Niobium Circularity: Linking the Chain Aiming at Sustainable Innovation

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Niobium (Nb) is in the list of critical raw materials for Canada [1], Europe [2], USA, India, Japan, South Korea and UK [2] whereas, in Brazil, it is listed as strategic due to its range of applications worldwide and the large reserves (95% of the total). World reserves are over 17,000 kt and production in 2022 was 79 kt [3]. Because of its high thermal and electrical conductivity, malleability, ductility and high resistance to corrosion, heat and wear, Nb is used in several metallic alloys to improve their properties. Applications stand out in the superalloys, aerospacial industries, in the production of energy superconductors, mechanical capacitors, optical and electronic devices [4]. Recently, Nb has also gained attention in the automotive sector of electric vehicles, with the development of anodes for lithium-ion batteries [4]. Niobium is obtained from the processing of Nb-ores, with pyrochlore and tantalite-columbite being the main Nb-bearing minerals. The mineral processing involves steps of comminution, concentration to separate the gangue, usually carbonates and silicates, and the reduction with iron to produce the Fe-Nb alloy. To get niobium oxide, Nb needs to be leached from the Nb concentrate, and products are obtained via crystallization and calcination steps. Considering the various applications and the need for circular economy, this work is part of a project that aims to develop solutions for obtaining niobium products from secondary materials, represented by Fe-Nb alloy fines and electrodes containing TNO (Titanium Niobium Oxides). TNO has been evaluated as anode in lithium-ion batteries, aiming for greater performance [5]. In the present project, funded by The National Council for Scientific and Technological Development (CNPq, Brazil), Fe-Nb alloy fines are leached with KOH at ~100 ^{o}C and in subsequent cooling crystallization, potassium niobate is recovered from the liquor. Crystallization is investigated to understand the effect of main variables (supersaturation, cooling rate, seeding, etc) on the solids properties. This material is used as a precursor for niobic acid precipitation with sulfuric acid. In the final stage, niobic acid is calcined, producing Nb_2O_5. The association of niobium products with other materials allows their evaluation as anodes in lithium-ion batteries and in other applications, e.g., catalysis and adsorption. A similar route can be used to recover titanium niobate from end-of-life battery anodes, after dismantling, physical separation, leaching, purification and subsequent precipitation steps. To model, quantify and evaluate the process, thermodynamic modeling (PHREEQC and OLI Studio stream analyser) and process simulation (METSIM) software are used. This approach allows understanding and quantification of the different Nb-containing streams, aiming to provide circularity in the niobium production chain.

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