and recycled eight times for 4-NP. Fig. 6a shows that after 11 times recycle, the removal efficiency of MB by the Au NPs/Wood was still over 85%. The catalytic reduction efficiency of 4-NP by the Au NPs/Wood remained above 85% after 8 cycles (Fig. 6b). Therefore, the Au NPs/Wood had robust stability and reusability, which has important guiding significance for its application in practical wastewater treatment. We speculated that there are three main reasons for the difference recyclability of Au NPs/Wood for the degradation of MB and 4-NP. Firstly, MB contains unsaturated bond in its molecular formula, and its induction effect is stronger than that of 4-nitrophenol (Qin, Lei et al., 2019). Secondly, the potential difference between NaBH_4 ($E^\circ = -1.33 \text{ V}$) and MB ($E^\circ = -0.21 \text{ V}$) is 1.12 V, while the redox potential difference between NaBH_4 ($E^\circ = -1.33 \text{ V}$) and 4-NP ($E^\circ =$

0.76 V) is only 0.57 V. Therefore, the catalytic reaction of NaBH₄ with MB is much easier than with 4-NP (Jacob, 1970; Nguyen et al., 2019). Finally, the unreduced 4-NP remained in the Au NPs/Wood during the recycling process occupying some catalytic active sites, which retarded the catalytic reaction efficiency.

Fig. 6 The recyclability of the Au NPs/Wood for catalytic reduction of MB (a) and 4-NP (b).

4 Conclusion

In this work, the Au NPs/Wood was fabricated by a facile and green approach, which exhibited excellent catalytic activity for MB and 4-NP. Wood plays an important role in membrane preparation and catalytic reaction. Lignin in wood *in situ* reduced Au (III) to form gold nanoparticles which were anchored and stabilized on the surface of three-dimensional porous wood. Meanwhile, the perforated plate connecting among channels elongated the contacting time between the catalyst and reagent which promoted the catalytic reaction. The removal efficiency of MB and 4-NP by the membrane composed with three layers Au NPs/Wood exceeded 98.0%. In addition, the Au NPs/Wood possessed good recyclability. Conclusively, the wood decorated with Au NPs has the advantages of high cost-effectiveness, biodegradability, simple preparation, green and pollution-free, and excellent catalytic activity.

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351 Technology Co., Ltd, Nanning 530007, China.

352 **Conflict of interest**

353 The authors declare there is no conflict of interest.

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Figures

Figure 1

Photos of (a) the wood and (b) the Au NPs/Wood. (c)-(f) C, O, Au elemental mapping of a transverse section of the Au NPs/Wood. (g) SEM image of Au NPs distributing on the wood. (h-j) SEM images of the Au NPs/Wood.

Figure 2

(a) UV-Vis spectrum of the wood and the Au NPs/Wood. (b) XRD patterns of the wood and the Au NPs/Wood. (c) XPS of the wood and the Au NPs/Wood, and (d) high-resolution XPS spectra of Au 4f in the Au NPs/Wood.

Figure 3

The successive spectra of the mixture of MB and NaBH₄ from 400 to 800 nm of (a) the wood and (b) the Au NPs/Wood. (c) The curve of $\ln(C_t/C_0)$ with reaction time and the quasi-first-order kinetic fitting of wood and Au NPs/Wood. The successive spectra of the mixture of NaBH₄ and 4-NP from 200 to 600 nm of (d) the wood and (e) the Au NPs/Wood. (f) The curve of $\ln(C_t/C_0)$ with reaction time and the quasi-first-order kinetic fitting of wood and Au NPs/Wood.

Figure 4

(a) The layer number of Au NPs/Wood impacting on the removal efficiency and filtration time. (b) The correlation between the removal efficiency and the water flux. (c) The relationship between the removal efficiency and MB concentration.

Figure 5

The UV-Vis absorption change of 4-NP during the filtration through the wood (a) and the Au NPs/Wood (b).

Figure 6

The recyclability of the Au NPs/Wood for catalytic reduction of MB (a) and 4-NP (b).

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