

## IP6 as a silver carrier agent and formation of Ag nanostructures

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In recent years, people have become aware of the importance of natural organic materials in geological systems. It would be important to clarify the interaction between natural organic materials and metallic ions.

Phytic acid, known as inositol hexakisphosphate (IP6), or phytate, C<sub>6</sub>H<sub>18</sub>O<sub>24</sub>P<sub>6</sub>, is found within the hulls of nuts, seeds, and grains, and it is the principal storage form of phosphorus in many plant tissues, especially bran and seeds. IP6 is not digestible to humans and animals, and phytic acid chelates make unabsorbable certain important minerals such as zinc, iron, calcium and magnesium.

On the other hand, for many years, it has been known that silver works for its catalytic activities, anti-microbial activities, and used to avoid infections and prevent spoilage. Many researchers have focused on the anti-bacterial, ability to kill microorganisms and multi-functional properties of silver nano-particles.

In this study, it is demonstrated that IP6 plays a role as a metal carrier agent for the formation of metallic nanostructures. For the preparation of the IP6 with Ag elements (Ag-IP6), The commercial IP6 solution (50 %) was diluted with distilled H<sub>2</sub>O at the H<sub>2</sub>O:IP6 solution ratio of 9:1, then 1g of AgNO<sub>3</sub> was added to the diluted IP6 solution of 100 ml, and long-term stabilized small Ag clusters were formed in the solution. A drop of the solution was dripped onto metallic substrates, then kept for the treatment time of 10 s to several min at room temperature. The solution was immediately dried using a gas burner or hot plate. Then, the reaction of the Ag-IP6 with several kinds of metals was examined. The structural and morphological properties of the Ag nanostructures were characterized by scanning electron microscopy (SEM) along with energy dispersive X-ray spectroscopy (EDS), transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM) with EDS. In addition, the surface condition of the Ag nanostructures reacted with Cu or Al and dried IP6 complexes was characterized by X-ray photoelectron spectroscopy (XPS) using a VG, ESCA-LAB Mk II with a non-monochromatized Al K $\alpha$  source ( $h\nu = 1486.6$  eV). The energy calibration for a charge correction in the spectra was made using the C1s peak. The FTIR spectra of the dried IP6 complexes were measured using KBr disks. Each disc was composed of powders consisting of IP6:KBr $\sim$ 1:100. The spectra were recorded in the range of 400 to 1400 cm<sup>-1</sup>. Raman spectra were obtained using an NR-1800 triple Raman system with backscattering geometry using the SHG(532 nm) of a Nd:YAG laser as the excitation source. All measurements were carried out at room temperature. It was found that various kinds of Ag nanostructures were formed with additional metallic sources using the Ag-IP6. Ag nanostructures with the three-dimensional dendritic structures replaced by Cu and Mn, the two-dimensional dendritic structures replaced by CaSi<sub>2</sub> and Mg, the two-dimensional fractal structures replaced by Fe, Ti, Al and Ni, the particles replaced by SrSi<sub>2</sub> and the nanowires replaced by Mo and W were formed. It is noted that the IP6 plays an important role as a silver carrier agent to control the structure and morphology of the Ag nanostructures. In addition, the experimental results suggest that the structural evolution of the Ag-IP6 reacted with Cu takes place to form the Cu-IP6 complex. However, the reaction of Ag-IP6 with Al is not active.

The structural properties of the Ag nanostructures were examined, and the growth evolution of the nanostructures was discussed. The results would help us to understand the nanostructure formation by the reaction between natural organic materials and metals in nature.

Keywords: IP6, nanostructure, dendrite growth, silver