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Investigation to Develop Highly Efficient Analytical Method to Trap and to Remove Heavy Metal Ions, Toxic Inorganic and Organic Ions from Environment

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Summary

1. Objectives and Contents

We investigated to develop analytical method to trap and to remove heavy metal ions, toxic inorganic and organic ions most efficiently from environment using metal nanoparticles such as silver nanoparticles (AgNPs). In this method, electrostatic and chemical interactions are utilized between negatively charged AgNPs and metal cations in test solutions. In the future, we will apply this method to natural water from ground, river, lake and sea to monitor environmental pollutions, and to clean it.

2. Experimental procedures

AgNPs with average radii of 15-20 nm and density of 3.3×10^{14} particles/L were prepared by using a citrate reduction method. As-prepared AgNPs, which are covered by citrate anions, and those substituted by Cl^- ions were utilized for electrostatic attraction of cationic ions in aqueous solutions. In addition, thiol molecules with functional groups like –COOH in p-mercaptobenzoic acid (PMBA) and $–NH_2$ in p-aminothiophenol (PATP) were used to trap cations and anions in solutions by adjusting pH in solutions. When electrostatic interactions between thiols on AgNPs and ions are switched on, AgNPs are flocculated, which is monitored by coupled plasmon peaks in extinction spectral measurements. Amount of trapped metal ions was quantitatively analyzed by subtractive absorption method [1], which was confirmed by ICP analysis. Furthermore, adsorbed species were elucidated by our flocculation-surface enhanced Raman scattering spectroscopy [2]. Such thiol molecules are useful to re-use AgNPs after centrifugation of flocculated AgNPs with heavy metal ions by tuning pH in solutions.

3. Results

We developed a new analytical method on the basis of flocculation of AgNP by utilizing electrostatic and chemical interaction between AgNPs and target ions.

(1) Metal cations in solutions were efficiently trapped on as-prepared AgNPs, with a typical quantity of 2,000-4,000 ions per each AgNP, which corresponding to ~1 mol ions/1 Kg-AgNPs, which was essentially the same for Cl^- substituted AgNPs.

(2) PMBA-SAM and PATP-SAM covered AgNPs showed essentially the same trapping efficiency as observed for as-prepared AgNPs. In addition, trapped species were elucidated by using flocculation-SERS method. We also confirmed that trapped anions and cations thiols on AgNPs can be released by adjusting pH in solutions.

Thus, we achieved our target to trap and elucidate target cations and anions in solutions with high efficiency.

4. Future prospects

Further efforts will allow us to establish this as a new analytical method for monitoring environmental pollutions in natural water quantitatively.

5. References

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