Dwindling resources - a molehill out of a mountain.

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Abstract

There has been plenty of publicity about the rapid increase in the price of Indium. This price rise was as a result of a number of factors such as it only being mined as a by-product of zinc (1) and their being only limited stockpiles. This was exacerbated by a large increase in its use for transparent conducting coatings for the display industry as well as the newer faster increase in the photovoltaic industry. The net result of this was that companies suddenly found that recycling did make sense and so the supply was enhanced, at least for a time, by the input of recovered indium.

Since that time if you have observed the metals trading markets you will have seen all kinds of price increases in materials that heretofore we have thought of as abundant. In reality with the increased world population and increasing affluence, the demand for goods is increasing and the amount of materials being tied up in these goods is increasing. This requires mining more materials and, for some, this is becoming more difficult and expensive as these materials are found to be increasingly scarce. Therefore it is likely that for many the standard of living and possession of goods will have to decline in future years because of this material scarcity (2).

In this paper I will highlight some of the other materials that may be under threat and hence likely to continue to rise in price.

Introduction

Indium has been under the spotlight for some time as the price has increased from around \$60/kg to >\$1000/kg in only 2 – 3 years. Historically indium was used as a low melting point material in dry bearings and a few other applications and then along came its use for transparent conducting coatings. The use for transparent conducting coatings has grown rapidly over the last couple of decades both for energy management in windows and also for displays, both primarily coatings onto glass. More recently the displays have grown significantly larger and also another potentially huge use of indium has appeared, that of solar cells where the indium is used as part of the active layer in the copper indium gallium diselenide (CIGS) photovoltaic coating and also is used as the transparent conducting electrode above the photovoltaic layer. Either of these two applications is predicted to consume more indium each year than is currently being mined or is available from all sources (mining, stockpiles and recycling). This makes the predictions of market grow interesting because I do not believe I have ever seen a prediction from any photovoltaic cell manufacturer that restricts the market growth because of lack of supply or increasing cost of indium.

However recently René Kleijn, a chemist at Leiden University in the Netherlands, has stated that he believes that, from his estimates, gallium and indium will probably contribute to less than 1 per cent of all future solar cells - a limitation imposed purely by a lack of raw material (3). This was looking at indium gallium arsenide new generation high efficiency semiconductor type solar cells but there is no reason to believe that a different argument would be used for CIGS type solar cells that use more indium per watt generated from the lower efficiency but cheaper large area photovoltaic devices.

Researchers from the University of Augsburg in Germany in their work estimated that gallium would run out by 2017. Most other work also suggests very limited availability of both indium and gallium that the shear weight of information would suggest that even if these numbers have errors associated with them there is an underlying problem.

There is an opposing view to this. As gallium is a by-product of both zinc and aluminium it has to be dependent upon the lifetime of these materials and as aluminium is predicted to have over 500 years of material still left then there must also be 500 years worth of gallium. The same argument can be used for both indium and gallium that are both a by-product of zinc mining and zinc has a lifetime of 34 years. This is not as good as the aluminium but is considerably better than the very short lifetimes being predicted.

Hubbert peaks for materials lifetimes

M. King Hubbert in 1956 predicted that the oil production in the USA would peak around 1965-1970 and that the global oil production would peak before the turn of the century (4). Initially Hubbert was, by many, regarded as a crank and his predictions disbelieved. Once they got close to his predicted peak he was vindicated as the oil companies agreed with his predictions and production of oil in the USA peaked and declined. Since then his simple model has been applied to many other materials. There are some materials such a mercury or lead that are already well past their peak in world production and so it has been possible to obtain accurate historic data to verify the model.

Where the model has problems is where there is still growth in production. This is more because the mining companies or countries tend be secretive about total production reserves and new finds. Thus until the peak is reached there can be significant errors. A number of materials are having extra high values of production currently which are above predicted values and this is because of the surge in the economies of China & India.

The other potential for error is that the model probably discounts the likes of undersea mining of low grade ores that are currently not economically attractive and so undeveloped but which might be perfectly viable given the incentives of rising prices.

Demographics

Reverend Dr Thomas Robert Malthus FRS, 1766 to 1834 the English political economist & demographer predicted that the world population would grow geometrically (1, 2, 4, 8, 16,…) whereas the food production would only grow arithmetically (1, 2, 3, 4, 5, 6…) and hence the limitations of food production would bring about a limit to world population (5). This proved to be wrong because of the ingenuity which set about massively increasing the food production. The ability to do this over the last hundred years was, in no small part, due to the availability of copious quantities of oil and gas. This enabled enough cheap fertilizers to be produced to enable food production to (almost) keep pace with population growth.

It is interesting to note that this may just have been a delay in the Malthus prediction coming true. Currently there is tremendous competition for land for the production of food, fuel and as an oil replacement to make polymers and other products. Thus even with plenty of fertilizers there is already a drop in world food production that has been felt by everyone but particularly the poor and, already, undernourished. This situation is likely to worsen as the energy costs rise and it becomes less economic to manufacture fertilizers which will cause a drop in yields. Thus there is the potential for famine and a self limiting world population.

The knock-on effect of this is that this would also imply a limitation the world market for existing products. Although many companies encourage us to replace goods before they are unusable but only ‘dated’ or ‘aesthetically tired’ this may become more difficult to do as the cost of energy rises and so disposable income declines.

Who knows it may be the ideal time for start-up companies to produce goods that are built-to-last rather than being disposable.

If we look at the pressures that are on materials supply we can perhaps understand why there is a concern about the future supply of materials. Currently there are approximately 800 million people in Europe and North America who have a consumer oriented lifestyle. These are the people who have driven the mining and use of resources to the current high levels. However to put this into perspective there are 8,500 million people who aspire to have a similar consumer oriented lifestyle. For this to occur would imply a tenfold increase in consumption of resources over current levels. It is hard to see this happening. If we look at mining in broad terms we see that most of the easy sources of materials have already been exploited. Large open cast mines have been common and in some cases whole hills have disappeared. Seams of ore are finite and as mines age there comes a time when the ore becomes more difficult to extract and the quality of the ore declines. At some point this combination makes the extraction of the ore uneconomic. So as times goes on the only source of some of these materials will be from hard to extract and low grade ores. As energy is also increasing in cost, the cost of extraction will rise more steeply than were it based on more difficult extraction and processing alone. This tells us that the prices are going to increase significantly. Coupled to the increasing demand, which will also increase the prices, this suggests that the price increases will be large. As with most things the supply & demand will come into balance at some elevated price.

Other materials

If we look at capacitors the most widely vacuum deposited coatings are aluminium, zinc and silver. There are also some newer materials such as tantalum that are being developed. If we look at the table below we can see that there are two columns that predict the number of years left for these materials, the first of these is an optimistic prediction that takes the reserve base and divides it by the annual global consumption. This is obviously a false figure as some highly developed countries, such as the USA, consume a much higher level of materials per capita than any of the third world countries. Then there are the rapidly growing countries such as China and India that as they expand are, for a time, consuming more than they are expected to when their markets become sated. Thus for the second more pessimistic column the reserve base is divided by the world population multiplied by 50% of the current US consumption.

It can be assumed that either of these figures will have large errors in the figures because of the following reasons. Mining companies and countries tend to be reticent about declaring the volumes of reserves. For the mining company it is information that is of potential use to their competitors and may also affect their share price. Countries also do not wish to highlight that one of their natural resources might be running out as this could affect inward investment into the country, international standing, employment levels, etc.

Material	Years left @ current global consumption rate	Years left – whole world consumes @ 50% US rate	Proportion of consumption met by recycling
Aluminium	1027	510	49%
Zinc	46	34	26%
Silver	29	9	16%
Tantalum	116	20	20%

Consumption figures may also be skewed because of speculation. Several times in living memory speculators have tried to corner the market in various materials, possibly most notably silver. This buying and stockpiling forced the price up and, had the plan worked, would have made the speculator a massive fortune. It was only by a concerted effort by many countries that defeated this attempt. As these materials reduce in availability they become more sensitive to this type of speculation both from individuals, companies or even countries.

This greed has also led to war (3). The Democratic Republic of the Congo has the biggest tantalum mines in Africa along with other natural resources. The increasing popularity on mobile phones (6) led to a price surge in tantalum metal and this increase in wealth is attributed as one of the key motives in the civil war there in 1998 – 2002.

The predictions of materials shortages means that within the world not everybody can expect to have the same standard of living and this too is likely to lead to civil unrest in the longer term.

There are reports that China has levied export taxes onto some goods with the idea that it will restrict the amount exported and thus preserve stocks within China. This has been selective and is generally on goods that are deemed critical.

When we look at indium and the use as a transparent conducting coating there are alternative materials such as zinc oxide that, whilst not as good, could still be used for many applications. However when we look at a material such as platinum there tends not to be any good substitute nor is it possible to produce a synthetic alternative as it is for materials such as oil.

We have the increasing use of catalytic converters for car exhausts and an embryonic industry in fuel cells. However it has been estimated that if all the vehicles in use today (500 million) were converted to use fuel cells then the platinum would run out within 15 years. This does not bode well for future transport or a reduction in pollution.

Terbium is used to make green phosphors for fluorescent lights and is predicted to run out within five years. Antimony use in fire retardants could last around 15years. Lead is way past peak world production and is rapidly running out but is still the material of choice for batteries which are increasing in use for storage of electricity generated either by wind or solar sources, particularly in more remote areas. Uranium used in nuclear power stations may only last around 17 years.

Material	Years left @ current global consumption rate	Years left – whole world consumes @ 50% US rate	Proportion of consumption met by recycling
Aluminium	1027	510	49%
Zinc	46	34	26%
Tin	40	17	26%
Tantalum	116	20	20%
Silver	29	9	16%
Lead	42	8	72%
Indium	**13**	**4**	**0%**
Copper	61	38	31%
Antimony	30	13	?
Gallium	9	?	?

If we consider all the limitations of power sources such as dwindling stocks of fossil fuels, dwindling reserves of materials to make alternative energy sources and limited possibilities for nuclear power then even the opportunity of having large amounts of low cost energy to be able to process low quality ores or wastes to make materials more available becomes problematic.

Gallium as used in gallium arsenide for solar cells and light emitting diodes and as used in copper indium gallium diselenide solar cells is expected to be in great demand. Ugo Bardi and Marco Pagani, members of Association for the Study of Peak Oil and Gas (ASPO) estimated that world peak production was reached around 2003, others put it earlier. Thus we know that we are somewhere on the downward slope of the supply graph. However the speed of exhaustion will be slow as gallium is mined as a by-product of bauxite and of zinc mining and as aluminium is expected to run out in ~500 years and zinc in 34 years. Thus we know that there will be a larger supply for the first 34 years until the zinc runs out and then a lower production based on aluminium production for a lot longer. Thus the prediction from Armin Reller of the University of Augsburg in Germany, who estimate gallium will run out by 2017, looks to be somewhat pessimistic (3). Also René Kleijn of Leiden University in the Netherlands who predicts that indium and gallium containing solar cells will contribute ~ 1% of all solar cells because of lack of indium and gallium (3) is probably based more on the availability of indium than of gallium.

Re-cycling

So where does all this leave us, well, if we do nothing we will be starved of materials and prices will spiral out of control. This is likely to result in government intervention to dictate what can and cannot be produced.

As this is likely to lead to civil unrest it is unlikely that any government will allow things to get so far out of control. Thus what can they do to prevent this? The answer is re-cycling. If we look at 1 tonne of electronic waste as taken from personal computers there is more gold that can be recovered from this than from 17 tonnes of gold ore (7). In addition from the same 1 tonne of scrap circuit boards there are the following materials that are typically available; Al, Sb, As, Ba, Be, Cd, Cr, Co, Cu, Ga, Fe, Pb, Mn, Hg, Pd, Pt, Se, Ag, and Zn which makes it a rich source of materials, if a little hazardous.

Metal	Metal content and value estimated for a typical cell phone		Metal content and value for 500 million obsolete cell phones in storage in 2005[2]	
	Wt[1] (g)	Value	Wt[3] (t)	Value
Copper	16	$0.03	7,900	$17 million
Silver	0.35	$0.06	178	$31 million
Gold	0.034	$0.40	17	$199 million
Palladiun	0.015	$0.13	7.4	$63 million
Platinum	0.00034	$0.01	0.18	$3.9 million
Total			**8,102**	**$314 million**

If we look at the above table it shows the [1]Metal content (wt) calculated from weight of a typical cell phone (Nokia, 2005) and data from Falconbridge Ltd. (8). This is followed by the calculation of the value of the materials for what was a projected number of cell phones that were deemed to be obsolete in 2005. It is predicted that >1bn cell phones will be sold in year 2009 with >2.5bn in use in the same year. We all know of people who regularly update their cell phone to get the latest gizmos included. It has been estimated that <1% of 'retired' cell phones get as far as re-cycling. Thus we can see how, even for something as small as a cell phone, how much resource is being thrown away or simply stored in the bottom of draws.

Despite international laws about dumping waste it is still a common site to see container ships offloading waste in third world countries and to see the poor of the world sorting through the detritus of the affluent. In this way there is a hidden amount of re-cycling occurring but generally this is at the risk of the health of those doing it. Open fires are used to burn of the insulation to recover copper wiring. This does nothing to improve the environment as all kinds of toxic gases and particulates are released into the atmosphere. The scavengers do not have any personal protective clothing or breathing apparatus and so are likely to have shortened lives.

Sooner or later the price of materials will rise to the point where it will suddenly become important for us to recycle our own waste as this will become an important and possibly critical resource.

Conclusions

Hopefully this has given a glimpse at a global view of what is happening to the supply of many metals. Many metals have already peaked in terms of global mining output and so we have a sight of the time these resources will become exhausted.

I fear this insight might also prompt some people into speculating in the metal markets and history tells us that speculation does not improve the situation at all.

This vision hopefully highlights why re-cycling is so important. If you take the cell phone example and multiply this up with computers, PDA's, videos, CD/DVD players, camcorders, cameras, TV's, radios, etc… it is apparent that the modern day miners could just be touring round yard sales and buying electrical cast-offs to make their fortune.

There is a saying in the UK that 'where there's muck there's brass (money)' which looks as true today as ever it did.

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