Upcycling of electronic scrap towards the production of matrixless metal nanoparticle systems

W. Hyk, M. Adamowska, M. Muszyńska

Department of Chemistry, University of Warsaw, Pasteura 1 Str., 02-093 Warsaw, Poland
Keywords: upcycling, e-scrap, precious metals, nanoparticles
Presenting author email: wojhyk@chem.uw.edu.pl

The presented work is strictly related to the circular economy concept but its outcomes go even further. Based on the effective methodology for recycling the precious metals from electronic scrap (e-scrap) we have develop a method for the transformation of the obtained metallic material (high purity precious metal) into a product with a value higher than output raw material. This process, called upcycling or creative reuse, allows one to reduce the amount of waste, return the critical metallic raw material to the closed circuit, but also to produce a highly processed preparations with unique properties, i.e. matrix-free aqueous systems of precious metal nanoparticles. The uniqueness of the proposed approach is related not only to the source of the nanoparticle raw material, but also to the use of an innovative method of synthesis, which, unlike the currently used ones, allow one to eliminate from the systems of synthesized nanoparticles a fairly extensive matrix containing stabilizing substances and undesirable by-products of chemical reactions. The schematic representation of the proposed upcycling process is illustrated in Figure 1.

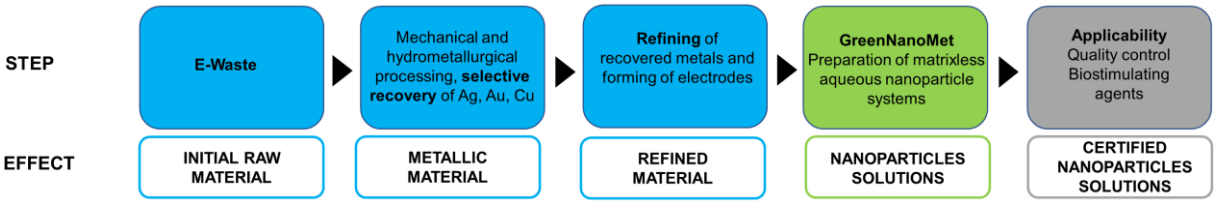

Figure 1. Block diagram of the process of e-scrap upcycling.

The developed method for the selective leaching of silver layers deposited on e-scrap components uses a reaction of a strong oxidant - molecular oxygen (a product of the reaction between sodium / potassium hydroxide and ammonia solution of sodium or potassium persulfate) with metallic silver, which is a galvanic coating covering the etched element (Hyk and Kitka (2017)). This process practically does not affect the base metal of the layer. The purity of the extracted metals is of key importance. The refined metals are then used for the formation of electrodes applied in the next stage of the upcycling process.

The obtained high-purity metallic silver is processed into a colloidal form. The method developed in our laboratory is based on the anodic dissolution of the electrode material made of recovered metal. The electrodes are immersed in ultrapure water without the addition of a supporting electrolyte. By applying the potential difference, the anode material is oxidized. The formed water-hydrated metal cations are transported (by diffusion and migration) to the counter electrode, where they are reduced to the metallic form and nucleated to form nanoparticles. The preliminary results of the synthesis, supported by transmission electron microscope imaging, confirm the effectiveness of the proposed method in the production of matrix-free Ag and Au nanoparticle systems (Adamowska et al. (2022)).

The produced matrixless Ag and Au nanoparticle systems are selected and tested for their suitability for the production of certified reference materials (nanoCRMs) with certified concentrations of nanoparticles in solution for the quality control purposes in chemical analysis of nanoparticle systems. Certification of the obtained nanoparticles as reference materials includes assessment of the homogeneity of the reference material batch, assessment of long-term stability (at least 6 months), metrological characterization using the selected analytical technique and finally preparation of the certificate (full documentation of the certification process containing the determined certified value - nanoparticle concentration - and the estimated standard uncertainty).

The obtained aqueous solutions of nanoparticles are also tested as plant stimulants. This research is currently in progress.

References

1. W. Hyk, K. Kitka, „Highly efficient and selective leaching of silver from electronic scrap in the base-activated persulfate –ammonia system”, Waste Management 60 (2017) 601.
2. M. Adamowska, B. Pałuba, W. Hyk, “Electrochemical determination of nanoparticle size: combined theoretical and experimental study for matrixless silver nanoparticles”, Molecules 27 (2022) 2592.