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Inauguration of ICAMPS 2018

The 3rd International Conference on Advanced Materials and Manufacturing Process (ICAMPS-2018) was organized by the Indian Institute of Metals, Trivandrum Chapter during October 25-27, 2018. The conference was inaugurated by Dr. G. Padmanabham, Director, ARCI, Hyderabad. The presidential address was deliverd by Dr. s. somanath, Director, VSSC, Trivandrum. The Souvenir of the conference was released by Dr. V.K. Dhahwal, Director, IIST, Trivandrum. The keynote lecture was delivered by Dr, C.G. Krishnadhas Nair, Former Chairman, HAL, Bangalore & Founder President, SIATI, Bangalore in the topic “Materials and Manufacturing Processes for Strategic Sector”. Dr. P.V. Venkitakrishnan, Chairman of the Organising Committee, ICAMPS 2018 welcomed all the members. The keynote speaker was introduced by Dr. P. Ramesh Narayanan, Chairman, Technical Committee and vote of thanks was proposed by Dr. S.V.S. Narayana Murty, Convener, ICAMPS 2018.

Editors desk

The editorial committee has great pleasure in informing to its members and readers that the METNEWS is marching successfully into thirty seventh year of its publication. In the present issue we could bring you some special articles on ablative composites in rocket launch vehicles and re-entry vehicles, Thermal management metallic materials, magnesium alloys for bioimplant applications and smart materials. We are grateful to all the contributing authors. We also request the members and readers to contribute articles in their areas of research and expertise.

A Brief Review on the Critical Process Variables Influencing the Functional Performance of Ablative Composites in Rocket Launch Vehicles and Re-Entry Vehicles

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Ablative composites are used for thermal protection in solid rocket motors, liquid engines and re-entry nose caps to protect them from the extremely severe operating conditions of high temperature, pressure and particle impingement. Ablation is a heat and mass transfer process in which a large amount of heat is dissipated in a very short period of time with sacrificial loss of material. The external surface of a re-entry space vehicle experiences high heat flux and temperatures of the order of 2500°C during re-entry into the atmosphere and the internal contour of a rocket motor nozzle has to encounter temperatures above 2000°C during its operation. These composites are processed from carbon-phenolic/silica-phenolic prepregs using a complex processing cycle starting from impregnating the fibres with phenolic resin followed by moulding or winding prepreg tapes over metallic mandrels before polymerization under pressure in Autoclave/Hydroclaves.

Ablative systems are basically designed based on thermal considerations but the structural properties also play a vital role during operation. The critical mechanical properties are compressive strength, compressive modulus and interlaminar shear strength, while thermal conductivity, specific heat, heat of ablation, rate of erosion and thermal diffusivity are the key thermal properties. There are a few key process variables which significantly influence the functional performance of ablatives. Ablative composites like any other composite are synthesized from a reinforcement fibre and a matrix resin. Carbon or Silica fibres woven into fabrics form the most common reinforcement and phenolic resin is the favourite choice for the matrix. Among the various properties of the carbon/silica reinforcement, the breaking strength, carbon/silica content, sodium content etc are the main factors. Breaking strength of the fabric directly contributes to the strength and stiffness properties while carbon/silica content determines the ablation resistance and thermal insulation properties of the composite. Sodium, which is an impurity in the fibre, if present in quantities higher than 1200 ppm can increase the rate of erosion of the composite during the functional regime. On the matrix side, the phenol/formaldehyde ratio, degree of advancement, solids content etc play a significant role. These values are to be kept in optimum limits to ensure good ablative performance.

During processing, impregnation, moulding and curing parameters influence the properties and performance of ablatives. During the impregnation of the fabric with resin, gap between the squeeze rollers determine the amount of resin content in the prepreg which decides the fibre volume fraction which in turn defines most of the properties of the composite. The temperature of dehydration, velocity of the prepreg, residence time in the hot zone, temperature of the hot zone etc are the other major parameters of impregnation. The higher the residence time and the temperatures quicker will be the advancement of the resin in the prepreg from ‘A’ stage (liquid stage) to ‘B’ stage (semi-cured stage). During moulding, layup or tape-winding, the next stage of processing, condition of the prepreg is the important parameter. Chang’s index is the indicator of the advancement of resin in the prepreg. Higher the index, less will be advancement. The prepreg condition is highly sensitive to temperature and humidity. Since the storage is always done at temperatures below 4°C to limit the advancement of the resin to the cured ‘C’ stage before or during processing. The processing area is also to be humidity controlled to have better process control. Contamination-free humidity controlled environment is a pre-requisite for quality products.

During tape-winding, machine parameters like pitch, feed rate, speed etc are to be maintained depending on the product size. Hot air blowers are used to condition the prepreg prior to winding and Liquid nitrogen cooling is employed for cooling larger liners to avoid undue advancement of resin due to hot air. Roller pressure of adequate measure is desirable for good compaction and as-wrapped density.

After moulding, layup or tape winding of the prepreg on a mandrel, the product is subjected to Curing or polymerization where the final density and thermo-mechanical properties are achieved. During Curing, the cure temperature and cure pressure are the critical parameters. These are decided based on the type of the resin system used, the thickness of the product and the density design requirements. While cure temperatures are around 150 to 180°C for phenolic resins, the cure pressure is between 20 and 65 bar for regular ablative liners. Lower pressure can lead to inadequate compaction and lesser densities. Improper cure temperatures can result in incomplete curing leading to lower mechanical and thermal properties. Curing is done under vacuum conditions to enable effective displacement of volatiles evolved during the ploymerisation process. Lack of vacuum can lead to entrapped volatiles in the product leading to delaminations.

After curing the composite, it is machined to get the desired size, shape and configuration. During machining suction systems are used for dust collection as the material removal is in the form of dust and not as chips in the case of metal machining. This suction also acts as a coolant for the Polycrystalline Diamond cutting tools used for ablative machining. The speed, depth of cut and feed rate are to be appropriately chosen to avoid delaminations, ply lift-off and edge peel-offs during machining.

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Metallic Materials for Thermal Management Systems

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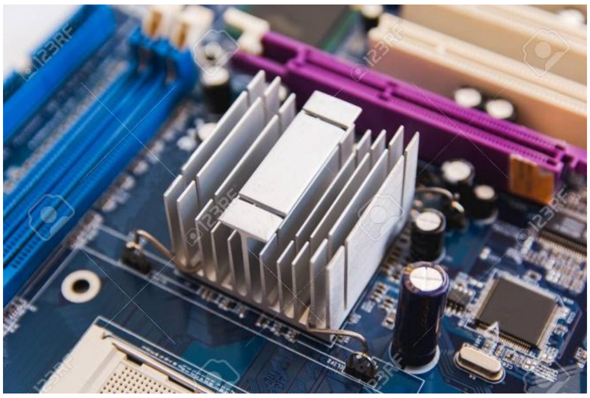
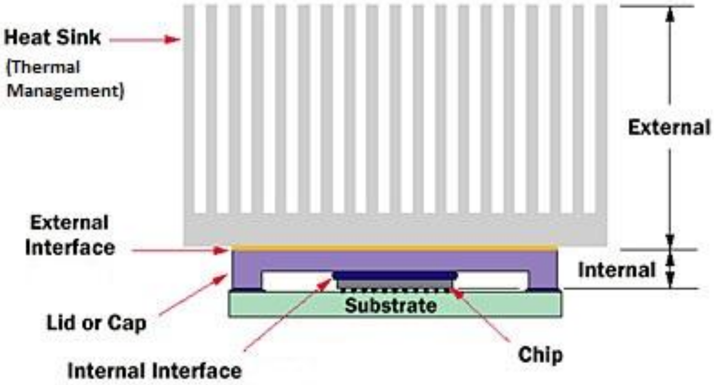
Introduction

The increasing requirement on thermalmanagement materials in microelectronics andsemiconductors drives, the development of advancedmetal matrix composites (MMC) with high thermalconductivity (TC) to effectively dissipate heat andtailorable coefficient of thermal expansion (CTE) to minimize thermal stresses. This is of vitalimportance to enhance the performance, life cycle andreliability of electronic devices.The laws of thermodynamics states that the total sum of energy in an isolated system is constant and when the process is irreversible, entropy must increase. Even though the speed of heat flow and the rate of entropy increases in the system are not determined. But we can easily control the speed of heat flow and rate of entropy increase to certain extent by changing the system size, shape, structure and the materials. Thermal management decisions remain a key part of the automotive electronic control unit (ECU) where the performance of the device is affected by temperature. The useful lifetime of electronic devices can be decreased significantly because of the large thermal stresses.In order to minimize thermal stresses that can cause component or solder failure, packaging materials must have coefficients of thermal expansion (CTEs) matching those of ceramic substrates and semiconductors. A low density is desirable in many applications, including portable systems such as lap-top computers, hand-held telephones, and avionics.





This article provides an overview of advanced composites used in thermal management, including properties, applications, and future trends. The focus is on materials having thermal conductivities at least as high as those of aluminum alloys.

Metal matrix composites as thermal management materials

The key electronic packaging MMCs are AlSiC, Beryllia particle- reinforced beryllium, and carbon fiber-reinforced aluminum. Table I presents properties of these materials. In recent years, a number of new metal metalcomposites have also been developed, including beryllium-aluminum, Invar-silver (Silvar), and Invar-copper (Cuvar). A material consisting of 60% aluminum and 40% silicon iscommercially available for many years has also been used for packaging. This material can be considered as a type of particulate MMC. The most successful of the newer MMCs at this time is

AlSiC, its low density and net-shape fabrication capability,have led to rapidly increasing use of this material. Beryllia particle-reinforced beryllium is also being used in commercial applications, although not as widely as AlSiCbecause of its higher cost. Based on literatures, it is observed that carbon fiber-reinforced aluminum has been used in a limited number of highly specialized applications. Other MMCs with high thermal conductivitiesare made by infiltrating porouscarbon/carbon composites withaluminum or copper.

The major attractions in manufacturing and utilizing MMC are improved strength to weight and stiffness to weight ratios in a low cost light material. MMCs are becoming the most promising materials to fulfill the current and future demands in thermal management. It is generally recommended that the thermal management materials used in electronics packaging should have a low coefficient of thermal expansion values between 4 and $7\times10^{-6}k^{-1}$).

Table 1. Properties of Selected Electronic Packaging Materials

Reinforcement	Matrix	Thermal conductivity(W/mK)	CTE (ppm/K)
	Silicon	150	4.1
	Alumina	20	6.7
	Aluminum	230	23
	Copper	400	17
	Epoxy	1.7	54
	Kovar	17	5.9
Copper	Tungsten	167	6.5
Copper	Molybdenum	184	7
Beryllium	Aluminum	210	13.9
Invar	Silver	153	6.5
Carbon Fiber (K1100)	Epoxy	300	-1.1
Carbon Fiber (K1100)	Copper	400	6.5
Carbon Fiber (K1100)	Aluminum	290	6.5
Discontinuous Carbon Fiber (K1100)	Polymer	20	4-7
Carbon Fiber (K1100)	Carbon	350	-1.0
Silicon Particle	Aluminum	126-160	6.5-13.5
SiC Particle	Aluminum	170-220	6.2-7.3
Beryllia Particle	Beryllium	240	6.16.2-7.3

Aluminum based composites

SiC additions decrease CTE without significantly degrading STC. In addition to useful CTE and STC, Al/SiC also provides a non-hazardous and cheaper solution than the other metal matrix composite.Whenpackaging structure is considered, Al/SiChas approximately three times the material strength and stiffness compared to the traditional Al-metal. AMETEK ismanufacturing AlSiC composites with 68 ± 2% SiC reinforcement by volume to provide a thermal conductivity value of 220W/mK.Although the price is low and they offer near net-shape fabrication versatility, the thermal conductivities of Al/SiC composites are still relatively low (maximum reported to be 250 W/mK)for many thermal applications.

Carbon based composites

The graphite foam based composites could also be a good thermal management material candidate as they show very attractive thermal properties and they are easily machinable. However, these materials are still far from commercialization because of their high cost. As reported in Table 1, the thermal properties of graphite flake composites are anisotropic (shows different thermal properties in xy and z planes). This is because the graphite flakes are oriented on a plane and therefore, shows highest maximum thermal conductivity and lowest CTE in xy-plane. Although anisotropy could be an issue for some applications, it could also be a benefit, allowing designers the ability to make heat preferentially flow in one direction. Therefore, the graphite flakes/metals composites represent another suitable alternative to the commercialized Al/SiC composites, given their superior Thermal conductivity and their cheaper price and ease of machinability.

The practical applications of graphene in thermal management are outlined in an example using thermal phase change materials. It is shown that the use of liquid-phase-exfoliated graphene as filler material in phase change materials is promising for thermal management of high-power battery packs. The described results indicate that graphene has the potential to outperform metal nanoparticles and carbon allotropes as filler in materials for thermal management.

Copper based materials

Copper is considered as one of the most important materials for contemporary thermal management. This is due to its high TC value (w400 W/mK). However, if weight is taken into consideration, the specific thermal conductivity (thermal conductivity divided by specific gravity) of Cu is only w45 W/mK. This makes it unsuitable for automotive applications where weight and cost (Cu is \$6.61/kg versus Al \$2.02/kg, as found in MetalPrices on 11 February 2010) is a significant concern. The use of SiC or diamond particles as reinforcements in copper was shown as quite attractive to meet the increasing demand for high performance thermal management materials. a vapor deposited molybdenum barrier coating onto SiC was used to control the chemical reaction of Cu and SiC. Mo coating was found to be quite effective in controlling interfacial reaction between SiC and Cu and enabled the production of high thermal conductive Cu/SiC composites.

Liquid-metal-infiltration processes for manufacturing thermal management materials

In this approach of casting a preheated preform (a shaped porous assembly of reinforcement elements such as particles, fibers or whiskers) is placed in a preheated die immediately before pouring of the liquid metal. A complete infiltration of the preform can be achieved within a few seconds (before the beginning of solidification) by applying a rapid pressure using a punch. However, the process is reported to be well suited for making metal composites with more than 50% volume fraction of reinforcement component. This makes the infiltration process very suitable for producing thermal management materials for electronics packaging where high volumes (>50%) of reinforcement are needed to increase thermal conductivity and to optimize CTE to match it with semiconductor materials. The Liquid-Metal-Infiltration process is also reported to be the easiest and cheapest method for processing continuously reinforced composites with Al-based matrices.

Table.2. Thermal properties of different C-based composites

Reinforcement	Reinforcement Vol (%)	Metal	Infiltration pressure (bar)	TC (W/mK)	CTE ($10^{-6}K^{-1}$)
90% Graphite flakes +10% carbon fibers	88	Al-12Si	15	xy: 367	z: 24 xy: 3.0
90% Graphite flakes + 10% carbon fibers	88	Ag-3Si	15	xy: 548	z: 21 xy: 3.0
60% Graphite flakes + 40% SiC	88	Al-12Si	15	xy: 368	z: 11 xy: 7.0
63% Graphite flakes + 37% SiC	88	Ag-3Si	15	xy: 360	z: 11 xy: 8.0
Graphite particles	67	Ag-12Si	40	xyz: 350	xyz: 11
Carbon fibers	55	Ag-12Si	40	xy: 330	z: 12 xy: 10
Graphite foam	60	Ag-12Si	40	xy: 387	z: 12 xy: 10

Future Trends

All of the experts predict that packaging density andthe need for continuing improvements in thermal management will continue to increase. Another important trend is the continuing competition to reduce the weight of portable systems. There will be a need for improved materials that have high thermal conductivities and low, tailorable CTEs. In addition, there is a need for low-density materials in many applications. In the near future, the world will see the development of improved and new reinforcements, matrix materials, material systems, and manufacturing processes. Increasing material production volumes and improved processes will reduce costs, making composites more competitive.

Conclusion

The need for improved thermal management materials will continue for the foreseeable future. We are now in a new era that requires using heat, a difficult form of energy to handle without waste and skillfully carrying out heat dissipation and maintenanceWe are in the infancy of an important materials technology that will continue to produce new and improved composite materials and manufacturing processes. The composites are more attractive technically and also reduce costs, resulting in increased use of composites in many thermal-control and electronic packaging applications. In short, we have barely begun to explore the potential for composites throughout the electronics industry. We also want to contribute directly and indirectly to fighting environmental problems including the energy problem and global warming

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Magnesium Alloys - As Potential Biodegradable Implant

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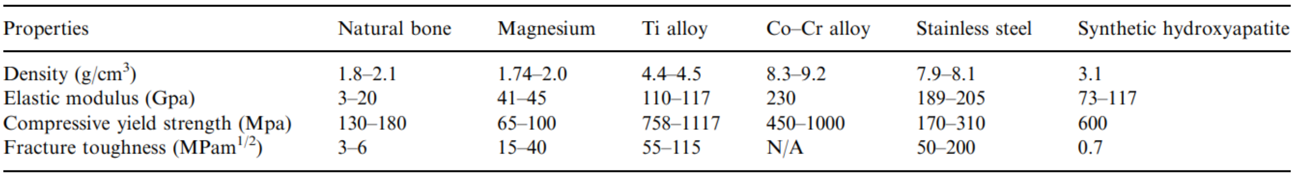
Introduction

Biomaterials could be defined as a natural or synthetic material that is suitable for introduction into living tissue especially as part of a medical device (such as an artificial joint). According to Markets and Markets Survey, biomaterials market is projected to reach USD 149.17 Billion by 2021 from USD 70.90 Billion in 2016, at a CAGR of 16.0%[1]. The growth of the overall market can be attributed to increased funds & grants by government bodies worldwide, the growing implantable devices market, technological advancements, rising number of hip and knee replacement procedures, and high growth in geriatric population coupled with growing incidence of cardiovascular diseases. On the basis of type of material (i.e. Metallic, Ceramic, Polymers and Natural), the metallic biomaterials segment is expected to account for the largest share of the global market, in 2016; owing to their unique properties such as biocompatibility, strength, and resistance to breakage, which makes them suitable for usage in various medical applications such as orthopedic, cardiovascular, wound healing, and dentistry. Some major players in the global biomaterials market include Royal DSM (Netherlands), Biotronik (Germany), Corbion N.V. (Netherlands), Covestro (Germany), Invibio Ltd. (U.K.), Carpenter Technology Corporation (U.S.), Evonik Industries AG (Germany), Berkeley Advanced Biomaterials, Inc. (U.S.), CAM Bioceramics BV (Netherlands), and Celanese Corporation (U.S.)[2].

Table 1: Mechanical properties of natural bone and existing bio implant[2].



Properties	Natural bone	Magnesium	Ti alloy	Co–Cr alloy	Stainless steel	Synthetic hydroxyapatite
Density (g/cm^3)	1.8–2.1	1.74–2.0	4.4–4.5	8.3–9.2	7.9–8.1	3.1
Elastic modulus (Gpa)	3–20	41–45	110–117	230	189–205	73–117
Compressive yield strength (Mpa)	130–180	65–100	758–1117	450–1000	170–310	600
Fracture toughness (MPam$^{1/2}$)	3–6	15–40	55–115	N/A	50–200	0.7

The first biomaterials such as stainless steel, Ti alloys were chosen primarily because they were bionert (i.e. they did not seem to result in any positive nor negative response from the host). Although acceptable for short periods of time, these materials had several drawbacks, including relatively slow healing times and higher rejection rate over long periods. Following this, biocompatible or biodegradable materials were developed, which could speed the rate of healing and only provide functionality for a required time, after which the material would safely degrade in the body. These materials include degradable polymers such as PMMA derivatives and minerals including those based on hydroxyapatite[3]. The advancement of implants from bio inert to biocompatibility/bioabsorbable to those designed to stimulate response/promote growth has thus far been mostly limited to polymers. However, metals are more suitable for load-bearing applications compared with ceramics or polymeric materials due to their combination of high mechanical strength and fracture toughness **[Fig 1]**. Currently approved and commonly used metallic biomaterials include stainless steels, titanium and cobalt–chromium-based alloys**(Table 1)**. A limitation of these current metallic biomaterials is the possible release of toxic metallic ions and/or particles through corrosion or wear processes that lead to inflammatory cascades which reduce biocompatibility and cause tissue loss [4]. Moreover, the elastic moduli of current metallic biomaterials are not well matched with that of natural bone tissue, resulting in stress shielding effects that can lead to reduced stimulation of new bone growth and remodeling which decreases implant stability. Also, current implants being non-degradable, a second surgery is required which increases costs to the health care system and further morbidity to the patient.These difficulties paved way for increased interest in development of Fe, Zn and Mg based alloys[5].

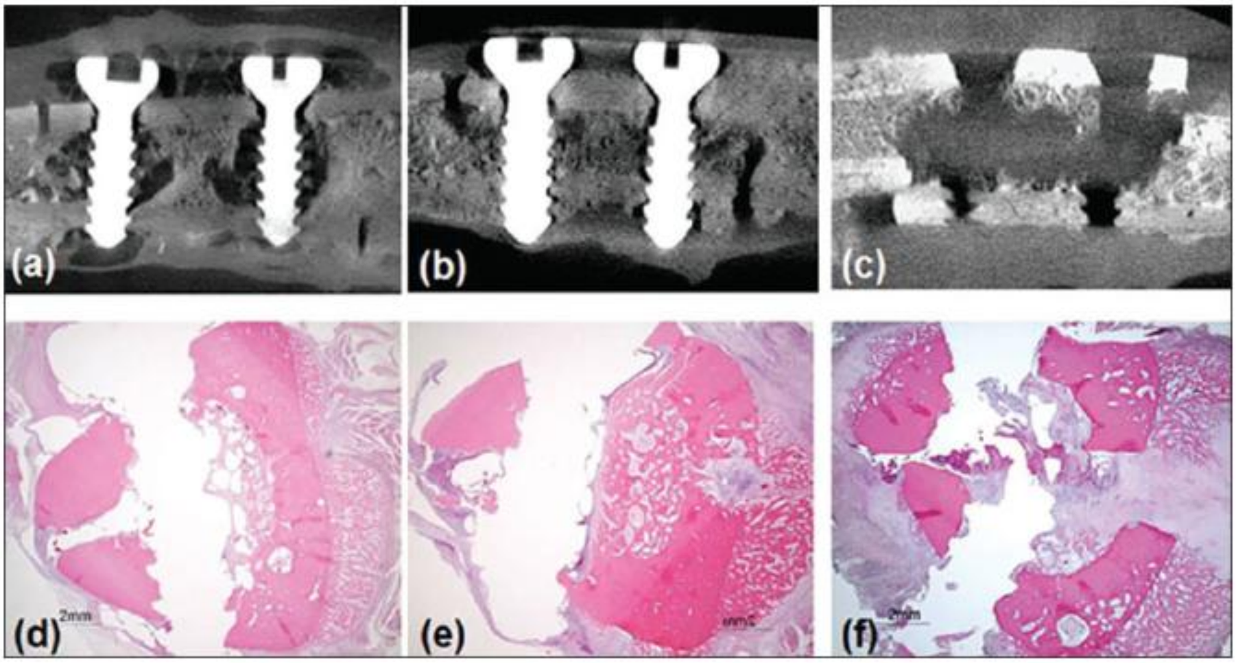


Figure 1: Top: The monolithic magnesium screws (a); the anodized magnesium screw (b), the PLLA screw (c). Bottom: the first two screws (d and e made from magnesium) stayed intact, whereas the PLLA (f) fractures at four weeks after implantation [6].

Among different metallic elements, Mg is mostly preferred as biodegradable metallic material owing to its low density (1.78 g/cm3) and elastic modulus (45 GPa), which are closer to that of the human bone (density 1.8 g/cm^3; elastic modulus: 2–20 GPa). Apart from the mechanical properties, the other main advantage of magnesium is its superior biocompatibility property. Mg is the fourth richest element present in the human body. It weighs about 21–28 g on an average 70 kg human being. The distribution of Mg in the human body is mainly concentrated in the bone (60%-70%) and the remaining in cells and blood vessels. It helps to maintain normal muscle (contraction of muscles), steady heart rhythm, healthy immune system, strong teeth and bones, and transmits nerve impulses (neurological). The blood sugar level, blood pressure, energy metabolism, and protein synthesis in the human body are managed mainly by magnesium. The Mg that gets degraded in the body will be first absorbed by ileum and colon and will be flushed out of the body through the regular functioning of the kidneys. Thus for the above said reasons, Mg is considered as one of the potential candidate as metallic biomaterial.

Magnesium Elektron, a global developer of magnesium technology, and Biotronik, a manufacturer of cardio medical devices, partnered to develop a cardiovascular stent that resorbs over time. This bespoke new technology was launched following a decade long research program in which SynergMag® 410, a magnesium alloy system, was created as the critical backbone to Biotronik’sMagmaris scaffold**[Fig. 2]**. The Magmaris magnesium scaffold was launched in the summer of 2016 by Biotronik, and it is now the world’s first clinically proven magnesium-based resorbable scaffold to obtain a CE mark[7].

Figure 2: The full Magmaris® scaffold created by Biotronik, which uses SynerMag® magnesium alloy as the key structural backbone of the scaffold[7].

Historical Background of magnesium alloys as biodegradable material

Scottish physician Joseph Black was the first to propose Mg as an element in 1755. However, it was Davy in 1808 who isolated metallic Mg for the first time. Corrosion behavior of Mg in aqueous solution and the phenomenon of anodic hydrogen evolution [also known as negative difference effect (NDE)] was initially reported by Beetz in 1866. The utilization of Mg alloys as biodegradable implants was first explored by Huse in 1878, who used Mg wires as a ligature to stop bleeding vessels in human patients. However, high degradation rate shown by Mg alloys remained a major challenge. In 1900, Payr used tubular Mg connectors for the anastomosis of vessels. The connection between the arterial and venous blood vessel ends solidified after eight days of implantation, with a severely thickened intima layer at the anastomosis and returned to normal thickness afterward. Several animal trails as well as human were successfully conducted for intestinal and nerve anastomosis using Mg connectors. During the same period, Payer also successfully used Mg sheets and plates to suture well vascularized parenchymatous organs such as the liver and spleen in humans. In 1907, Lambotte used a Fe wire cerclage and an Mg plate with six steel screws to stabilize the fracture of the lower leg.Extensive subcutaneous gas cavities, local swelling and pain were observed one-day post-surgery, which were caused by the fast corrosion of Mg due to the electrochemical reaction between Mg and Fe. Lambotte learned that to prevent galvanic corrosion of the Mg it should not be implanted with other metals. With such knowledge in mind, he started his investigation for Mg with his assistant Verbrugge[4]. In total, they reported 25 clinical cases using Mg and its alloys (Dow metal AZ63 and Electron Mg–8 wt.% Al) for fracture treatments in the next several years. In these cases, the total resorption of Mg was observed over a period, ranging from three weeks to one year depending on the implant dimension and size and the site of implantation in the body. In 1940, Maier used pins made of spindle-shaped Mg sheets in a humerus fracture, and the patient demonstrated positive functional results in the following 14 years. Troitskii and Tsitrin reported on

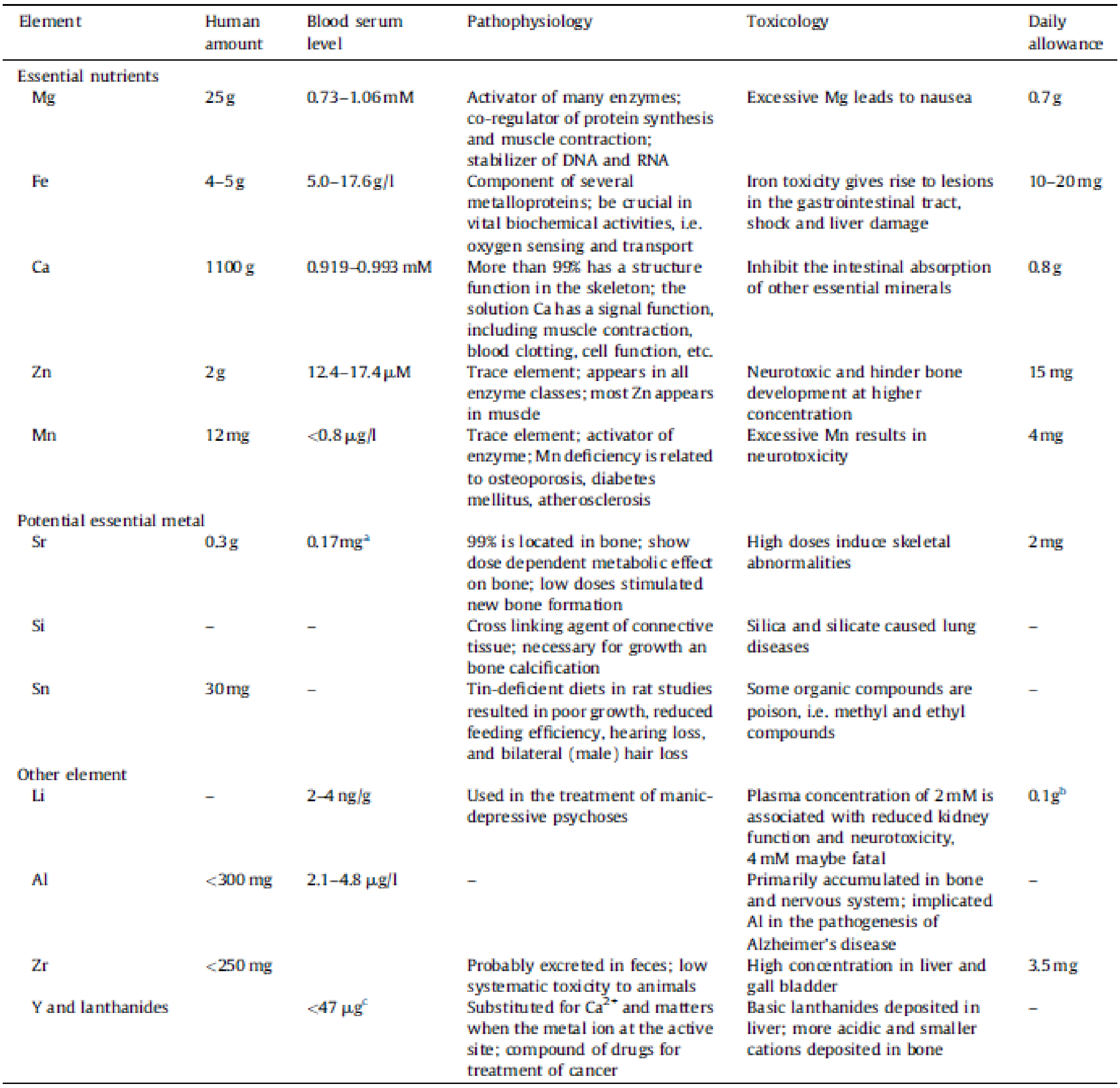
34 cases of pseudarthrosis treated with Mg-Cd alloy plates and screws, which were absorbed completely and stimulated callus bone formations[4].

Although the investigations revealed obvious advantages of Mg alloys, they were abandoned at the time due to their undesirable degradation in addition to the boom of inert stainless steel. In recent times, as Mg alloy technology advances, both the mechanical and corrosion properties have been improved. The idea of degradable metals has been rediscovered and has attracted greater attention for temporary implant materials. Therefore, several key issues for BMs, have been widely investigated over the last decade, including the selection of alloying elements, adjustment for microstructural and mechanical properties, biodegradation mechanisms and their influencing factors, control of degradation rates and ion release behavior, and in vitro and in vivo biocompatibilities of BMs [4].

Role of alloying in Mg alloys

Pure Mg is incapable of providing the necessary mechanical and corrosion properties required for a wide variety of implant applications. Therefore, potential alloying elements need to be carefully considered[8]. Common alloying elements for Mg include Al, Zn, Ca, rare earths (RE), Li, Mn and Zr. Unlike for structural applications, the alloying element present for implant application need to carefully selected. This is because all the elements present in the alloy will eventually end up in the human body and if the amount of alloying element is more than what is required may lead to several health issues and may even cause death. For example, of all the available elements, perhaps the most controversial is Al. Al is the most common alloying addition to structural Mg alloys, allowing a gain in mechanical properties while not increasing the corrosion rate. Several studies have found few if any negative side effects when testing Al containing Mg alloys both in vitro and in vivo. It must be considered though that such studies were typically short term and may have been heavily influenced by the corrosion of the alloy itself, especially in in vitro tests, where platelet adhesion or similar methods are used. In such cases, it is realistically impossible to isolate the effect an increased corrosion rate might have on the perceived toxicity of the investigated alloy. Long term effects of exposure to Al are unclear, and animal studies have found Al toxicity to result in a variety of potential problems, from affecting their productive facilities to inducing dementia, andpotentially leading to Alzheimer's disease[4]. The summary of the pathophysiology and toxicology of Mg and the commonly used alloying elements are provided in **Table2.**

Table 2: The summary of the pathophysiology and toxicology of Mg, Fe and the common used alloying elements[4].

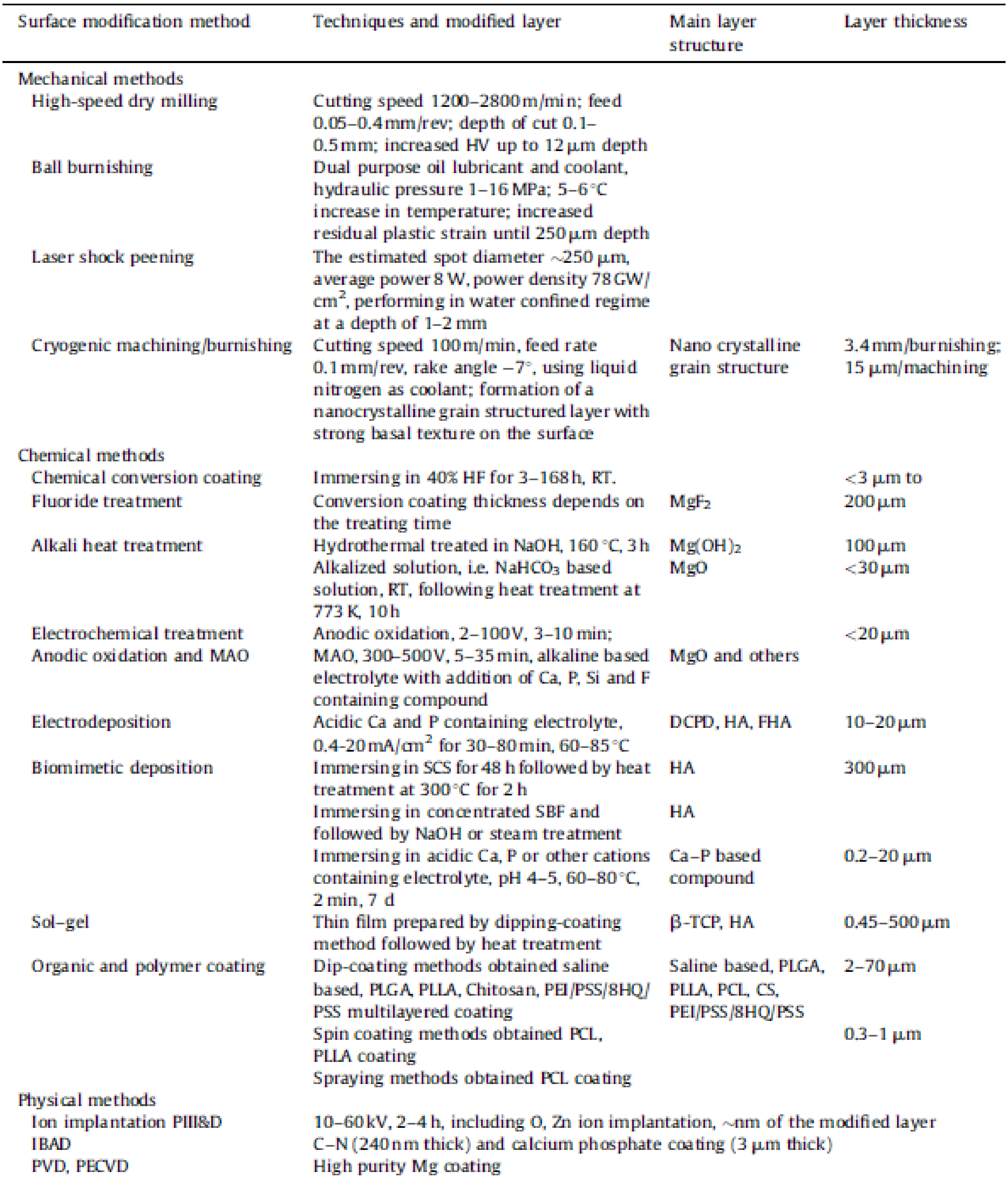


Element	Human amount	Blood serum level	Pathophysiology	Toxicology	Daily allowance
Essential nutrients					
Mg	25 g	0.73–1.06 mM	Activator of many enzymes; co-regulator of protein synthesis and muscle contraction; stabilizer of DNA and RNA	Excessive Mg leads to nausea	0.7 g
Fe	4–5 g	5.0–17.6 g/l	Component of several metalloproteins; be crucial in vital biochemical activities, i.e. oxygen sensing and transport	Iron toxicity gives rise to lesions in the gastrointestinal tract, shock and liver damage	10–20 mg
Ca	1100 g	0.919–0.993 mM	More than 99% has a structure function in the skeleton; the solution Ca has a signal function, including muscle contraction, blood clotting, cell function, etc.	Inhibit the intestinal absorption of other essential minerals	0.8 g
Zn	2 g	12.4–17.4 µM	Trace element; appears in all enzyme classes; most Zn appears in muscle	Neurotoxic and hinder bone development at higher concentration	15 mg
Mn	12 mg	<0.8 µg/l	Trace element; activator of enzyme; Mn deficiency is related to osteoporosis, diabetes mellitus, atherosclerosis	Excessive Mn results in neurotoxicity	4 mg
Potential essential metal					
Sr	0.3 g	0.17 mg[a]	99% is located in bone; show dose dependent metabolic effect on bone; low doses stimulated new bone formation	High doses induce skeletal abnormalities	2 mg
Si	–	–	Cross linking agent of connective tissue; necessary for growth an bone calcification	Silica and silicate caused lung diseases	–
Sn	30 mg	–	Tin-deficient diets in rat studies resulted in poor growth, reduced feeding efficiency, hearing loss, and bilateral (male) hair loss	Some organic compounds are poison, i.e. methyl and ethyl compounds	–
Other element					
Li	–	2–4 ng/g	Used in the treatment of manic-depressive psychoses	Plasma concentration of 2 mM is associated with reduced kidney function and neurotoxicity, 4 mM maybe fatal	0.1 g[b]
Al	<300 mg	2.1–4.8 µg/l	–	Primarily accumulated in bone and nervous system; implicated Al in the pathogenesis of Alzheimer's disease	–
Zr	<250 mg		Probably excreted in feces; low systematic toxicity to animals	High concentration in liver and gall bladder	3.5 mg
Y and lanthanides		<47 µg[c]	Substituted for Ca^{2+} and matters when the metal ion at the active site; compound of drugs for treatment of cancer	Basic lanthanides deposited in liver; more acidic and smaller cations deposited in bone	–

Importance of Mg alloy coating

An area that has recently received (in the past 2 years) the most attention in the Mg biomedical field is the study of coatings or surface modification to slow the degradation rates of various Mg alloys. Coatings for biomaterials, especially biodegradable Mg, have the same requirements as the base materials themselves of being biocompatible and fully degradable. The latter point is particularly salient for understanding what occurs over the implant life cycle. In the case of Mg, coatings themselves cannot be perfect barriers to corrosion (which would be the goal of a coating system on a structural material). To allow an Mg implant to biodegrade, the coatings must, at some stage, cease to be a corrosion barrier, although they may be required to provide an effective method to reduce the initial corrosion rate of the bare metal so the surrounding bone tissue (in the case of orthopedics) may start to form. Ideally, the coating would itself degrade gradually, helping to control the overall corrosion process while leaving no harmful traces. This also presents certain, if not infinite, opportunities to functionalize coatings in order to assist in bio acceptance or minimize adverse surgical aspects. There are a large number of possible coating technologies for Mg biomaterials, including anodization, metal–metal coatings, plasma spray, chemical vapour deposition, pulsed laser deposition, ion beam assisted deposition, solution coatings, calcium phosphate (CaP) deposition achieved by various means and the well-known methods of electro-deposition and conversion coating[9,10]. Summary of different surface modification techniques for biomedical Mg alloys are provided in **Table 3**.

Table 3: Summary of different surface modification techniques for biomedical Mg alloys[4].



Surface modification method	Techniques and modified layer	Main layer structure	Layer thickness
Mechanical methods			
High-speed dry milling	Cutting speed 1200–2800 m/min; feed 0.05–0.4 mm/rev; depth of cut 0.1–0.5 mm; increased HV up to 12 µm depth		
Ball burnishing	Dual purpose oil lubricant and coolant, hydraulic pressure 1–16 MPa; 5–6 °C increase in temperature; increased residual plastic strain until 250 µm depth		
Laser shock peening	The estimated spot diameter ~250 µm, average power 8 W, power density 78 GW/cm^2, performing in water confined regime at a depth of 1–2 mm		
Cryogenic machining/burnishing	Cutting speed 100 m/min, feed rate 0.1 mm/rev, rake angle −7°, using liquid nitrogen as coolant; formation of a nanocrystalline grain structured layer with strong basal texture on the surface	Nano crystalline grain structure	3.4 mm/burnishing; 15 µm/machining
Chemical methods			
Chemical conversion coating	Immersing in 40% HF for 3–168 h, RT.		<3 µm to
Fluoride treatment	Conversion coating thickness depends on the treating time	MgF_2	200 µm
Alkali heat treatment	Hydrothermal treated in NaOH, 160 °C, 3 h	$Mg(OH)_2$	100 µm
	Alkalized solution, i.e. $NaHCO_3$ based solution, RT, following heat treatment at 773 K, 10 h	MgO	<30 µm
Electrochemical treatment	Anodic oxidation, 2–100 V, 3–10 min;		<20 µm
Anodic oxidation and MAO	MAO, 300–500 V, 5–35 min, alkaline based electrolyte with addition of Ca, P, Si and F containing compound	MgO and others	
Electrodeposition	Acidic Ca and P containing electrolyte, 0.4-20 mA/cm^2 for 30–80 min, 60–85 °C	DCPD, HA, FHA	10–20 µm
Biomimetic deposition	Immersing in SCS for 48 h followed by heat treatment at 300 °C for 2 h	HA	300 µm
	Immersing in concentrated SBF and followed by NaOH or steam treatment	HA	
	Immersing in acidic Ca, P or other cations containing electrolyte, pH 4–5, 60–80 °C, 2 min, 7 d	Ca–P based compound	0.2–20 µm
Sol–gel	Thin film prepared by dipping-coating method followed by heat treatment	β-TCP, HA	0.45–500 µm
Organic and polymer coating	Dip-coating methods obtained saline based, PLGA, PLLA, Chitosan, PEI/PSS/8HQ/PSS multilayered coating	Saline based, PLGA, PLLA, PCL, CS, PEI/PSS/8HQ/PSS	2–70 µm
	Spin coating methods obtained PCL, PLLA coating		0.3–1 µm
	Spraying methods obtained PCL coating		
Physical methods			
Ion implantation PIII&D	10–60 kV, 2–4 h, including O, Zn ion implantation, ~nm of the modified layer		
IBAD	C–N (240 nm thick) and calcium phosphate coating (3 µm thick)		
PVD, PECVD	High purity Mg coating		

Conclusions

Bioresorbable/biodegradable composites and ceramic implants are of growing interest because of their ability to provide a necessary mechanical function for the tissue reconstruction process after the designated function in the body. These bioresorbable materials should degrade at a tolerable range for the body and an optimized degradation rate is required based on the function that the material serves in the body. There is not enough human in vivo data to validate the biodegradability of bioresorbable materials. This inhibits the valorization of the materials for marketing purposes. There are many challenges, such as faster than expected degeneration of the mechanical properties of Mg-based alloys during the tissue remodeling process. Surface coatings and modifications are suggested as an alternative to achieve the extended mechanical integrity of these materials. More research has to be focused on materials such as Mg-based and Fe-based alloys to determine their mechanical and degradation kinetics. The biosafety of the degrading material should be ensured with the host tissue and implant interface.

Magnesium alloys are proven to be an advantageous alternative to other bioresorbable materials, suitable for use in many different applications. Magnesium promotes new bone growth, and it does not take on water, which would cause a loss in its integral shape during degradation. The success of magnesium in the medical device sector so far has led to it being developed for a number of different applications. It also shows great promise for use in the pharmaceutical sector as a drug-delivery device.

Magnesium Elektron has successfully produced magnesium alloys for commercial applications. Its magnesium alloy product, SynerMag, which has already been used successfully as a platform material in the healthcare sector, can be designed to resorb at different rates to suit individual requirements.

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Smart materials – A Glimpse

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Intelligent or responsive materials are the links towards the process of evolution of civilizations as the ages advance from Stone Age to current silicon age. The inspiration of these systems originates from Mother Nature where the vivid depiction of smart and intelligent mechanisms exists. These smart materials possess the capability to sense and respond to external stimuli / environmental changes. Numerous practical applications of such smarts systems were developed taking inspiration from the natural intelligent systems. This includes the stimuli responsive materials used in robotics, medical, mechanical, robotics and aerospace technologies. Piezoelectric materials, quantum tunneling composites, magnetostrictive materials, light responsive materials, smart inorganic polymers, halochromic materials, chromogenic materials, photochromic materials, ferrofluids, photomechanical materials, dielectrics, thermoelectric materials and shape memory materials, etc., are the prominent terms associated with smart materials based on the definition.

The research works on such smart materials traverse either of the three paths as mentioned below, for uses in actuators, microphones, sensors etc.

a. Material synthesis with atomic / molecular level changes
    - electronic industry uses this concept by doping of micro/nano materials

b. Embedding of smart systems in conventional structures
    - Mechanical / aerospace industry uses this approach for structural health monitoring devices

c. Blending of individual smart components to form composite materials
    - Nanocomposite systems used for high precision space applications

The evolved definition of smart materials can be stated as the materials that can change the behaviour physically or morphologically corresponding to specific environmental stimuli such as heat, magnetism, electricity, moisture etc.

The camouflaging mechanism of change in body colour of chameleon, zebrafish and squid (as depicted in Figure 1 (a) &(b) are few examples of natural smart stimuli responsive systems that inspires the researchers and materials scientists across the globe. The chameleon achieves the body colour change by dispensing the colour pigments in its body based on various factors affected by the environment (body temperature, mood etc.). The squid has color-changing cells with a central sac holding granules of pigment encapsulated with muscles, contraction of which sprays the pigment/ink granules on hostile environments.

The most commonly found 'touch me not' plant also depicts smart stimuli responsive mechanism by closing the leaves in response to touch. Chemicals such as potassium ions are released at certain regions of the plant body resulting in initiating flow or diffusion of electrolyte towards inside or out of cells resulting in loss of cell pressure causing closing of leaves. The transmittance of this stimuli to neighboring leaves a series of closure of leave can be observed (Figure 2 shows the smart response of *mimosa pudica* – the touch-me-not plant).

Figure 1 Natural smart systems; (a)Camouflage of chameleon; (b) Squid spraying ink to escape from predators;

Figure 2 Nature's demonstration of stimuli response; (a) touch me not plant leaf in regular open configuration; (b) Leaves close in response to touch (courtesy: Shape memory materials, Taylor & Francis Ltd, 2018)

Similar systems are adopted in various daily use structures across different engineering fields. The sattelite antennas are exposed to extreme temperature changes resulting in dimensional variations and its related issues. It is inevitable that these materials should have very minimal variations in the geometry / dimensions for its best performance. Smart material if used in such an antenna would sense the change in dimensions, judge the correction requirements and autonomously bring the structure to its best performance. Sensing, actuating and controlling capabilities can be intrinsically built into the microstructure of such materials to make a judgment and react to the changes in ambient environment conditions.

Materials those respond to various stimuli are studied across past few decades and are in use in various systems in engineering. This includes piezoelectric materials, quantum tunneling composites, electrostrictive / magnetostrictive materials, color changing materials, shape memory materials etc.

Shape memory materials

Materials those change the shape towards a specific stimulus memorizing the original shape from a trained temporary shape are termed as Shape Memory Materials (SMM) and the phenomena is called Shape memory effect (SME). The domain of shape memory can be sub-categorised into Shape Memory Alloys (SMA), Polymers (SMP), Hybrids (SMH), Ceramics (SMC) and Gels (SMG). Combinations of these with reinforcement materials to enhance specific properties can form composite materials generally termed as Shape Memory composites. These distinctive behaviors make them useful in various engineering and scientific applications, including textile, deployable structures, shape morphing, cardiovascular surgery, and many other fields.

Among the SMM mentioned, the demand for lighter and easy synthesizable materials led to increased researches on shape memory polymers. **They possess the advantages like capability to respond to different stimuli,** (temperature change, electric or magnetic field, light source, presence of chemical or moisture etc), can exhibit elastic deformations, available at lower cost, possess lower density, can have tunable actuation temperatures, easy to synthesize / process, has potential biocompatibility and biodegradability properties. The macro and micro properties of such shape memory polymer composites are studied across decades and current focus is on polymeric resin matrices with nano-sized filler materials.

Polymeric shape memory materials with organic / inorganic fillers of nanoscale (between 10 and 100 nm in at least one dimension), distributed homogeneously across the matrix and are synthesized by physical blending or chemical polymerization methods are termed as Shape memory polymer nanocomposites (SMPC). Material properties are enhanced by the synergistic combination of one or more kind of nanofillers and polymer matrix from application point of view. These nano-fillers used are specific to enhance the properties of the SMPC for the final application, and this includes carbon black (CB), carbon nanotubes (CNT), carbon nanofibers (CNF), graphenes, SiC, Ni, Fe_3O_4, clay, etc.

Applications of SMPC includes but not limited to heat shrinkable polymer tubing, films, safety tags, self-deploying chair, surgical tools and products, cardiovascular stents, orthopedics, endoscopic surgery, orthodontics, kidney dialysis, photodynamic light therapy, aneurysm therapy or neuro-prosthetics, drug delivery system, smart surgical sutures, and laser-activated SMP microactuator to remove a clot in a blood vessel, artificial muscles research, sutures in cryo-surgery, remotely deployable clinical devices implanted in the human body, textiles, automobile actuators and self-healing systems etc.

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Member News

Sl No.	Name	Achievements
1.	Dr. S.V.S. Narayana Murty VSSC	Received "Metallurgist of the Year-2018" under 'Non-Ferrous' category by the Ministry of Steel, Government of India. The award carries a cash prize of Rs.1,25,000/- and a scroll of honor. The award was given for his contributions to the development, processing and characterization of aerospace materials for launch vehicle applications. The award was presented by Secretary, Department of Steel, Govt. of India during the National Metallurgists day on 14th November 2018 at Kolkata.
2.	Dr. Bhoje E Gowd CSIR-NIIST	Received Professor Kaushal Kishore Memorial Award of the Society for Polymer Science, India during SPSI-MACRO 2018 at IISER, Pune on December 19, 2018. The award recognizes young outstanding polymer scientists of our country who have made important research contributions and have demonstrated the potential to become global leaders in their chosen fields of research. The award carries a cash prize of Rs. 1,00,000/- along with a citation
3.	Dr. M.T. Sebastian CSIR-NIIST (Rtd)	Received Kikuo Wakino Memorial Award. The award is instituted by Murata Manufacturing Co Ltd. in honor of Dr. Kikuo Wakino who is considered as a Father of High Q dielectric materials. The award carries ~€1000 Acted as a Lead Editor for the special issue on Electromagnetic Interference Shielding Materials for the Journal of Electronic Materials, Springer USA Received ourstanding reviewer award by the American Ceramic Society for its three Journals and also publons reviewer award
4.	Dr. Swapankumar Ghosh CSIR-NIIST (Rtd)	Received VIRA 2018 (Venus International Research Award) Life time Achievement Award in Nanotechnology under Engineering discipline in June 2018
5.	Dr. T.P.D. Rajan CSIR-NIIST	Received "Award for Excellence in Corrosion Science and Technology" conferred by NACE International, Mumbai (2018) towards the contribution in the corrosion studies of metallic composites and functionally graded materials and for the development of multifunctional and smart anticorrosive coatings.
6.	Dr. P. Ramesh Narayanan VSSC	Become IIM Fellow during 2018
7.	Dr. A. Srinivasan CSIR-NIIST	Received Best Reviewer Award for IIM Transactions for the year 2018 and received the certificate during NMD-ATM 2018 at Kolkata
8.	Mr. Paul Murugan VSSC	Received VSSC-SBF best idea award on the year 2018 The award carries Rs. 5000, citation and a memento

9.	Dr. J. Mary Gladis IIST	Received following best oral/ poster awards 1. Ionic Shield for Polysulfides Towards High-Performance Lithium-Sulfur Battery, Haritha H. and Mary Gladis J., Indian Institute of Metals Trivandrum Chapter - Research Scholars Symposium on Materials Science and Engineering, CSIR-NIIST Trivandrum, 6 April 2018 (Oral presentation - Best Paper Award) 2. Bifunctional Separator as a highly efficient polysulfide mediator for Li-S batteries, Haritha H. and Mary Gladis J., International Conference on Advanced Materials and Manufacturing Processes for Strategic Sectors (ICAMPS 2018), Thiruvananthapuram, 25-27 October 2018 (Poster presentation - Best Poster Award) 3. Iron, Nitrogen and Oxygen Co-Doped Hierarchically Porous Carbon for Long Cycle Life Lithium Sulphur Battery” in International Conference on Chemistry and Physics of Materials (ICCPM 2018), Organized by St. Thomas College, Thrissur on December 19 –21, 2018 (oral presentation- Best paper award). 4. Polyelectrolyte Decorated Separator to Prolong Lithium-Sulfur battery life, Haritha H. Sreekala K. and Mary Gladis J.**,** National Conference on Emerging Trends in Science, Technology & Application of Electron Microscope (STAEM 2018), CSIR-NIIST Trivandrum, 19-21 December 2018 (Oral presentation - Best Presentation Award) 5. Modified Separator Performing Dual Functions to Inhibit the Shuttle of Polysulfides for Lithium-Sulfur Batteries Haritha H. Sreekala K. and Mary Gladis J., Twelfth International Symposium on Advances in Electrochemical Science and Technology (iSAEST-12), Organized by Society for Advancement of Electrochemical Science and Technology (SAEST), at Chennai January 8-10, [Oral presentation - Best PaperAward(I prize)]
10.	Dr. K. Jayasankar CSIR-NIIST	His paper titled ‘Environmental Benign Process for Production of Molybdenum Metal from Sulphide Based Minerals’ published in the Series ‘D’ Journal of IEI, Vol. 98, Issue 2 has been selected for the Metallurgical & Materials Engineering Division Prize and received the medal and certificate during the Prize Distribution Ceremony of the 33rd Indian Engineering Congress at Udaipur, Rajasthan on December 21, 2018
11.	Dr. V. Anil Kumar VSSC	Received Best Poster Award in International Conference on Advanced Materials and Processes for Strategic Sectors (ICAMPS-2018), Trivandrum held during 24th-26th October-2018 for the paper titled “Deformation Behavior and Active Micro- mechanisms in a Third generation γ-TiAl alloy” Co Authors: Bhavanish Kumar Singh, R.K.Gupta, Anand Kanjarla Book Chapter Published with Arjun Sukumaran, R.K.Gupta, P.V. Venkitakrishnan in *Encyclopedia of Aluminum*

		alloys, 1st Edition, 2018
12.	Mr. Agilan M VSSC	Received following best paper and poster awards: 1.Panthaki Memorial Award-2018 for best technical paper in International Welding Congress, award given by Indian Institute of welding during National Welding Seminar-2018 (NWS 2018), Kochi for the paper titled "Mechanical properties and microstructural evolution in Al-Cu-Li 2195 alloy GTA and FSW welds" with co authors: G.Phanikumar, D.Sivakumar 2.Best Poster Award in International Conference on Advanced Materials and Manufacturing Processes for Strategic Sectors (ICAMPS 2018), October 25-27, 2018, Trivandrum for the poster entitled "Effect of Friction Stir Welding Parameters on Mechanical Properties of 2195 Al-Cu-Li alloy Welds" Co-authored by G.Phanikumar, D.Sivakumar. 3.Best Paper Award: IIM Research Scholars Symposium, April 6th 2018, CSIR-NIIST, Trivandrum, Paper titled: Weld Solidification Cracking Behaviour of AA2195 Al–Cu–Li alloy, Co-Authors: G.Phanikumar, D.Sivakumar
13.	Dr.Sushant K. Manwatkar VSSC	Received Best Poster Award in International Conference on Advanced Materials and Manufacturing Processes for Strategic Sectors (ICAMPS 2018), October 25-27, 2018, Trivandrum for the Poster titled "Failure analysis of MDN59 steel poppet guide used in pressurization line of carbon overwrapped pressurized tank". The Co authors are S.V.S. Narayana Murty, P. Ramesh Narayanan
14.	Ms.Ulaeto, Sarah Bill CSIR-NIIST	Received Best poster award on 'Bionanocomposite Coatings Tailored for Corrosion Protection of Aluminium Alloys', Co authored by Anju V. Nair, Jerin K. Pancrecious, T. P. D. Rajan, B. C. Pai. during ICAMPS, Oct. 25-27, 2018, Trivandrum, Kerala, India
15.	Dr. S. Chenna Krishna, VSSC	Received Best Poster Award for poster entitled "Microstructural Evolution of Inconel 718 during Pancake Forging" Co-authored by N.K. Karthick, Ashok Kumar, Abhay K. Jha, Bhanu Pant, R.M. Cherian at ICAMPS 2018 held during Oct 25-27 2018, Trivandrum
16.	Mr. P. Manikandan, VSSC	Received Best Poster Award for poster entitled "Fracture Toughness of Ti-15V-3Cr-3Sn-3Al Titanium Alloy in Different Heat Treated Conditions" Co-authored by K. Naresh Kumar,G. Sudarshan Rao, Abhay K Jha, P.Ramesh Narayanan, Bhanu Pant, Roy M Cherian at ICAMPS 2018 held during Oct 25-27 2018, Trivandrum
17.	Dr. P.V Subha CSIR-NIIST	Received best poster award for the poster tiltled "Ultrafast sorption performance of wet chemically derived Lithium silicates" at International Conference on Carbon Capture and

		Its Utilization held in CSIR-NCL, Pune, India , 14-15th December 2018 Name of Co Authors: V. Visakh, Minju Thomas, R Achu, Balagopal N. Nair, U. S. Hareesh
18.	Mr. Dineshraj S VSSC	Received Best Poster Award for poster entitled “Analysis on Defect Healing Ability of Hot Isostatic Pressing (HIPing) in Aerospace Cast Components.” Co-authored by Arun Dwivedi, Alok Agarwal, Mayukh Acharya, S. Giri Kumar, Madhukar R Marur, Govind, Bhanu Pant Roy M Cherian at ICAMPS 2018 held during Oct 25-27 2018, Trivandrum
19.	Mr. Pravin Muneshwar VSSC	Revived best paper award along with a NIT trichy team for the paper entitled “Studies on Friction welded Titanium alloy and Stainless-Steel rods for Space Applications” at International Welding Symposium (IWS-2K18) held during Nov 27-29th 2018 at Mumbai
20.	Dr. Venkateswaran C VSSC	Secured First Position in the Quiz conducted as part of Continuing Education Programme (CEP) on Advanced Magnetic Materials: Processing and Characterization held at DMRL, Hyderabad, August 2018
21.	Mr.Rejith R G CSIR-NIIST	Best Poster Presentation at National Conference on Emerging Trends in Science, Technology & Application of Electron Microscopy (STAEM-2018) jointly organized by CSIR-NIIST and Academy of Microscope Science and Technology (AMST), India on December 19 – 21, 2018
22.	Dr. Salil Kanj Jalan VSSC	• Won First Prize in User's Meet for giving best suggestions to improve IT facilities in the VSSC during Digital India Week-2018 held from 31st July to 3rd August 2018. • Selected as the best Library user in the National Library Week-2018 of VSSC • Won second prize in Elocution and third prize in Essay Writing during the Hindi month-2018 organized by VSSC
23.	Dr. S. Christopher Solomon, VSSC	Obtained his PhD degree from IISc, Bangalore on June 2018. Topic: Estimation and control of friction in bulk plastic deformation