Zirconium and establishing a domestic rare earths supply chain

A clear path forward required for reducing our reliance on China

Despite its relative obscurity, zirconium remains a critical material with significant supply risk. China controls most of the industrial production capacity to process zirconium mineral concentrates into the basic starting compounds needed for downstream zirconium products. In fact, **China controls 95% of the world's production of the key zirconium compound** Zirconium Oxychloride ("ZOC"), which is the starting material required for downstream manufacturing into various commercial products including nuclear-powered naval vessels. Currently, 100% of the ZOC used outside China must be purchased from producers in China. A second basic zirconium compound required by industry is Zirconium Basic Carbonate (ZBC). The ZBC is derived from ZOC. The current North American annual demand for ZOC is approximately 50,000 tonnes. Worldwide demand outside of China is approximately 150,000 tonnes per year.

To reduce reliance on China for a domestic supply of critical zirconium starting compounds such as ZOC, a North American production facility for zirconium compounds must be established. And, with zirconium minerals often found associated with rare earth minerals, developing a rare earth supply chain could create an opportunity to establish a new primary supply of zirconium minerals at the same time.

There are several examples in North America of primary rare earth resources that also contain zirconium minerals. This is commonly the case with rare earth deposits that occur in

alkaline igneous intrusive rocks. These rocks may contain resources of a number of critical minerals as well as some more familiar metallic commodities such as copper and iron ore. In some cases, where such resources were mined for base metals, the tailings may contain significant quantities of recoverable critical minerals. An appropriate rare earth / zirconium resource could supply the ZOC compound for the zirconium production industry as well as the refined rare earth products to downstream users.

Zirconium dioxide is a white crystalline oxide of zirconium. Its most naturally occurring form is the mineral baddeleyite.

Zirconium is usually found in the silicate mineral zircon ($ZrSiO_4$) which always contains another rare element, hafnium, averaging a low 2% concentration. Hafnium can be a valuable by-product of zirconium recovery from a zircon resource. One interesting application for hafnium is its addition to nickel-based superalloys used in gas turbines. The other zirconium ore mineral occasionally found in a type of alkaline intrusive rock called carbonatite is baddeleyite, a pure ZrO_2 mineral that offers a simpler processing solution to produce ZOC, if it can be found in sufficient concentrations to justify recovery.

Unlike the rare earth industry’s lack of domestic, downstream-refining and manufacturing capacity to make the needed derivative products such as magnet alloys, **the zirconium industry does have downstream manufacturers for all the current products needed in industry**. Because the downstream manufacturing capacity of zirconium products is available, it could be argued that an attractive development option for a combined rare earth / zirconium resource would be to start by selling ZOC and stockpile the rare earths until downstream rare earth consumers can come on line. There is also a potential role for government to purchase the rare earths for

a government managed stockpile of critical minerals until the downstream components of the supply chain are established.

The critical importance of zirconium alone could be sufficient to justify the need for bringing a combined rare earth zirconia resource into production. Significantly, there are many applications that require both a rare earth and zirconium to develop the necessary properties for the application. One example is the use of yttria-stabilized zirconia in hydrogen fuel cell technology.

Zirconium needs to be considered part of the solution for establishing a rare earths supply chain, along with other critical minerals such as scandium, that often occur together with rare earths in the same resource. Developing these resources in alkaline igneous rocks, of which there are a number of examples in North America, offers a clear path forward for reducing our reliance on China for a basket of critical materials.