Recovery of Uranium using bisphosphonate modified nanoporous silicon

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Abstract Uranium is a highly toxic metal which can cause, for example acute kidney failure. Therefore, effective removal of uranium from mineral resources and mine waters is important. Furthermore, uranium-bearing polymetallic deposits are also enriched in precious rare earth elements of high demand e.g. scandium. Commercial recovery of uranium as a by-product is also an option in exploitation of uraniferous resources. Standardized use of uranium offers the long-term green fuel supply for nuclear power plants.

Keywords removal of uranium, nanoporous silicon, bisphosphonates

The present study focuses on development of a reliable and cost-effective method for purification of uraniferous waters, even at low concentrations. The method is based on bisphosphonate (BP) modified porous silicon (PSi) hybrid material. PSi, prepared by electrochemical etching of Si wafers, contains a large number of small nanopores, ca. 10 nm in diameter and a large surface area (ca. 200 m^2/g). The particle size and porous structure of PSi is tuned to optimize the metal adsorption process regarding the rate and quantity of the adsorption. Large surface area enables grafting of large number of bisphosphonate molecules on the surface. Bisphosphonates are able to reversibly and selectively chelate metals from dilute solutions. Hence, BP grafted PSi facilitates i) reversible chelation of the metal cations ii) large surface area to adsorb high amount of the metal and iii) relatively large pore size allowing suitable diffusion kinetics of the metal solution.

We have shown that BP-PSi was able to reversibly chelate and release metals from aqueous solutions for at least 50 consecutive times without major reduction of its capacity. Preliminary results show that the maximum capacity of BP-PSi filter for uranium was 13 mg/g in an aqueous solution at pH 1. The material was also able to release ca. 70 % of uranium in 1M sulphuric acid. Optimal parameters and conditions such as pH influence, ion selectivity and kinetics of the material in adsorbing and desorbing uranium will be investigated.

The work shows that it is possible to extract uranium form aqueous solutions with BP-PSi. However, at this point the cost of the material is too high for industrial applications. Further work will aim to reduce the cost of the material by employing alternative methods, such as using quartz sand or biogenic silica to produce porous silicon. The low cost BP modified PSi would be a promising material in terms of novelty and ecoefficiency for removal of uranium from contaminated water streams as chelation/adsorption is highly energy efficient process.