UPDATE

//Rare Earths

STORMCROW

UCORE RARE METALS [TSXV: UCU]

RapidSX Looks Real and Looks Important

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- Overall Progress: On April 19, 2022, the Company announced the departure of executives as Ucore and wholly-owned subsidiary IMC streamline themselves for a commercialization effort. On April 20, 2022, the company announced that thyssenkrupp Materials Trading would likely supply a minimum of 1,000 tpa of rare earth carbonates to the Company's Strategic Metals Complex, likely to be located in Alaska. But it is an announcement made on April 27, 2022 that is the focus of this note.

- Study on RapidSX: RapidSX is the trade name for an advanced form of solvent extraction intended for the separation and purification of rare earth elements by IMC, a wholly-owned subsidiary of Ucore Rare Metals. A 3rd party report by a subject-matter expert has determined that the use of RapidSX for the separation and purification of rare earths should have an operating cost roughly 20% below that of conventional solvent extraction for the same output. Further, because RapidSX is now showing itself to be roughly three times as efficient as conventional SX, the 3rd party report concludes that the capital cost of a RapidSX plant should be half the cost of a conventional SX plant, or better.

- Financial Analysis and Price Target: Our analysis of the potential profitability of a single 5,000 tpa RapidSX processing plant using an average-quality feed derived from monazite mineral concentrate suggests that the continued development of RapidSX is an investment worth making. We are placing a price target of $4.25 on Ucore Rare Metals, considerably higher than the $0.75 per share recent value of the stock. However, in our estimation this is a bet worth making, because RapidSX appears poised to become an actual game-changer in the global rare earth industry.

	New	Old
Recommendation	$4.25	N/A
Target	Positive	Positive

Shares O/S (mm)	49
Recent Price	0.75
Market Cap (mm)	36.75
Cash (mm)	3.8

See the end of report for important disclosures

To build any minor metal supply chain, you need to do much more than dig ore out of the ground. Rare earth elements (REEs) are even worse than most. First, you need to extract ore and concentrate it as much as economically feasible into the rare earth-bearing minerals. Then, those minerals need to be leached to extract as much as possible of the rare earths while minimizing extraction of undesirable contaminants. Next, the rare earths need to be separated from one another, which is made more difficult by the fact that the rare earths tend to behave similarly to one another, chemically, while having very different magnetic or other physical properties (which is what makes them useful). Finally, some of those separated rare earths need to be turned into metal in a way that usually looks something like making aluminum metal from aluminum oxide.

We have plenty of rare earth-bearing ore in Canada and the western world. What we don't have is a lot of expertise in designing, building and, most importantly, operating the most widely accepted technology for separating the rare earths from one another, known as solvent extraction (SX). SX is ubiquitous in the Chinese rare earth industry. In principle, it's a simple technology that involves adding the REEs, dissolved in an acid, to an organic liquid (simply a chemical made from carbon, hydrogen, oxygen and nitrogen) reagent, with a chemical extractant mixed into the organic that can bind to the rare earths and pull them out of the acid and into the organic liquid. There is a slight difference between the proportion of a given rare earth that will be pulled out of the acid compared to the rare earths around it. So, if you know those relative extraction rates, then you can design a processing chain that can successfully separate all the relevant rare earths from those around them, to a commercially necessary degree.

But…

There are some problems with this approach. To maximize the rate of extraction of the rare earths into the organic liquid at any given stage, you want to increase contact between the two liquids. Simply letting the organic float as a layer on top of the acid, like olive oil floating on top of vinegar in a salad dressing, isn't going to cut it. So the liquids flow into a settler/mixer stage, and blades are used to break the two liquids into small droplets moving around in contact with one another. But the more mixing you do, to decrease droplet size and increase the relative surface area in contact, the less able the droplets are to break apart from one another so you can actually get the organic liquid and extractant holding the rare earths out of the settler/mixer tank within a reasonable amount of time. Because separation is far from instantaneous or perfect, you flow the organic liquid, chemical extractant and the REEs it has picked up into the next stage to try and pick up even more REEs, and you let the depleted acid flow into another settler/mixer in the other direction to meet fresher organic and extractants to get even more REE stripped from it (a counter-current system). At the end of a chain, the extractant within the organic is stripped of its REEs using acid, the REE is precipitated (often using oxalic acid) and the precipitate is then calcined to make a commercially marketable REO.

If during SX, however, we've mixed the acid and organic solvent too aggressively, the droplets will be very small and you might even form what is called an emulsion; a quasi-stable suspension of the droplets that will take a long time to separate out and may even need the addition of chemicals to do so. The extra time needed to complete a single extraction in a settler/mixer stage will become excessive and your production rate will suffer. If you've mixed the acid and organic solvent insufficiently, then you will get rapid separation of the two liquids but you won't achieve sufficient separation of the REEs. Again, your production rate will suffer and the final product may not meet specification. The right amount of mixing is a balancing act that is determined both by trial and error over time and by initial design. Having expertise in operating these systems is a critical part of tuning them to operate correctly.

Worse, the long time taken for a properly operating solvent extraction plant to take completely mixed REEs dissolved in acid and output separated and useful individual rare earth oxides (REOs) means other things become a problem. The time frame of processing is weeks to months, depending on how pure the individual REOs must become. These other problematic things range from temperature changes in the SX plant, because the extraction rate into the organic varies with temperature, to power failures, mixer motor breakdown or pump failures that can lead to a portion of the working fluid in the plant being mixed for less or more time than it should have been mixed. It is possible that any one of these effects could result in a significant amount of material not meeting desired specifications and a significant amount of time before the SX plant reaches a state of stability that can output acceptable end products, again.

Now add to all this that the SX plant is quite large and relatively expensive. The acids and organic solvents used also have value, not to mention that the REEs dissolved in the acid can be worth a lot of money (especially at recent high prices). A company doing this work needs to have raised a lot of money to build a SX plant, they need to have a lot of working capital to carry the cost of their REEs in solution until they can sell them, and they will somehow need to have acquired a lot of understanding of the SX process in operation so they don't make any mistakes and suddenly discover that they won't be producing any saleable REOs for months.

What has been desired for some time is a technology that could cut time and capital cost from the processing of REEs. Yes, it would be nice if the cost of the separation could be dramatically reduced, but this has never been the biggest issue, anyway. We know from looking at the price at which mixed hydrometallurgical REE concentrates are bought and sold in China (the feed that will be dissolved in acid and introduced at the start of the SX plant) and the prices of the various REOs as sold by the separators that the cost of separating rare earth is highly likely to be less than $10 per kg for the "lighter" rare earths (like neodymium oxide, which is used to make high-power rare earth magnets and is currently selling for about USD$138 per kg) to less than USD$20 per kg for the "heavy" rare earths (like dysprosium oxide, which is used to make those high-power rare earth magnets capable of operating in a high-temperature environment for longer, and is currently selling for about USD$390 per kg). So the big concerns are really operating time and capital cost; the more rapid the throughput, the less time for something to go wrong, and the lower the capital cost because it should likely take a physically smaller plant to do the same job.

The author of this update has been involved with a number of alternative REO separation technologies. None of those has been commercially successful to date. This is the unfortunate outcome of most technology development; a new technology might appear able to overcome one problem, but it introduces a new problem or problems that can't be solved without spending too much money to do so. Which is why we are so pleased to be able to say that the RapidSX technology developed by IMC with financial support from IMC's owners, Ucore Rare Metals, now appears to be commercially viable.

What is RapidSX?

RapidSX can be thought of as an advanced version of conventional SX. It can use precisely the same combinations of acids, organic solvents and chemical extractants that are used in conventional SX. This means that buyers of REOs can have a reduced degree of anxiety about the quality of the products they are buying as they will be familiar with the types of product quality issues that they will face and are not likely to be surprised by an issue they are not equipped to test for or readily identify.

What is different about RapidSX is that it is a column-based approach to SX. Rather than using mixing blades to churn up the acid and organic liquid into a mess of droplets of widely varying size, an approach is taken that uses an apparatus in a column to create a mixture of droplets that has a much tighter distribution of droplet sizes. Column-based SX is not a novel idea, it has been worked on extensively in the past, but the solutions developed at the time had inherent drawbacks including increased cost or poor recoverability (the ability to recover from a problem during processing).

There is no doubt in our minds that RapidSX is inexpensive enough, on a per-column basis. While we cannot describe the exact technology used, we can say it is simple and straightforward with no expensive components involved. The most important aspects of RapidSX in commercial use have been investigated by Dr. Ahmad Ghahreman of AG Hydrometallurgy Services Inc. in a third-party report commissioned by the Alaska Industrial Development and Export Authority (AIDEA) regarding the RapidSX technology. Dr. Ghahreman is the founder of AG Hydrometallurgy Services and is also Associate Professor of Hydrometallurgy at Queen's, and is one of Canada's most in-demand researchers with respect to developing and commercializing new technology within the critical materials and, more broadly, the industrial metals sectors. We will rely on Dr. Ghahreman's conclusions for our evaluation of the potential impact of RapidSX on the REE industry and on IMC and Ucore.

We must remember to be realistic. We believe, and Dr. Ghahreman concludes, that RapidSX may eventually demonstrate a slightly lower cost of separation per kg of a given REO, perhaps as much or more than 20%. Such a reduction in cost will very likely be insufficient to convince, say, a SX plant operator in China to throw their currently-installed equipment out in the street and adopt RapidSX. However, the reduction in capital cost required to build a plant using RapidSX versus conventional SX, the increased speed of production leading to a lower required working capital level for the operator and using a technology that still relies on well-understood conventional SX chemistry for REEs will likely make RapidSX an enticing option for any company contemplating adding new REE separation capacity.

What is likely most important when evaluating RapidSX is the potential capital cost reduction for a separation plant. First, let's look at potential or commercial conventional SX plants. Years ago, Avalon Rare Metals of Canada issued a PFS for a conventional REE SX plant to be built in Louisiana in the United States. The plant was to be a 10,000 tonne per year producer that was meant to sell 10 fully separated REOs and a mixed heavy REE purified concentrate. The plant was to incorporate more than 1,000 settler/mixer units, and it had a PFS-estimated cost of USD$302 million at the time. Clearly, separating rare earths is not an inexpensive activity.

Lynas Rare Earths in Australia constructed a conventional REE SX operation in Malaysia. The capacity of this separation plant is roughly 26,000 tpa REO, in five major product streams (NdPr for magnets, La, Ce, mixed LaCe and a combined medium- and heavy-REE solution). The plant has 76 employees and is organized into an upstream section of 4 circuits with a total of 136 settler/mixer stages that separate heavy from light REEs), the process core of 500 settler/mixers in five separate batteries (making NdPr, La, Ce and LaCe) and the final impurity removal section of 70 stages in five batteries. The capacity of the plant is limited by licenses from the Malaysian government, and production has been running at levels of 15,000 tonnes per year for the last two fiscal years. In rough terms, the cost of the entire facility at Kuantan, Malaysia was about USD$600 million, and various industry experts would put the cost of the SX plant portion of the facility at roughly USD$400 million.

Note that these two REO separation plants produce different products in different quantities and are very different from a plant that could process both light and heavy rare earths in order to produce the entire suite of REOs. However, we can apply some standard scaling techniques to these two plant designs and suggest that a cost of roughly USD$200 million for a conventional SX plant processing 5,000 tpa (the amount of REO that we would suggest might be a good starting point for Ucore) would be reasonable.

With that value in mind, Dr. Ghahreman has concluded that RapidSX is more than three times as efficient in operation as conventional SX. His conclusion is that the cost of a RapidSX plant producing the same products as a conventional SX facility would be less than half. So if our hypothetical 5,000 tpa conventional SX plant might cost USD$200 million, a RapidSX plant capable of producing 5,000 tpa from the same feedstock would be roughly 1/3 the size and cost no more than USD$100 million. Further, Dr. Ghahreman notes that a single RapidSX column is capable of conducting its task of separating materials in 1/3 the time of a conventional SX settler/mixer. This means that the residency time of REEs within a separation plant, from the time new material is introduced to the time the separated products are available to be sold, should be no more than 1/3 the time taken by a conventional SX plant.

This reduced processing time is extremely important. First, it greatly reduces the chance that an adverse event will occur and ruin a given amount of material. If such an adverse event takes place, the RapidSX plant will very likely resume normal operations much faster than a conventional SX plant. Perhaps most important, though, is the reduction in working capital. Let’s assume operation of a 5,000 tpa plant, with rare earths are now selling for USD$100,000 per tonne when separated (perhaps a low estimate, given where REO prices are as we write this). If the process time in the plant is 30 days for conventional SX, at any given time the plant contains USD$42 million in work-in-process materials, alone. However, if the efficiency of RapidSX is 3x conventional SX, then the residence time is only 10 days. At any given time, there is only $14 million of materials flowing through the plant. The RapidSX plant requires much lower levels of working capital and has far lower exposure to variations in rare earth prices.

We also note that the RapidSX technology uses much smaller amounts of relevant reagents during separation. This is part of what contributes to a lower operating cost. That lowered use of reagent chemicals also argues for RapidSX being regarding as the "greener" or environmentally superior technology, compared to old-fashioned SX. With the use of ESG metrics becoming more and more important with respect to institutional investment, and with so few options in the natural resources space that carry a positive ESG argument, Ucore might find itself in a fairly unique position with RapidSX, especially as RapidSX is leveraged into areas outside rare earths.

Today, it may seem that there should be no issue with respect to a publicly-listed rare earth company raising money to build whatever it wants. However, we watched rare earth prices do a slow collapse from 2011 through 2019, after another period where the hope was that the industry would enjoy sustained high prices. Having to find only half the money to build a 5,000 tpa plant, and therefore suffering half the dilution to the company that building a conventional SX plant would require, is not unwelcome. Because no sooner did authorities in China question why rare earth prices were so high (on March 4, 2022) than some of those high prices that have pertained recently began to reverse themselves. We would rather see a company deploy cheaper solutions and superior technology, simply because lower costs make things easier on everyone concerned.

A High-Level Financial Analysis

Ucore is doing the right things to become a commercial producer. Recently, the company announced the departure of several of the senior executives at their wholly-owned IMC subsidiary. Commercialization requires a different skill-set than R&D, and Ucore had to streamline their executive team, with a focus on final testing and commercial production. By ramping up the involvement of parties, including members of the team at Kingston Process Metallurgy Inc. (KPM, the group involved in bench-scale and pilot testing) and some external consultants, we believe Ucore will be successful in commercializing RapidSX. In particular, we would highlight the involvement of KPM in Kingston, Canada. KPM played a crucial role in the development and commercialization of the battery recycling process owned by Li-Cycle (LICY:NYSE). We believe that having the same level of commercial focus and attention to detail applied to RapidSX by KPM has served Ucore well.

Figure 1 – KPM staff working on RapidSX trials

Source: Ucore

And without actual feedstock, there is no way to commercialize a new separation technology. The announcement of the involvement of thyssenkrupp Trading, although it did not seem to cause any excitement amongst investors, is a major one because thyssenkrupp controls several sources of rare earth and can provide what are likely to be scarce REE units for processing.

Because we believe that there is a very reasonable probability of RapidSX being successfully commercialized, we have constructed a financial model for Ucore. We do not assume the immediate construction of the Bokan Mountain rare earth mine by Ucore, nor any other mine for rare earth supply. Instead, we are assuming that Ucore will source the feed for a new 5,000 tpa plant (less cerium, since that is likely to be largely extracted chemically, prior to use of RapidSX) from a monazite or other feed.

We also believe that Ucore will be able to purchase non-Chinese hydrometallurgical concentrate. That is, the company will be able to source a mixed rare earth chemical that has already been metallurgically extracted from a mineral source. This will remove the need for a full hydrometallurgical plant from Ucore's plans.

On this basis, the cost of the Ucore 5,000 tpa RapidSX plant is USD$100 million. We will use a blended rare earth profile from several monazite sources as a "typical" monazite. Our proposed hypothetical feedstock is:

Figure 1 – Hypothetical Feedstock Composition (Monazite)

La	22.6%
Ce	44.3%
Pr	5.0%
Nd	18.1%
Sm	2.7%
Eu	0.4%
Gd	1.7%
Tb	0.2%
Dy	0.9%
Ho	0.1%
Er	0.3%
Tm	0.0%
Yb	0.1%
Lu	0.0%
Y	3.5%

Source: Stormcrow

We note that if Ucore secures a superior source of high-value rare earths, such as from one of the new ionic clay deposits being developed around the world, then the value of this business would be higher as revenues from the sale of a relatively higher proportion of magnet materials and heavy rare earths would increase compared to an average monazite supply. We will assume that Ucore can sell all the rare earths it produces, but that they only separate and sell elements up to and including Dy. We also note that there is a good market for La outside China, but we will not sell any Ce. And we will sell Y, because, again, it can largely be chemically removed from the rest of the REOs and then purified to the required level afterward.

On the basis of the above, we will assume that Ucore purchases 8,975 tonnes of contained rare earth in a good-quality hydrometallurgical concentrate with the above proportions of REOs. This results in 5,000 tonnes of useful REO once Ce is removed. Annual production would be:

Figure 2 – Hypothetical Annual Production (tonnes oxide)

La	2,031
Ce	3,975
Pr	453
Nd	1,621
Sm	246
Eu	32
Gd	156
Tb	18
Dy	79
Ho	11
Er	24
Tm	2
Yb	10
Lu	1
Y	317

Source: Stormcrow

Ucore would sell only those rare earth oxides marked in light green, a total of 4,952 tonnes of the purchased REO. It is possible that the remaining heavy REOs would be sold to another processor, likely in China, but we assume no revenue from this sale. We also assume a conservative purchase price (based on historical information) for the monazite-derived hydrometallurgical feedstock of 50% of the total contained and separated REO value, and we assume our latest long-term price deck for REOs, as shown below:

Figure 3 – Long-Term REO Pricing (USD/t)

La (USD/t)	$	1,650
Ce (USD/t)	$	1,660
Pr (USD/t)	$	135,500
Nd (USD/t)	$	128,000
Sm (USD/t)	$	2,600
Eu (USD/kg)	$	30,000
Gd (RMB/t)	$	62,800
Tb (USD/kg)	$	1,250,000
Dy (USD/kg)	$	550,000
Ho (RMB/kg)	$	149,200
Er (USD/kg)	$	32,000
Tm		n/a
Yb (RMB/kg)	$	17,300
Lu (RMB/kg)	$	785,500
Y (USD/kg)	$	7,500
Sc (RMB/kg)	$	895,500

Source: Stormcrow

We have built a simple financial model that includes SG&A expenses of USD$2 million per year, increasing at 4% per year, and an annual output of 5,000 tonnes REO purchased for 50% of total contained and separated REO value while Ucore will not sell Ce or any REO on the tables above listed below Dy. The capital cost for the facility, spent in the year before processing commences at the RapidSX-based separation plant, is $100 million.

Now, we have used a 35% discount rate to evaluate the value of Ucore's first RapidSX plant. This likely looks excessive compared to the evaluation of a mining project with a 10% or even 8% applied discount rate. However, what Ucore and IMC are doing with RapidSX is not mining, it is technology development, and the results will be somewhat binary. We believe that the prospects for commercialization are high, but risks remain ahead of the construction of a commercial demonstration facility and thus an investment into Ucore on the basis of the value in IMC is something of a venture investment, where use of a 35% discount rate would be prudent.

And even on that basis, the result is spectacular. This suggests to us that the investment is worth making, if even on the basis of a 35% discount rate there is a substantial potential increase in value from current levels. And there is, because our analysis suggests a value per share of $4.38 compared to the current average trading level of roughly $0.75. Note, too, that if Ucore can demonstrate the commercial readiness of RapidSX and if it can demonstrate an ability to source significant amounts of feedstock, either from a wholly-owned project such as Bokan Mountain or an alternative or from sellers of concentrates outside of China, there would be literally nothing other than market demand preventing Ucore from building additional 5,000 tpa plants and selling the separated rare earths to multiply this value even more.

Conclusions

RapidSX has significant potential. A 3rd party report written for AIDEA by Dr. Ghahreman of AG Hydrometallurgical Consulting Services suggests that using RapidSX to separate rare earth oxides will have an operating cost perhaps 20% lower than conventional SX. However, because RapidSX is 3x as efficient as conventional SX the processing plant should have a capital cost of only half the conventional SX plant, or better. So while it would appear that no existing processor will pull out their equipment and replace it with a RapidSX system, it would be foolish not to consider implementing RapidSX in a new plant as best practice.

Ucore is also concentrating on what needs to get done in order to bring quantities of separated and purified REOs to market for sale. Recent announcements emphasize that IMC has entered a commercialization phase of its RapidSX technology with the changes made in IMC management. The announcement that thyssenkrupp have become involved to help supply feed to the proposed Ucore SMC is an absolutely essential step for any company with a promising separation technology; you can't separate and sell REEs that you don't actually have.

Our financial analysis of the implications for Ucore suggest that building a 5,000 tpa RapidSX-based processing plant and sourcing even average-quality hydrometallurgical concentrates derived from monazite gives Ucore a value of $4.38 a share, compared to the current rough trading level of $0.75. Obviously, there is still technological, execution and financial risk to deal with, but we certainly do not minimize these risks because our model incorporates a 35% discount rate.

Given the likely financial implications of RapidSX, including a much lower capital cost, improved operating cost and much lower working capital needs, the continued development of RapidSX by IMC and Ucore is highly encouraged. We are placing a target of $4.25 on Ucore shares and reaffirming our POSITIVE recommendation.

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