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RARE EARTH ELEMENTS IN INDIAN CONTEXT: RECENT PROGRESS & CHALLENGES

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Abstract

Rare-earth elements (REE), are a set of seventeen nearly indistinguishable lustrous silvery-white soft heavy metals are also called the rare-earth metals or rare-earth oxides. REE are widely utilized in high tech manufactured goods including electronic products. These metals are tremendously strenuous to excavate since it is atypical to perceive them in assemblage or agglomeration intensified for economical extraction. China owns largest reserves of REE and hence the world, including India, has become increasingly dependent on China for manufactured goods. However, Government has in the recent past given thrust to campaigns of 'Make in India' and 'Atma Nirbhar Bharat', which may be realised by securing critical resources like REEs. It is relevant mention that spin offs after research in field of REE will pay rich dividends to industries and has applications in diverse areas such as renewable energy, aerospace, defence, electrical equipment, electronics and can be easily achieved through Public Private Enterprises. The purpose of the paper is to reassess major climacteric that constructed the stage for the expansion of the today's Rare Earth Elements including adequate detail to au courant reader with their fundamental principles, robustness, challenges and its praxis.

Keywords - Rare Earth Eelememt(REE), Beach Sand Minerals(BSM)

I. INTRODUCTION

Irrespective of branch of engineering and field of science, the materials with their properties and applications play a decisive role for the end use. In present days developments on new materials, smart materials, powder metallurgy, rare earths, metamaterials, nano materials and diversified alloys are the backbone of advancement in science, technology and enhancement of quality of life. Amongst the aforemention, in domain of elements, REE is emerging as most sought since applications are extensive from lenses to electromagnets and aerospace to submarines[1]. The rare-earth elements (REE), also called the rare-earth metals or rare-earth oxides are determined as seventeen nearly indistinguishable lustrous silvery white soft heavy metals. Despite their name, most are abundant in nature but are hazardous to extract due to uses of extensive chemicals. These minerals show signs of being scant, and in consequence these bright to light contrive unearth elements were named “rare earths.” These rare earth materials find a wide range of use in the field of automobiles, semiconductor manufacturing, electronics, medical imaging, battery manufacturing, aerospace, submarines, optoelectronics , coating and paintings, magnets , armoring, gems, stones, abrasive blasters, powder metallurgy application, uses in nano science and technology, memory chips, additives in polymers, nuclear medicine, florescence materials, refractories, catalyst in chemical industry, carbon luminaries and durable components. Rare earths are generally trivalent elements, but a few have other valences. Cerium, praseodymium and terbiumare tetravalent while samarium, europium and ytterbium, on the contrary are divalent[2].

II. WHAT ARE RARE EARTH ELEMENTS

Notwithstanding their name, most of REE are abundant in nature and the name rare earths itself is misleading. When discovered in eighteenth century REE had complex oxides as its components known as rare earths.

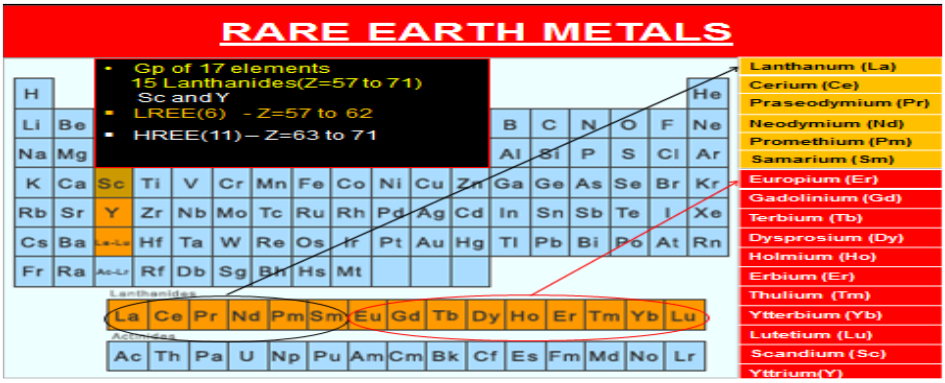

Fig. 1 Rare Earth Elements: Periodic Table with HREE and LREE

The Fig 1 depicts the Rare Earth Elements depicted in periodic table and further classified into Heavy Rare Earth Elements (HREE) as well as Light Rare Earth Elements (LREE) represented by atomic number and properties. The rare earth elements represents metals, and the group is earmarked as the ‘Rare Earth Metals’. These metals display similar properties, and are found together. They are cited as ‘rare earth oxides’ for the reason of availability as oxide compounds[3]. The REE have unique qualities hence application is selective. Few important properties are as follows:-

- The elements of rare earths represents silver, silvery-white, or grey metals.
- The metals reflects luster, however get tarnished in air readily.
- The REE display high electrical conductivity.
- Small differences in complete solubility with complex formation in REE is prevalent.
- Concentration of REE reduces moving from surface soil to deeper soil.
- These metals pose negative environmental impacts

Ilmenite, garnet, zircon, sillimanite, monazite and rutile are called Beach Sand Minerals(BSM). India has almost 35 per cent of the world’s total beach sand mineral deposits. Also, India ranks as the seventh country as far as potentials in rare earth reserves are concerned. As per estimates by experts belonging to the Beach Minerals Producers Association (BMPA), the rare earth mineral downstream industry can net a capital employment of about Rs 121,000 crores, including Rs 50,000 crores worth of foreign exchange. Besides this, according to Indian Rare Earth industry representatives, potentially worth Rs 90,000 crores in annual turnover, lies wasted and underused. The most plentiful of REEs include Lanthanum, Yttrium, Cerium and Neodymium. They typically seems similar to recurrently utilised commercial purpose metals namely as Lead, Zinc, Molybdenum, Nickel, Chromium, Tungsten incl Tin. REEs oxides were discovered in 1788. Nevertheless, annual worldwide REEs production, manufacturing and utilization was far lesser to 5000 metric tons. (REO) prior to 1950s, and as late as 1960s, REE were seldomly utilise in circadian lives of the mankind. In consideration to 1960s, rare earth relevance gradually enlarged to quotient life, and found usefulness in production of television screens, application in the petroleum industry, and computer systems. Therefore, the global REEs yield and utilization have witnessed a noteworthy expansion in latterly decades[4].

III. APPLICATION OF REE

During the past two decennium sudden bloom in demand of commodity stand in need ofrare earth minerals. Earlier than two decimvir a sprinkling people possess mobiles however this very day approximately five billion humans own the same. The usage of rare earth elements displayed in computers has grown multifold as cell phones. Rechargeable batteries have high content of rare earth compounds. Escalation in demand of batteries is steered by portable electronic devices. They are used in fin actuators, in missile guidance, control systems, disk drive motors installed in aircrafts, satellite communications, radar and sonar systems. The glass industry emerged as large user of rare earths required for polishing and to provide colour and special optical qualities to finished products. Digital camera lenses can be up to 50 percent lanthanum[5].

- Military Applications:- Rare earth elements form an important component in any country's advance weapon systems. The Defence Forces uses night-vision goggles, communications equipment, precision-guided weapons, GPS equipment power devices and other defence electronics as shown in Fig.2. REM facilitate as key ingredients for building the roboust and unyielding alloys utilized armoured fighting vehicles with shell that shatter badly upon impact. Substitutes areavailable for these distinct elements in numerous defence applications; nevertheless, substitutes are traditionally not as efficacious and that diminishes military superiority. Various application of REE in the defence industry are illustrated in Fig .3, Fig.4 and Fig.5.

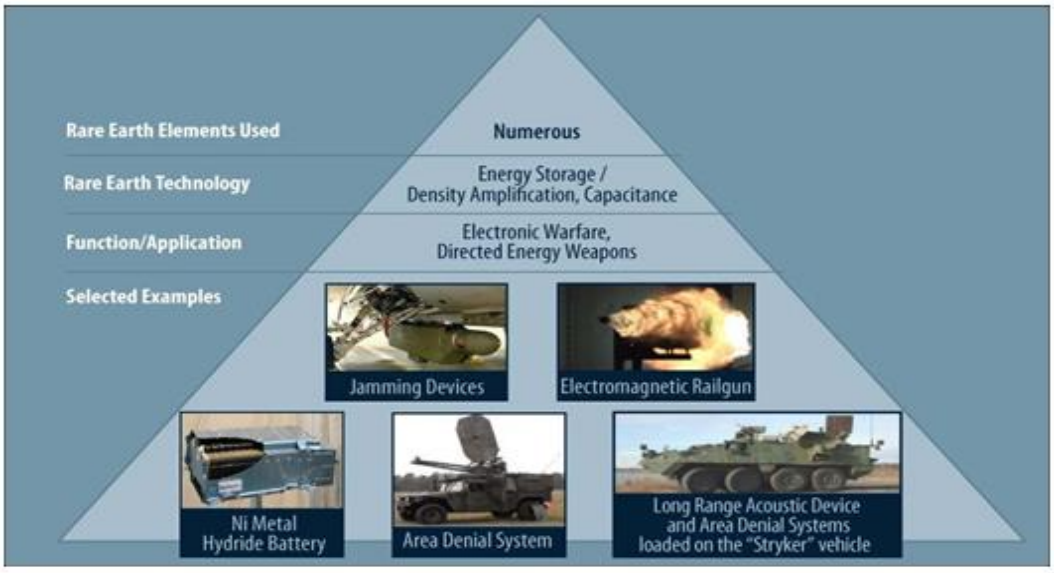

Fig. 2 Rare Earth Elements in Guidance and Control System.

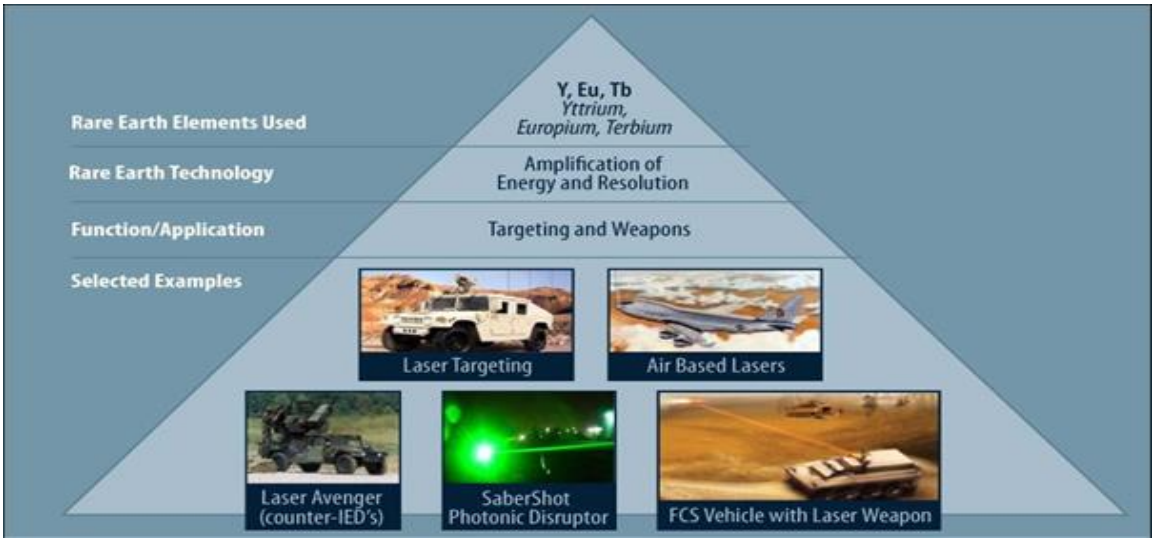

Fig. 3 Rare Earth Elements in Defence EW System.

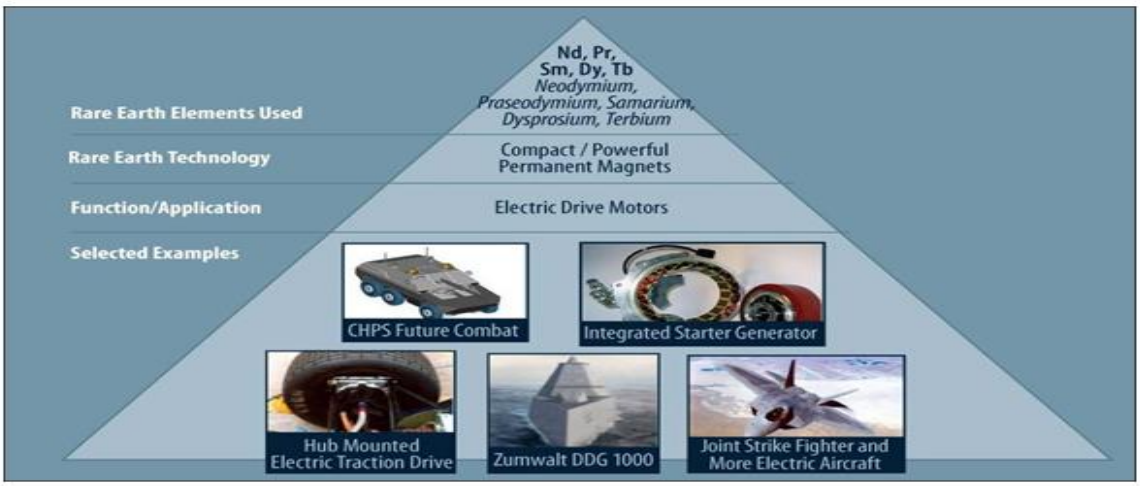

Fig. 4 Rare Earth Elements in Targeting & Weapon

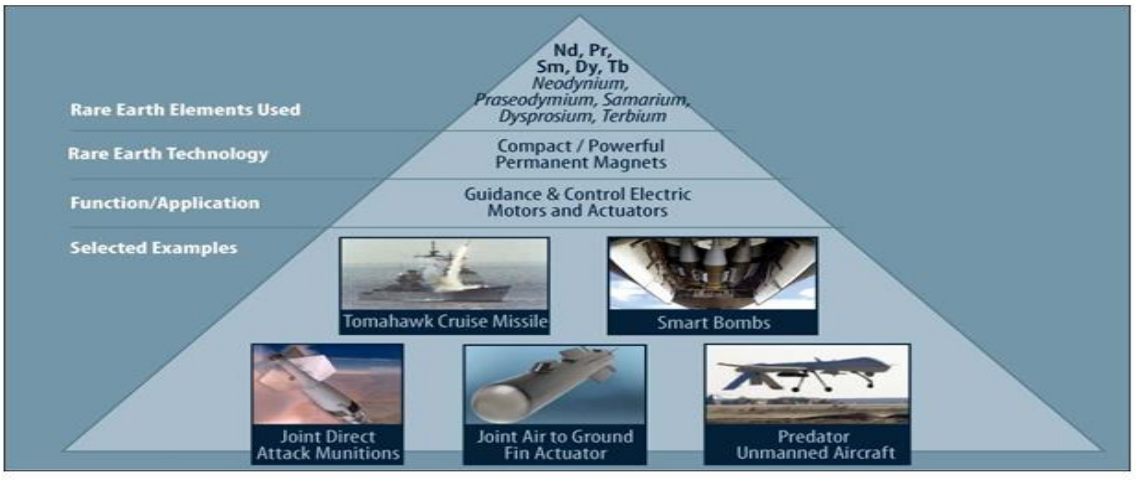

Fig.5 Rare Earth Elements in High Powered Engines.

IV. GLOBAL SCENARIO

REE Reserves. According to the survey conducted by United States Geological Department in 2018 estimated of total REE world reserves in 120 Metric Ton. China accounts for 37% of ibid global reserves, Brazil and Vietnam account of 18% reserves of REE individually. Russia holds REE reserves ores of approx. 10% and is followed by India which has approx 6% of global reserves (stands at fifth fosn). Other African nations to include South and Tanzania Africa have considerable REE reserves. While many countries held REE reserves, but rare earth extraction out of ores produces ammonia and thorium which are toxic and detrimental to environment. China's relatively weak environmental norms, cheap labour and higher subsidies for chemical which are utilised for REE extraction has given china and competitive edge in REE production. The details of global reserves is as given in Table-1.

Table 1 –Global Reserves of Rare Earth in "000 Tone (2018)

Country	Global Reserves	Share in World reserves (%)
China	44000	36.7
Brazil	22000	18.3
Vietnam	22000	18.3
Russia	12000	10.0
India	**6900**	**5.8**
Australia	3300	2.8
Greenland	1500	1.3
USA	1400	1.2
Tanzania	890	0.7
Canada	830	0.7
South Africa	790	0.7
Other countries	4080	3.7
World total	**1,20,000**	**100%**

Significant rare earths minerals ore available in India are sillimanite, monazite, rutile, garnet, zircon and ilmenite commonly known as Beach Sand Minerals (BSM). The total reserves of BSM in India is approx. 35%. Also, India ranks as the seventh country as far as potentials in rare earth reserves are concerned. Beach Minerals Producers experts estimate indicates that REE industry can evolve total employment of Rs 121,000 crore worth and shall also allow earning of Rs 50,000 crore of foreign exchange[9].

Production. Demand for the metals is increasing as renewable energy becomes the distinct choice across the globe. Rare earths which are important in clean and green energy applications and high-tech industries are in spotlight, particularly in electric vehicles and hybrid cars. The rare earth metal productionworldwide in percentage for the year 2020 is as given in Table 2:-

Table-2 –Worldwide Production of REE for the Year 2020

Ser No	**Country**	**% Production**
(a)	China	57.57
(b)	USA	15.63
(c)	Burma	12.34
(d)	Australia	6.99
(e)	Madagascar	3.29
(f)	India	1.23
(g)	Russia	1.11
(h)	Thailand	0.82
(j)	Brazil	0.41
(k)	Vietnam	0.41
(l)	Burundi	0.21

Indian Concern. Thevast developments impacting countries across the globe in field of REE and long-term concern of security which is major concern for India presently. India holds an important position in all countries holding REE reserves and hence has potential to become key supplier of REE. The following issues are a matter of concerns for India:-

- The Indian REE reserves are richer in LREE and are deficient in HREE.

- Exploration conducted by Bureau of Mines and Department of Atomic Mass Energy. Unexplored Reserves needs to be tapped at the earliest to acquire the self reliance.

- Conventional and Non-conventional sources of energy utilisation in three stage nuclear energy pgme of the country necessitates the production of REE in the country.

- A new use of Rare Earth Materials is being discovered every three to five years and pattern of their usage significantly changed in every decade.

- Extraction of REE is a complex process and needs establishment of facilities in critical time domain.

- The concentration of REE in India is 1000 times lower in ppm values than China, making the extraction costlier and thereby increasing the manufacturing cost. Besides this, uranium and thorium tailings (radioactive) are present after rare earth metal mining from beach sand in India which prevents private sector involvement in rare earth mining.

Any further delay in addressing the important issue of REE will impact India adversely and India will miss the opportunity to be a world player in supply of REE .The downstream REE industries are likely to move to Mexico or Canada owing to geographical locations and cost of REE. As China moves to control REE supply chains in Indian Ocean Region, Indian industry will perpetually be dependent on Chinese supplies and NATO countries are already considering non-Chinese supply chains. Delay in decision making will cause these counties to freeze supply chain outside India. Moreover once the electric vehicle manufacturing establishes in China it will not relocate due to economic factors and delay will give Chinese companies time to ring fence metallurgical research with global patents[10].

V. RESEARCH & DEVELOPMENT

Extensive R & D by Govt agencies & Private entities are underway to get immense benefits of rare earth applications. Few current trends are as follows:-

- Established on complete analysis, we can anticipate that there is likely hood of growing importance of environmental studies and analysis in field of prophesy *REE research*, development and implementation. While the broadening of *research* on REEs was modelled as exponential process, the market is segmented by Elements (Cerium, Neodymium, Lanthanum, Dysprosium, Terbium, Yttrium, Scandium), Application wise (Catalysts, Ceramics, Phosphors, Glass and Polishing, Metallurgy, Magnets, and Other Applications), and Geography dominant (Asia-Pacific, North America, Europe, South America, and Middle-East and Africa). Even research and development is thus subjective and Elements/ Application/ Geography dominant.

- The current focus of Indian Research and Development is based on scope that, Rare earth elements usage in communications, telescope lenses, studio lighting, and computer hard drives to enable them to be smaller and more efficient. They are extensively utilised in screens and displays as they can produce different colors. REE display high electrical conductivity, and they naturally occur together in minerals. Rare earth magnets are the strongest magnets available today having phenomenal residual magnetism. Hence Semiconductor Complex of India & BEL, both Govt PSUs are depending on R & D in these specified areas as they are extensively consumer oriented with moderate cost and appreciable durability.

Challenges of REE Usage. The under mentioned challenges are encountered during exploitation, processing and producing finished products from Rare Earth Elements.

Challenges in Procuring and Constraint: Rare Earths. In Indian context the challenges in procurement and processing are multiple due to following facts and figures:-

- The directives of National Green Tribunal and Pollution Control Boards restrict exploration of rare earths. Also restrains of Non

Govt Organisations (NGOs) to stall industrialisation is a challenge.

- The agencies involved in procurement restricted to very few namely National Mineral Development Corporation and IREL (India). The private involvement is still barred on the pretext of security and critical information sharing.

- The Foreign Direct Investment (FDI) required for accelerating the processing and producing end products are still in pipe line. The FDI will ensure time bound availability of technology, plant and machineries and required testing infrastructures.

- Institutional funding within India is not forthcoming since clarity on Govt policies and Transfer of Technology (ToT) are yet to be formalised.

Challenges of REE Usage. Few common challenges in use of REEs are brought out as under:-

- Ores of rare-earth contain less than 10 percent REO (Rare Earth Oxides) and needs to be upgraded to nearly sixty percent to be processed thereafter. They are first grinded to powder thereafter separated out from the other metals constituted in the ore body owing to different standard processes that including magnetic and/ or electrostatic separation followed by flotation.

- In the conventional process, minerals containing many rare earth elements are first dissolved in concentrated alkalis or acids. This is by far the simplest step; further segregation of Rare earth elements is few of the most difficult problems in inorganic chemistry.

- Rare earth elements exhibit a huge range of applications in metallurgy, fuel cells, the colouring of different type of glass and ceramics, and the production of magnets, however their separation is difficult, leading to high prices. A dedicated strategic investment for ensuring security of REE assets should be initiated which operates under ambit of specialised government financial institution. The proposed organisation is necessitated to work with other existing financial institute with

specific operation in diverse field of REE. Strategic fund should be created for realising ambition and aspiration of India becoming a front runner in manufacturing especially electronic goods and products, eg. electric vehicles (national objective to achieve it by 2030) and other Atma Nirbhar initiatives. This shall greatly reduce dependence on other countries for importing electronic products and can be easily achieved through Public Private Enterprises. Thus, it shall bolster overall security and strategic aims of the country[3].

Extensive R & D by Govt agencies & Private entities are underway to get immense benefits of rare earth benefits and applications. Few current trends are as follows:-

- Based on the studies supplemented with analysis forecast of requirement of proportion of REM research will increase to 60% by 2023 from 52% at 2020. While the growth of research on REEs was modeled as an exponential process.

- The market is segmented by Elements (Cerium, Neodymium, Lanthanum, Dysprosium, Terbium, Yttrium, Scandium, application wise (Catalysts, Ceramics, Phosphors, Glass and Polishing, Metallurgy, Magnets, and Other Applications), and geography dominant (Asia-Pacific, North America, Europe, South America, and Middle-East and Africa). Hence R & D development is subjective to Elements/ Application/ Geography dominant as the case may be.

- The current focus of Indian R & D is based on scope that, rare earth elements usage in loudspeakers, telescope lenses, studio lighting, and computer hard drives to enable them to be smaller, cheaper and more efficient. They are used in screens and displays as they can produce different colors. Rare earth elements exhibit have high electrical conductivity, and they naturally occur together in minerals.

Rare earth elements forms strongest magnets available today. Hence Semiconductor Complex of India & BEL both Govt PSUs are depending on R&D on these specified areas since extensive consumer oriented.

CONCLUSION

Over the next decade, global demand for autos, consumer electronics, energy efficient lighting and catalyst is predicted to skyrocket. Surgical lasers, magnetic resonance imaging and position emission tomography scintillation detectors are projected to be used more frequently as medical technology advances. All of the aforementioned industries rely heavily on rare earth elements Therefore demands will continue to be high. The investment in Rare Earth Elements usage will be a game changer step for Indian context and is necessitated as inescapable requirement Having established the enormous potential of REE towards defence applications, a well chalked out policy and impetus is required at the National level to harness the applicability of these elements in the following military/ defence applications:-

- Night vision devices to include opto-electronic equipment like LRFs etc.
- Precision Guided Weapons and Guidance Systems.
- GPS equipment.
- Development of Composite Body Armour for vehicles and helicopters.
- Collaboration for development of bullet proof human bodyarmour.
- Shape Memory Alloys with their requirement for Army.
- Usage in armour of AFVs for systems and sub-systems. In addition, focused R & D by various establishments viz IREL (india), RCI, Midhani, DMRL, etc is the need of the hour for realization of these elements usage in manufacture of telescope lens, computer hard drives, screens & display systemsetc towards commercial end applications.

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