1. INTRODUCTION

In order to really define what metal oxides are we have to start by understanding the nature of metals-meaning their physical and chemical characteristics- as well as their reactive capabilities with oxygen to form metal oxides.
Metals are, chemical elements displaying certain properties by which it is normally distinguished from a nonmetal, notably its metallic luster, the capacity to lose electrons and form a positive ion, and the ability to conduct heat and electricity. The metals comprise about two thirds of the known elements. Some metals, including copper, tin, iron, lead, gold, silver, and mercury, were known to the ancients; copper is probably the oldest known metal.

a. Physical Properties

Metals differ so widely in hardness, ductility (the potentiality of being drawn into wire), malleability, tensile strength, density, and melting point that a definite line of distinction between them and the nonmetals cannot be drawn. The hardest elemental metal is chromium; the softest, cesium. Copper, gold, platinum, and silver are especially ductile. Most metals are malleable; gold, silver, copper, tin, and aluminum are extremely so. Some metals exhibiting great tensile strength are copper, iron, and platinum. Three metals (lithium, potassium, and sodium) have densities of less than one gram per cubic centimeter at ordinary temperatures and are therefore lighter than water. Some heavy metals, beginning with the most dense, are osmium, iridium, platinum, gold, tungsten, uranium, tantalum, mercury, hafnium, lead, and silver.
For many industrial uses, the melting points of the metals are important. Tungsten fuses, or melts, only at extremely high temperatures (3,370°C.), while cesium has a melting point of 28.5°C. The best metallic conductor of electricity is silver. Copper, gold, and aluminum follow in the order named. All metals are relatively good conductors of heat; silver, copper, and aluminum are especially conductive. The radioactive metal uranium is used in reactor piles to generate steam and electric power. Plutonium, another radioactive element, is used in nuclear weapons and nuclear reactors as well as in pacemakers. Some of the radioactive metals not found in nature, e.g., fermium and seaborgium, are produced by nuclear bombardment. Some elements, e.g., arsenic and antimony, exhibit both metallic and nonmetallic properties and are called metalloids. Furthermore, although all metals form crystals, this is also characteristic of certain nonmetals, e.g., carbon and sulfur.

b. Chemical Properties

Chemically, the metals differ from the nonmetals in that they form positive ions and basic oxides and hydroxides. Upon exposure to moist air, a great many undergo corrosion, i.e., enter into a chemical reaction; e.g., iron rusts when exposed to moist air, the oxygen of the atmosphere uniting with the metal to form the oxide of the metal. Aluminum and zinc do not appear to be affected, but in fact a thin coating of the oxide is formed almost at once, stopping further action and appearing unnoticeable because of its close resemblance to the metal. Tin, lead, and copper react slowly under ordinary conditions. Silver is affected by compounds such as sulfur dioxide and becomes tarnished when exposed to air containing them. The metals are combined with nonmetals in their salts, as in carbides, carbonates, chlorides, nitrates, phosphates, silicates, sulfides, and sulfates.

c. The Electromotive Series

On the basis of their ability to be oxidized, i.e., lose electrons, metals can be arranged in a list called the electromotive series, or replacement series. Metals toward the beginning of the series, like cesium and lithium, are more readily oxidized than those toward the end, like silver and gold. In general, a metal will replace any other metal, or hydrogen, in a compound that it precedes in the series, and under ordinary circumstances it will be replaced by any metal, or hydrogen, that it follows.

d. Sources and Uses

Although a few metals occur uncombined in nature, the great majority are found combined in their ores. The separation of metals from their ores is called extractive metallurgy. Metals are mixed with each other in definite amounts to form alloys; a mixture of mercury and another metal is called an amalgam. Bronze is an alloy of copper and tin, and brass contains copper and zinc. Steel is an alloy of iron and other metals with carbon added for hardness.

Since metals form positive ions readily, i.e., they donate their orbital electrons, they are used in chemistry as reducing agents in redox reactions (complementary chemical reactions characterized by the loss or gain, respectively, of one or more electrons by an atom or molecule). Finely divided metals or their oxides are often used as surface catalysts. Iron and iron oxides catalyze the conversion of hydrogen and nitrogen to ammonia in the Haber process (the principal commercial method of producing ammonia, by direct combination of nitrogen and hydrogen under high pressure in the presence of a catalyst, often iron). Finely divided catalytic platinum or nickel is used in the hydrogenation of unsaturated oils. Metal ions orient electron-rich groups called ligands around themselves, forming complex ions. Metal ions are important in many biological functions, including enzyme and coenzyme action, nucleic acid synthesis, and transport across membranes.

What are oxides? Any of a large and important class of chemical compounds in which oxygen is combined with another element. Oxides are widely and abundantly distributed in nature. Water is the oxide of hydrogen. Silicon dioxide is the major component of sand and quartz. Carbon dioxide is given off during respiration by animals and plants. Carbon monoxide, sulfur dioxide, and oxides of nitrogen are among the waste gases of gasoline-burning internal-combustion engines. Nitrous oxide is an oxide of nitrogen often called laughing gas. Many of the metals form oxides. Some metal oxides, e.g., those of iron, aluminum, tin, and zinc, are important as ores. Litharge and red lead are lead oxides used as pigments in paint. A number of elements, e.g., arsenic, carbon, manganese, nitrogen, phosphorous, and sulfur, combine with oxygen to form more than one oxide. The inert gases do not form oxides. The halogens and inactive metals do not combine directly with oxygen, but their oxides can be formed by indirect methods. Oxides are usually named according to the number of oxygen atoms present in a molecule, e.g., monoxide (or simply oxide), dioxide, trioxide. In a molecule of carbon monoxide, CO, for example, there is one oxygen atom; in carbon dioxide, CO2, there are two; and in phosphorus pentoxide, P2O5, there are five. Oxides are commonly classified as acidic or basic oxides or anhydrides. Sulfur trioxide is an acid anhydride; it reacts with water to form sulfuric acid. Phosphorus pentoxide reacts vigorously with water to form phosphoric acid. Many metal oxides react with water to form alkaline hydroxides, e.g., calcium oxide (lime) reacts with water to form calcium hydroxide (slaked lime). Some metal oxides do not react with water but are basic in that they react with an acid to form a salt and water. Others exhibit amphoterism; i.e., they react with both acids and bases. Still others are neutral and nonreactive.

Having this background about metals and oxides and combination thereof, we can now focus on their modern usage and application as compounds.

Metal oxides are emerging as important materials for the versatile properties and are used in these identifiable areas:

- Powder production
- Pressing
- Sintering
- Aluminum
- Copper
- Iron and steel
- Magnesium
- Molybdenum
- Nickel
- Titanium
- Tungsten
- Ceramic materials
- Composite materials
- Electrical and magnetic materials
- Hard materials and tool steels
- Mechanical alloying

- Porous materials
- Powder forging
- Powder injection moulding
- Powder compaction
- Metal matrix composites
- Surface treatment and coating
- Process modeling
- Colouring agents

Research and development in these varied is an ongoing exercise, which is an effort to expand on the present applications. Accordingly, there are leading nations in this R&D endeavour of which Germany is also as leading light on this front. Their R&D quest is to promote access to environmentally sustainable technologies according to the Agenda 21 requirement, which is an environmental standard on which more cleaner production/ manufacturing methods are encouraged. Germany enjoys an excellent reputation in developing technologies around areas like waste management, air quality control, noise abatement, water protection and energy technology etc.

An immediate example of groundbreaking applications of metal oxide under air quality control is in cleaning of exhaust air in road tunnels and other facilities by using precious metal catalysers for removing substantial carbon monoxide from the exhaust air emitted by cars. In order to fully appreciate the leapfrog made in utilizing the metal oxide technology in its varied forms, one needs to know a bit about nanoscience.

2. NANOSCIENCE

In essence nanoscience, which is the building block of nanotechnology, allows for the manipulation of matter at the atomic level. Atoms are the smallest units of matter. One nanometer is a billionth of a meter, or about the length of 10 hydrogen atoms or five silicon atoms.
It is not a new industry or science; basically it is an application of the new knowledge of the nanoscale to existing industries-whether it is improved disease detection mechanisms or producing nanoclay particles for the plastics industry. It is an enabling technology rather than an industry in its own right.
Governments and companies around the world are ploughing R600m/year into nanotechnology in the belief that it will usher in new area of growth and productivity.

The South African Government has twin agendas for nanotechnology:

Social agenda, where nanotechnology could lead to improvements in water sanitation, cheaper energy, low cost electronics and better ways in combating diseases like TB, malaria and HIV/AIDS
Industrial front, where nanotechnology could add enormous value to SA's minerals-gold, titanium, palladium, platinum- once simply exported raw materials to be transformed by others.

Government departments like the Department of Trade and Industry; Department of Arts, Culture, Science and Technology together with institutions like Mintek and CSIR are increasing efforts in improving capacity as far as nanotechnology is concerned.

On the German front things are so advanced that Microsystems engineering and nanotechnology are combined to give major impulses to technical innovations in a variety of industrial sectors in the future. This field of research plays a role in the implementation of additional functions and novel materials and effects. Nanotechnology provides access to so far unused, completely novel effects. Microsystems engineering allows for the development of complete systems solutions due to its pronounced systemic capability, therefore applications-tailor made solutions can be made. This is achieved by using interdisciplinary approaches based on a pool of technologies comprising mechanical, optical, magnetic, fluidic, electrical, material science, and information technology competencies.

The benefits of this combination approach results in the following benefits:

- Access to materials, components, and systems with new functions and effects
- Increased functional density on system platforms
- Improvement of already implemented products
- Use of novel processes and techniques to open up new fields of application and business
- More efficient solutions for the saving of resources and the avoidance of waste

3. SOUTH AFRICAN SCENARIO

South Africa's future growth and prosperity have been and will continue to be closely linked to the mining and metallurgical industry. Almost fifty percent of our country's income from foreign exchange arises from the industry and this points to a need to continue in improving our global competiveness. Therefore Research and technology will play a very important part in this industry given the limited resources to work from. There are priority areas that need to be focused on as a matter of fact. Topping the list on priorities to be tackled is wealth creation and quality of life for all people of South Africa. This will be done in a sense that the past social imbalances are eradicated in form of job creation, so the sector needs to be competitive and meet the challenges of globalization. So there will be a need for new mining technologies and more highly skilled and better trained workforce. This need to be balanced against the need to further process the mineral/metal mining output for end products directly consumable locally and for export purposes. Nanotechnological capability will advance the collective use we make of metal oxide as elaborated above in their varied applications.

4. LIMPOPO SCENARIO

The above Research and Development imperatives for South Africa are interchangeably relevant to Limpopo as a province. Focusing on the Provincial Growth and Development Strategy, key sectors delineated as provincial growth sectors are accordingly- mining, manufacturing, agriculture and tourism.

Limpopo is well endowed with natural resources as it boasts some of the greatest reserves in agriculture, mineral and tourism resources. Technological advances in Germany can come in handy, especially in nanotechnology, to be applied especially in agriculture and mining.

a. In mining

Limpopo has an abundance of mineral resources and mining is a critical sector of the economy, which contributes 22% of the GGP. The platinum group includes platinum, chromium, nickel, cobalt, vanadium, tin, limestone and uranium clay. Other reserves include antinomy, phosphates, fluorspar, gold, diamonds, copper, emeralds, scheelites, magnetite, vermiculite, silicon, mica, black granite, corundum, feldspar and salt.
All these minerals/metals can be adequately obtained by the improvement in extractive technologies.

b. In Agriculture

Closer improvements arising from nanotechnology as applied to metal oxides can be achieved in food processing, by using for example, powder products in food.

- In dressing/topping: by using emulsion stabilizer
- In beverages: suspension, thickener and emulsion
- In sauces/gravies: maintain product integrity
- Bakery: viscosity and suspension
- Processed meats: stabilizer and texturizer

Another example of nanotechnological application of metal oxide is by reducing available amounts of heavy metals in contaminated soils by adding iron oxide.
In forestry and timber related industry it can be beneficial to promote healthy forests and water, products that use nanosensors to measure changes in the environment such as moisture levels and temperatures. Nanoparticles and polymers can reduce the cost of treating water. Paper making process can be improved by developments in nanosilica and nanocoatings and additives so that high gloss papers can be developed more easily and efficiently

5. SUPPLY CHAIN ANALYSIS

Ore and Mining: first step

Metals are often extracted from the Earth by means of mining, resulting in ores that are relatively rich sources of the requisite elements. Ore is located by prospecting techniques, followed by the exploration and examination of deposits. Mineral sources are generally divided into surface mines, which are mined by excavation using heavy equipment, and subsurface mines.
Once the ore is mined, the metals must be extracted, usually by chemical or electrolytic reduction. Pyrometallurgy uses high temperatures to convert ore into raw metals, while hydrometallurgy employs aqueous chemistry for the same purpose. The methods used depend on the metal and their contaminants.

Metallurgy: second step

Metallurgy is a domain of materials science that studies the physical and chemical behavior of metallic elements, their intermetallic compounds, and their mixtures, which are called alloys. From this step metal oxides are obtainable from raw materials/metals reacting with the required oxides in natural experiments and controlled experiments. With nanotechnology used as a tool for beneficiation, manufacturing, materials engineering etc. some value added can be achieved using metal oxides.

Applications: third step

- Powder production
- Pressing
- Sintering
- Aluminum
- Copper
- Iron and steel
- Magnesium
- Molybdenum
- Nickel
- Titanium
- Tungsten
- Ceramic materials
- Composite materials
- Electrical and magnetic materials
- Hard materials and tool steels
- Mechanical alloying
- Porous materials
- Powder forging
- Powder injection moulding

- Powder compaction
- Metal matrix composites
- Surface treatment and coating
- Process modeling
- Colouring agents

Areas in which the above metal oxide products can be applied: fourth step

Transportation:

- Techno-economic modeling
- Neural networks
- Real time information processing
- Bulk horizontal and vertical transportation systems
- Simulation modeling
- Underground milling
- Sensor technology

Information Technology:

- Real-time information processing
- Neural networks
- Sensor technology
- Control systems
- Simulation modeling, including virtual reality

Mineral processing:

- Mineral processing
- Hydrometallurgical techniques
- Pyrometallurgy
- Electrotechnogy processes
- Materials engineering

Mining equipment and methods:

- Rockbreaking
- Underground support
- Seismic technologies
- Ore-body delineation
- Hydraulic conveyancing
- Engineering design
- Control systems

Surface environment:

- Desalination process
- Bioleaching
- Sulphur emission control technologies
- Clean air technologies
- Waste stabilization and vitrification technologies

Exploration techniques:

- Remote sensing
- Seismic techniques
- Electromagnetic techniques
- 3D simulation modeling
- Image enhancement techniques

Automation, robotics and control:

- Sensor technology
- Image enhancement techniques
- Control systems
- Real-time information processing
- Simulation modeling

Refrigeration, cooling and Insulation:

- Sensor technology
- Real-time control systems
- Simulation modeling
- Operations management
- Materials engineering

Some metals and metal alloys possess high structural strength per unit mass, making them useful materials for carrying large loads or resisting impact damage. Metal alloys can be engineered to have high resistance to shear, torque and deformation. However the same metal can also be vulnerable to fatigue damage through repeated use or from sudden stress failure when a load capacity is exceeded. The strength and resilience of metals has led to their frequent use in high-rise building and bridge construction, as well as most vehicles, many appliances, tools, pipes, non-illuminated signs and railroad tracks.
Metals are good conductors, making them valuable in electrical appliances and for carrying an electric current over a distance with little energy lost. Electrical power grids rely on metal cables to distribute electricity. Home electrical systems, for the most part, are wired with copper wire for its good conducting properties.
The thermal conductivity of metal is useful for containers to heat materials over a flame. Metal is also used for heat sinks to protect sensitive equipment from overheating.
The high reflectivity of some metals is important in the construction of mirrors, including precision astronomical instruments. This last property can also make metallic jewelry aesthetically appealing.
Some metals have specialized uses. Mercury is a liquid at room temperature and is used in switches to complete a circuit when it flows over the switch contacts. Shape memory alloy is used for applications such as pipes, fasteners and vascular stents.
Astronomy

a. Mining

A Major strength of the South African economy, also taking Limpopo into consideration, is a well developed mining and metallurgical industry and the associated infrastructure and high level, commercial and technical expertise base. Limpopo is endowed with the abundance of mineral resources and locating mining as a critical sector of the economy in the province, I contribute 22% of the GGP. The Platinum group includes, chromium, nickel, cobalt, vanadium, tin, limestone, and uranium clay. Other reserves include antinomy, phosphates, fluorspar, gold, diamonds, copper, emeralds, scheelites, magnetite etc.
All these minerals will be adequately obtained by utilizing cutting edge technology from international developed economies like Germany. The country and interchangeably Limpopo province has favorable energy costs and significant scope to generate a larger amount of electrical and fossil-fuel-based energy, which is crucial area for enhancing economic growth as other areas of industrial activity are directly linked to it.

The development of the Industrial Development Zones (IDZs) will catapult the economic growth as proposed metallurgical clusters are incorporated into them.
Cooperation between industry and research and development organization is generally good and this favours the implementation of improved technology. The existing manufacturing industry that supplies the mining and metallurgical industry is also well placed to move into more added-value areas. The existing minerals cannot be mined easily, therefore operating costs are high and again the transportation costs involved in ferrying the final products to suitable markets is high. This calls for improved processes in the value chain, applying cost cutting technologies in form as arising from nanotechnological advances.
A trained workforce is also important in the broader scheme of things as it will bolster productivity. There is also a gap to be exploited by small and medium enterprises, which bodes well for communities closer to mining areas as they will be empowered.

b. Agriculture

According to Provincial (Limpopo) Growth and Development Strategy, cluster value chain formation is the way to go as mechanism to raise international competitiveness and investment rating of the province and also to combine public and private sector contributions to development.
Briefly, the cluster formation objectives in this sector will benefit from nanotechnological inventions as they are applied throughout the value chain as happened above in mining, more or less.
Key points touch on:
Improving education and skills; there must be more PhD output in various tertiary institutions to consolidate R&D capacity, for example in bioscience and environmental science.
Provision of essential infrastructure; there must be increased commercialization of state farms, rehabilitation of community irrigation schemes etc.
Building of capacity in technology; these tallies well with the improvement of education and skills.
Opening access to capital markets and export market; access to finance will enable more small and medium enterprises to explore more value add options to satisfy international consumers.
Improving institutions/ institutional efficiency; less red tape scenarios will lead to cost cutting outcomes.