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Review on mechanical & biological property of silicon dioxide & zirconia based epoxy polymer composite

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JITENDRA KUMAR*, NITESH KUMAR DIXIT, DEEPAK AGRAWAL

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ABSTRACT

This study compares the tensile and flexural properties of Sio2 & Zirconia /epoxy polymer nanocomposites. Dispersion of Sio2 & Zirconia nanoparticles in the epoxy polymer was achieved by ultrasonic mixing. Sio2 & Zirconia /epoxypolymer nanocomposites contain varying amount of nano size Sio2 & Zirconia up to 4wt.%& 3wt.% respectively. The tensile test and three-point bending test were performed to obtain the tensile strength and the flexural properties of nanocomposites respectively by different researchers. The investigated properties of Sio2 & Zirconia /epoxy polymer nanocomposites increase with the increasing other nanoparticles dispersion like as silicon oxide nanoparticles and deterioration in the mechanical properties is realized above wt.%. This may be due to the significant increase in agglomeration and settlement of the Sio2 & Zirconia nanoparticles during the long curing time. This paper also reviews the mechanical and biological properties of different nanopowder material used during composite fabrication. It has been investigate that the mechanical properties (hardness, fracture toughness, Young's modulus, and compressive strength), and biological properties (biocompatibility and bio- activity) of zirconia and silicon dioxide are favorable for the biomedical implant.

KEYWORDS-

Epoxy; Sio2 & zirconia nanocomposites; ultrasonic mixing; tensile properties; flexural properties, biomedical implant.

1. INTRODUCTION

Maximum times of the engineering purposes in today's era needs substances which well-known shows excessive strength to weight ratio. Polymers are one type of materials that exhibits fantastic homes from engineering software factor of view. Polymers are light in weight and have high corrosion resistivity however they are low in strength. To overcome this drawback, difficult secondary phase materials are bolstered into the soft polymer matrix which outcomes in enhancement of mechanical and thermal properties. These challenging section materials can be either fiber or/and fillers types which are typically inert in nature. Epoxy polymers are a type of high-performance thermosetting polymers which are widely used in aerospace, automobile industries as structural composites and adhesives. However, epoxy polymers have low toughness, stiffness and have an impact on resistance due to their rather cross-linked structure. This cross-linked shape leads to brittle behavior ensuing in crack initiation and boom. Hence, the epoxy resins famous low resistance to fracture. This inherent brittleness of the epoxy resin has restrict their utility in fields requiring high flexural, tensile and fracture strengths. However, via suitably reinforcing the epoxy with quite a number dispersants can decorate their mechanical homes and has incredible viable to alternative the common steel substances to many applications. Development of new or enchantment of exiting epoxy based totally matrix composite substances are classical task for the material engineers. Polymer matrix amendment is one of the methods to advance new team of polymer structural substances. This modification can be executed by way of incorporation of a second micro-phase of a dispersed rubber, or a thermoplastic polymer and one-of-a-kind inorganic particles of exceptional sizes to achieve the required mechanical houses. Therefore it has been well hooked up from many years that incorporation of a 2nd phase of a dispersed rubber or a thermoplastic polymer into the epoxy polymer increases their toughness. The rubber or thermoplastic particles used are commonly about 1 to 5 μm in diameter the presence of the rubbery phase normally increases the viscosity of the epoxy monomer mixture. This reduces the fundamental mechanical properties, such as strength, modulus and glass transition temperature (Tg) of the cured epoxy polymer. These limitations favor the want of rigid inorganic particles having particles of diameter between four and one hundred μm. However, these especially massive particles additionally notably make bigger the viscosity of the resin, decreasing the ease of processing.

Dept. of Mechanical Engineering, Institute of Engineering & Technology Faizabad India 224001
*Corresponding author email- jitenderku1994@gmail.com

Therefore, the use of nano-fillers is preferred. An addition of small amount of inorganic nanofillers in epoxy matrix leads to a large enhancement of mechanical residences of the base epoxy, mainly durability and stiffness. The properties of dispersed epoxy matrix substantially rely upon dispersion country and the structural homogeneity of the dispersant. Thus, the dispersion of nanofillers in matrix is regarded as an important measure to achieve the preferred material Property. In this work, an attempt has been made to produce Sio2e & Zirconia /epoxy nanocomposites by homogeneous dispersion of the nano sized particles in epoxy resin via ultrasonication and the effect of particle loading and their dispersion on tensile and flexural properties of Sio2e & Zirconia /epoxy composite has been investigated [1-2].

Table 1 Different Materials, Particle size and analysis of Property

S. N	Researcher ,Year	Material	Particle Size (nm)	Research Objective	Analysis on Property
1	Zhang, Honggang Zhang, NanFang, Fengzhou(2020)	nickel/graphene oxide	30	Fabrication of high-performance Mechanical property nickel/graphene dioxide composite coatings using ultrasonic-assisted electrodeposition[3]	Mechanical property Electrical property
2	Parale, Vinayak G. Kim, Taehee Lee,KyuYeon(2020)	TiO2-SiO2	40, 20	Hydrophobic Titanium dioxide and silicon dioxide composite aerogels synthesized via in situ epoxy-ring opening polymerization and sol-gel process for enhanced degradation activity[4]	Mechanical property Biological property
3	Kumar, Sandeep Nehra, Monika Kedia, Deepak Dilbaghi, Neeraj Tankeshwar, K(2020).	Different nano material	25	Nanotechnology-based materials for orthopaedic applications: Recent advances and future application[5]	Mechanical property biological property
4	Li, Wen Zhang, Lei Zhang, Mutian Dou,Wenwen(2020)	SiO2	15	The effects of interfacial water and SiO2 surface wettability on the adhesion& mechanical properties of SiO2 in epoxy nanocomposites[6]	Mechanical property optical property
5	Naderi, Armaghan Dolati, Abolghasem Afshar, Abdollah Palardy, (2020)	zirconia	45	A simple route to synthesize zirconium dioxide antistatic thin films on glass substrates and their application to epoxy polymer-based composites[7]	Mechanical property Electrical property
6	Damian, C. M. Necolau, M. I. Neblea, I. Vasile, (2020)	SiO2 nanostructures	15	Synergistic effect of graphene oxide functionalized with SiO2 nanomaterials in the epoxy nanocomposites[8]	Mechanical property Biological property Optical property
7	Rahmani, Hossein Eslami-Farsani,Reza(2020)	Aluminum - Carbon, Nano Silica and Zirconia	<45	High velocity impact Response of Al-Carbon nanoparticles Fibers-Epoxy Laminated NanoComposites Toughened by Nano Silica and Zirconium dioxide.[9]	Mechanical property Electrical property
8	Sun, Pan Liang, Xiayi Ding, Yue Tingwei(2020)	SiO_2	20	Experimental evaluation on H2O-based and flexible epoxy polymer /SiO_2 nanocomposites to enhance anti-sliding effectiveness of pavement[10]	Mechanical property Electrical property
9	Hampali, Chennabasappa Dushyanth Manjunatha(2020)	Zirconia etc.	45	Investigation of mechanical properties(tensile & flextural) of polymer composites used for orthopedic application[11]	Mechanical property Biological property
10	Rawat, Neha Kanwar Khatoon, Halima Kahtun(2019)	boron and zirconia	45	Conducting polyborozirconia nanostructures: Effect of boron and zirconia doping on synthesis, characterization and their corrosion protective performance[12]	Mechanical property Biological property
11	Sonekar, Mahesh M. Rathod, WalmikS.(2019)	(SS-316 l & Ti6Al4V)	25	An experimental analysis on bologial behavior of bio-implant material (SS-316 l & Ti6Al4V) for orthopedic applications[13]	Mechanical property Biological property
12	Sadeghi, M. Kharaziha, M. Salimijazi, H. R. (2019)	graphene oxide	30	Double layer graphene oxide-PVP coatings on the textured titanium alloy for improvement of frictional and biological property.[14]	Mechanical property Biological property
13	Ogbonna, O S Akinlabi, S A Mashinini, P M Fatoba, O S Kumpaty, S(2019)	Titanium-Molybdenum	25	Exploratory Investigation of Biocompatibility in Laser Metal Deposited Titanium dioxide-Molybdenum Composite[15]	Mechanical property Electrical property
14	Kanthrajau, B.S. Suresha, Bheemappa Somashekar, H.M.(2019)	Zirconia	45	Role of Zirconia Filler on Mechanical Properties(tensile & flexural) and Dry Sliding Wear Behavior of Glass/Basalt Hybrid Fabric Reinforced Epoxy Composites[16]	Mechanical property Optical property

15	Long, Jia Peng Li, San Xi Liang, Bing Wang,ZhiGuo(2019)	graphene oxide	25	Investigation of thermal behaviour and mechanical property of the functionalized graphene oxide/epoxy polymer nanocomposites[17]	Mechanical property Thermal property
16	He, Xianglei Wang, Zhi Pu, Yuan Wang, Dan(2019)	zirconia	45	High-gravity-assisted scalable synthesis& ditermination of zirconia nano dispersion for LED with enhanced light extraction efficiency.[18]	Mechanical property Electrical property Optical property
17	Mohammed, Alaa A.,Al-Hassani, Emad S.Oleiwi, Jawad K.(2019)	DOPO and Nano-SiO 2	20	Fracture Toughness of DOPO and Nano-Silicondioxide Combinational Effects[19]	Mechanical property Biological propert
18	Mohammed, Alaa A. Al-Hassani, Emad S. Oleiwi, Jawad K.(2019)	NIL		The nano mechanical characterization like as XRD ,SEM and elastic tensile & hardness trial of polymer nanocomposites for bioimplants applications..[20]	Mechanical property Biological propert
19	Parente, João M. Silva, Marco P. Santos, Paulo Reis, Paulo N.B. (2019)	graphene	25	Viscoelastic behaviour of nano composites enhanced by graphene [21]	Mechanical property Electrical property Optical property Magnetic property
20	Asgar, Hassnain Deen, K. M. Rahman, Zia Ur Shah, Umair , Waseem(2019)	graphene oxide	25	Functionalized graphene oxide coating on Ti6Al4V alloy for improved biocompatibility and high corrosion resistance[22]	Mechanical property Biological propert
21	VairaVignesh, R. Padmanaban, R. (2019) Govindaraju, M.	SiO2	15	Experimental Analysis and Characterization of Magnesium Alloy nano Composite (AZ91D - SiO2) by Friction Stir Processing for Bioimplants[23]	Mechanical property Biological propert
22	Singh, Balraj Singh, Gurpreet Sidhu, Buta Singh(2019)	hydroxyapatite–tantalum	30	Examination of high corrosion resistance and surface unpleasantness properties of plasma-splashed composite covering of hydroxyapatite–tantalum on biodegradable Mg combination ZK60[24]	Mechanical property Biological propert
23	Patel, Krishan Kumar Purohit, Rajesh Hashmi, Sandeep Kumar(2019)	SiO2	15	Development of Nano SiO2 Particles Dispersed Shape Epoxy polymer Composites[25]	Mechanical property Electrical property
24	Kancherla, Kishore BabuSubbappa, Dakshayini B.Hiremath, (2019)	Fabric& zirconia	45	Enhancing mechanical properties tensile strength of glass fabric composite with surfactant treated zirconia nanoparticles[26]	Mechanical property Electrical property
25	Liao, Jingjing Zhang, DouWu, Xuewen Luo, HangZhou, KechaoSu, Bo(2019)	zirconia	45	Arrangement of high elasticity tensile strength zirconia by epoxy gel-sol strategy throwing utilizing hydantion epoxy polymer as a gelling liquid.[27]	Mechanical property Electrical property

2. DISCUSSION

All research paper study with their result then we find out some variance like as, H. Zhang et.al, [3] is used Ultrasonic-assisted electro deposition to fabricate the nickel/graphene oxide composite coatings with high hardness, low friction coefficient, and high wear resistance and measure the micro hardness using ultrasonic electro deposition using fixed concentration graphene oxide (0.1g/l) compare to pure graphene concentration, the hardness will be increased 4.4 times. V. G. Parale et.al. [4] in this paper that TiO_2–SiO_2 composite composed of an organic-inorganic molecular network was epoxy-ring opening polymerization and sol-gel procedure followed by supercritical drying. After that the 87% degradation was achived. S. Kumar et.al, [5] in this paper nanomaterials are used in orthopedic applications like as regain, modifying tissues and we know that nanoparticle have less weight and then it is also used in bone making or bone joining .if any tissues or bone are damage then orthopaedic implant in terms of success or failure, their antimicrobial/antibacterial activities. If graphene particle used in this then it create some blood reaction problem. We always want to be a corrosion resistence, blood reaction resistence, etc property in the particle. W. Li et.al, [6] in this paper compare the silicon dioxide mixed with epoxy without used water and sio2 mixed water then mixed epoxy polymer then get a result binding strength increased when water is used in sio2 and epoxy. C. M. Damian et.al, [8] in this paper graphene oxide mixed with sio2 nanoparticle and then mixed with epoxy polymer with reinforcing agent in a ratio of 0.25%, 0.5% and 1% wt.and then get a result young modulus will be improved 20% and tensile stress improved more than 40% by using tensile test and using SEM test then get lattice of electron. H. Rahmani, et.al, [9] in this paper aluminium –corbon fiber using laminated coating of zro2 and sio2 by high velocity impact procedure.then findout the mechanical property will be increased according to increased percentage of nanopowder increased.when sio2 percentage is 5% and zirconia use 3% and coated on the fiber of al-corbon then tensile strength improved more than 20 %. C. Hampali, et.al, [11] in this paper Poly Tetra Fluoro Ethylene and Titanium Dioxide and other nanopowder composites were developed as secondry materials for orthopaedic applications. the ranges of 5%, 10% and 15% of weight proportion. The nanoparticle are used with epoxy then improved bending strength and compressive strength .and then we say that its used in orthopedic application easy way. J. P. Long, et.al, [17] in this paper graphene oxide mixed with epoxy polymer then find a result showed when the 0.2% graphene oxide was filled into the epoxy polymer, the tensile strength was 55.4 MPa, the impact strength was 17.5 KJ/m2, the flexural strength was 82.2 MPa, and the flexural modulus was 2760 MPa. The mechanical properties of nano materials were more than those of pure epoxy and improved the strength and flextural of epoxy nanocomposites. In this paper DOPO and nano powder sio2 are mixed with the epoxy novelac resin and solifying then doing different test like as fracture test and get flextural strength improved and a one thermogravimetric test are occurs at 800 degree celcius then improve property [19]. A. A. Mohammed, et.al,[20] in this paper Nanoindentation is a powerful method to determine various mechanical properties of materials at the nanoscale, such as for example young's modulus and hardness.polyetheretherketon is the best material for biomedical application in this material strength is more then is used in human bone .and get tensile strength and hardness 20-30% increase and young modulus 79MPA. [21] in this paper show that the any mechanical property are find out when doing any nanopowder mixed to any epoxy but when we see this viscoelastic property then get max. improvement. [22] in paper studythe magnesium functionalized grapphene coating are occurs at the titanium plate (Ti6Al4V) by electrophortic deposition and then get the result decrease corrosion density and improve corrosion resistence of plate and also improve the biocompativility property.[23] in this study magnesium are best material for the bioimpolant .but when we used magnesium –sio2 material and then get high tensile strength , corrosion resistence, high biocompativility then we say that its material sare basically very helpful for bone joining and bio implant. [24] in this same as the upper paper .but some difference is magnesium are used by plasma spray coating on the hydroxyapatite–tantalum on biodegradable Mg alloy ZK60. And then get good corrosion resistence. [27] in paper zirconia are mixed in the water based hydantion epoxy resin then get the solid loading 52%vol achieved and 0.8& dispersant and high mechanical strength of 942.77 ± 95.61 MPa. [35] in this titanium dioxide are mixed with viscoelastic epoxy resin and then get the fracture toughness for nano-sized TiO2 reinforced epoxy composites is 43.70% and 41.85% and tesile strength is 32.57% and 44.95% improved at 8% wt of epoxy. [37] these nano materials are designed to degrade or to be resorbed inside the body rather than removing the implant after its function is served. Many properties such as mechanical properties tesile flextural hardness etc, non-toxicity, surface modification, degradation rate, biocompatibility, and corrosion rate are considered.

3. CONCLUSION

In this review, the an investigation on mechanical & biological property of SiO2 & Zirconia with epoxy polymer and application in Bioimplant have been discussed. It is found from this study that the XRD, SEM, Tensile & flextural test is the most appropriate and viable method for this purpose. This review concluded that for the nanopowder and epoxy polymer mixing method, the selection of precursors (starting materials), use of binder and thining agent, sintering temperature, and solidifing time have a significant role in the analysis of different nanopowder with epoxy and used different applications. In addition, we study the different materials mixed with epoxy but when silicon dioxide are mixed with epoxy then mechanical property are increased. When sio2 percentage are 4% of weight then max strength and max flextural strength is obtained. When % of sio2 are increrad like as 6, 8 % then mechanical property decreased gradually. Some research paper shows that the zirconia is best material for the applications of bioimplant and when zirconia are used for the mixing of epoxy polymer araldite 106 and hardner HV953IN then we find out the improved strength at any %.and its also used in biomedical application. Moreover, the mechanical properties of silicon dioxide and zirconia powder can also be enhanced by different materials into it. Due to improved mechanical properties (adhesion strength and porosity), the Sio2 nanomaterials offer great potential for surface modification of biomedical implants. Despite initial research, Zro2 material still requires more attention and characterization (testing) before their final use for biomedical, as most of the available research work is based on the Investigation on Mechanical & Biological Property of SiO2 & Zirconia with epoxy polymer and application in Bioimplant. In this review paper we conclude that when mixed the Sio2 and Zro2 in different percentage and its further mixed with epoxy polymer then we find out the max strength and then it is used for bioimlant. From literature it is found that the use of zirconia is very high for biomedical areas.

REFERENCES

[1] S. Kumar Singh, A. Kumar, and A. Jain, "Improving tensile and flexural properties of SiO2-epoxy polymer nanocomposite," Mater. Today Proc., vol. 5, no. 2, pp. 6339–6344, 2018, doi: 10.1016/j.matpr.2017.12.243.

[2] P. S. Prakash, S. J. Pawar, and R. P. Tewari, "Synthesis, characterization, and coating of forsterite (Mg2 sio4) based material over medical implants: A review," Proc. Inst. Mech. Eng. Part L J. Mater. Des. Appl., vol. 233, no. 6, pp. 1227–1240, 2019, doi: 10.1177/1464420717705151.

[3] H. Zhang, N. Zhang, and F. Fang, "Fabrication of high-performance nickel/graphene oxide composite coatings using ultrasonic-assisted electrodeposition," Ultrason. Sonochem., vol. 62, p. 104858, 2020, doi: 10.1016/j.ultsonch.2019.104858.

[4] V. G. Parale et al., "Hydrophobic TiO2–SiO2 composite aerogels synthesized via in situ epoxy-ring opening polymerization and sol-gel process for enhanced degradation activity," Ceram. Int., vol. 46, no. 4, pp. 4939–4946, 2020, doi: 10.1016/j.ceramint.2019.10.231.

[5] S. Kumar, M. Nehra, D. Kedia, N. Dilbaghi, K. Tankeshwar, and K. H. Kim, "Nanotechnology-based biomaterials for orthopaedic applications:

Recent advances and future prospects," Mater. Sci. Eng. C, vol. 106, no. May 2019, p. 110154, 2020, doi: 10.1016/j.msec.2019.110154.

[6] W. Li, L. Zhang, M. Zhang, W. Dou, X. Zhang, and S. Chen, "The effects of interfacial water and SiO2 surface wettability on the adhesion properties of SiO2 in epoxy nanocomposites," Appl. Surf. Sci., vol. 502, no. September 2019, 2020, doi: 10.1016/j.apsusc.2019.144151.

[7] A. Naderi, A. Dolati, A. Afshar, and G. Palardy, "A simple route to synthesize zirconia antistatic thin films on glass substrates and their application to polymer-based composites," Mater. Chem. Phys., vol. 244, no. January, p. 122696, 2020, doi: 10.1016/j.matchemphys.2020.122696.

[8] C. M. Damian, M. I. Necolau, I. Neblea, E. Vasile, and H. Iovu, "Synergistic effect of graphene oxide functionalized with SiO2 nanostructures in the epoxy nanocomposites," Appl. Surf. Sci., vol. 507, p. 145046, 2020, doi: 10.1016/j.apsusc.2019.145046.

[9] H. Rahmani, R. Eslami-Farsani, and H. Ebrahimnezhad-Khaljiri, "High Velocity Impact Response of Aluminum- Carbon Fibers-Epoxy Laminated Composites Toughened by Nano Silica and Zirconia," Fibers Polym., vol. 21, no. 1, pp. 170–178, 2020, doi: 10.1007/s12221-020-9594-4.

[10] P. Sun, X. Liang, Y. Ding, W. Tingwei, S. Xiang, and D. Cai, "Laboratory evaluation on water-based and flexible epoxy/SiO2 nanocomposites to enhance anti-sliding effectiveness of pavement," Mater. Res. Express, 2020, doi: 10.1088/2053-1591/ab6e83.

[11] C. Hampali, C. K. Dushyanth Kumar, D. Manjunatha, A. Rohith, and T. Vinay Kumar, "Investigation of mechanical properties of polymer composites used for orthopedic application," Mater. Today Proc., vol. 20, no. xxxx, pp. 213–216, 2020, doi: 10.1016/j.matpr.2019.11.056.

[12] N. K. Rawat, H. Khatoon, S. Kahtun, and S. Ahmad, "Conducting polyborozirconia(o-toluidine) nanostructures: Effect of boron and zirconia doping on synthesis, characterization and their corrosion protective performance," Compos. Commun., vol. 16, pp. 143–149, 2019, doi: 10.1016/j.coco.2019.10.002.

[13] M. M. Sonekar and W. S. Rathod, "An experimental investigation on tribologial behavior of bio-implant material (SS-316 l & Ti6Al4V) for orthopaedic applications," Mater. Today Proc., vol. 19, no. xxxx, pp. 444–447, 2019, doi: 10.1016/j.matpr.2019.07.633.

[14] M. Sadeghi, M. Kharaziha, and H. R. Salimijazi, "Double layer graphene oxide-PVP coatings on the textured Ti6Al4V for improvement of frictional and biological behavior," Surf. Coatings Technol., vol. 374, no. June, pp. 656–665, 2019, doi: 10.1016/j.surfcoat.2019.06.048.

[15] O. S. Ogbonna, S. A. Akinlabi, P. M. Mashinini, O. S. Fatoba, and S. Kumpaty, "Experimental Investigation of Biocompatibility in Laser Metal Deposited Titanium-Molybdenum Composite," no. May, pp. 1–8, 2019, doi: 10.15224/978-1-63248-170-2-08.

[16] B. S. Kanthrajau, B. Suresha, and H. M. Somashekar, "Role of Zirconia Filler on Mechanical Properties and Dry Sliding Wear Behavior of Glass/Basalt Hybrid Fabric Reinforced Epoxy Composites," Appl. Mech. Mater., vol. 895, pp. 200–205, 2019, doi: 10.4028/www.scientific.net/amm.895.200.

[17] J. P. Long, S. X. Li, B. Liang, and Z. G. Wang, "Investigation of thermal behaviour and mechanical property of the functionalised graphene oxide/epoxy resin nanocomposites," Plast. Rubber Compos., vol. 48, no. 3, pp. 127–136, 2019, doi: 10.1080/14658011.2019.1577027.

[18] X. He et al., "High-gravity-assisted scalable synthesis of zirconia nanodispersion for light emitting diodes encapsulation with enhanced light extraction efficiency," Chem. Eng. Sci., vol. 195, pp. 1–10, 2019, doi: 10.1016/j.ces.2018.11.036

[19] Ects, "and Fracture Toughness of DOPO and Nano-SiO 2 Combinational E ff ects," 2019.

[20] A. A. Mohammed, E. S. Al-Hassani, and J. K. Oleiwi, "The nanomechanical characterization and tensile test of polymer nanocomposites for bioimplants," AIP Conf. Proc., vol. 2123, no. July, 2019, doi: 10.1063/1.5116992.

[21] M. Diseases et al., "Viscoelastic behaviour of nanocomposites enhanced by graphene: An overview," Mater. Sci. Eng. C, vol. 1, no. 2, pp. 1–10, 2019, doi: 10.1002/mdp2.99.

[22] H. Asgar, K. M. Deen, Z. U. Rahman, U. H. Shah, M. A. Raza, and W. Haider, "Functionalized graphene oxide coating on Ti6Al4V alloy for improved biocompatibility and corrosion resistance," Mater. Sci. Eng. C, vol. 94, no. October 2018, pp. 920–928, 2019, doi: 10.1016/j.msec.2018.10.046.

[23] R. Vaira Vignesh, R. Padmanaban, and M. Govindaraju, "Synthesis and Characterization of Magnesium Alloy Surface Composite (AZ91D - SiO2) by Friction Stir Processing for Bioimplants," Silicon, 2019, doi: 10.1007/s12633-019-00194-6.

[24] B. Singh, G. Singh, and B. S. Sidhu, "Analysis of corrosion behaviour and surface properties of plasma-sprayed composite coating of hydroxyapatite–tantalum on biodegradable Mg alloy ZK60," J. Compos. Mater., vol. 53, no. 19, pp. 2661–2673, 2019, doi: 10.1177/0021998319839127.

[25] K. K. Patel, R. Purohit, S. A. R. Hashmi, R. K. Gupta, and S. K. Dwivedi, "Development of Nano SiO 2 Particles Dispersed Shape Memory Epoxy Composites," vol. 1, no. March, pp. 21–24, 2019.