ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

Influence of Cu Micro Particles on Mechanical Properties of Injection Molded Polypropylene/Cu Composites

M. A. Kori[*1], M. G. Kulthe[2], R. K. Goyal[3]

Post Graduate Student, Department of Metallurgy and Materials Science, College of Engineering, Pune, Shivajinagar, Maharastra, India. [*1]

Associate Professor, Department of Metallurgy and Materials Science, College of Engineering, Pune, Shivajinagar, Maharastra,, India.[2]

Assistant Professor, Department of Metallurgy and Materials Science, College of Engineering, Pune, Shivajinagar, Maharastra,, India. [3]

ABSTRACT - Copper reinforced polymer matrix composites are widely studied for the applications in electrostatic dissipation (ESD) and electromagnetic interference (EMI) shielding. Mechanicalpropertiesof copper powder filled polypropylene composites are investigated experimentally.Filler content varies in between 0–40% by weight andare blended by mechanical mixing under dry conditions for 4 hours at 60 rpm and processed by injection molding at 215°C and 150 bars. Optical microscopy showed uniform dispersion of Cu particles at lower composition whereas agglomerates were observed in the composites at higher Cu loading. Mechanical properties of the injection molded samples were studied systematically. As compared to pure PP, density and micro hardnessof composites increases with Cu addition by 35%. Impact energy and impact strength were increased by almost 50%. This was attributed to the better and uniform dispersion of the Cu particles in the matrix. The tensile strength and % elongation were found to decrease with increasing Cu content in the matrix, as the Cu act as stress arising points under deformation as compared to pure PP.

KEYWORDS: polymer matrix composites, injection molding, copper.

1. INTRODUCTION

In our daily life we are surrounded by more and more articles produced of polymers rather than traditional materials such as wood, metals or ceramics. One of the main drivers contributing to the popularization of polymers is their ease of processing into complexly shaped parts at high speeds and low costs via relatively simple processes, such as extrusion, injection and compression molding. Complementary advantages of polymers are their low density and large range of specific properties; due to these properties polymers are becoming attractive. Polymers generally referred as insulators of both thermally and electrically because of their low thermal and electrical conductivity. Increasing the thermal and electrical conductivity of these polymers allows them to be used in various applications for replacing metals for various shielding applications in defense, electrical and electronics industries. This is mainly due to their better characteristics in terms of electrostatic discharge, shielding from electromagnetic interference (EMI), radio-frequency interference (RFI), and thermal expansion, density and chemical (corrosion and oxidation resistance) properties [1-2]. The main drawback of polymers is their low mechanical properties. PP is a form of thermoplastic used in the production of non-woven fiber and structural plastic products. The properties of PP that make the material popular include the non-toxic and non-staining nature of the plastic and the relatively inexpensive cost of production and can be recovered and recycled to 100% during the production phase. The literature indicates that Cu reinforced polymer composites are suitable for making complex shaped components with good electrical and mechanical properties [1-7]. Moreover, they display good impact energy absorption characteristics [4]. Hence, in this study conductive polymer composites Cu is used as reinforcement and thermoplastic polymer PP (PP) as matrix [5-8].

II. EXPERIMENTATION

2.1 MATERIALS

Commercial grade PP granules of density 0.905 g/cc (REPOL H026SG Homopolymer) was purchased from Reliance Industries Limited (REPOL). It was grinded to fine powder of few microns in presence of liquid nitrogen as per the ASTM D638. 99.5 % Commercial purity electrolytic Cu powder (10-44 µm) purchased from Otto Kemi, Mumbai, India is used as Cu particles without treatment. It has density of 8.9 g/cc and was used for the research work. Both PP and Cu powders were blended in laboratory developed mixers for about 4 hours, at various speeds and positions.

2.2 PREPARATION OF PP/CU COMPOSITE USING INJECTION MOLDING MACHINE

Test specimens were processed by injection molding machine [9-11], Boolani Engineering, BRT-50, Pure PP material was injected at 215 ^{o}C at 150 bar initially until process gets stream lined and once all the required parameters are succeeded and steady state is achieved then composite powder mixture was added at hopper and specimens are fabricated and are allowed to cool at room temperature. Specimens of compositions containing PP-0, PP-5, PP-10, PP-20,PP-30 and PP-40 wt% respectively are fabricated as shown in table 1. Once fabrication is completed purging was carried out by pure PP to remove any Cu existing in barrel until pure epoxy specimens are obtained. The following procedure was used for the injection molding of the composites.

TABLE 1,
Composition of PP/Cu Specimens

Specimen code	% Reinforcement of Cu in PP matrix	
	By weight	By Volume
PP-0*	0	0.000
PP-5	5	0.531
PP-10	10	1.115
PP-20	20	2.474
PP-30	30	4.167
PP-40	40	6.335

* wt.% of Cu in the PP matrix

2.3 CHARACTERIZATION

Properties of composite depend upon the volume fraction of reinforcing particles. Volume fraction of Cu particles for a given weight fraction [12] was determined using Eq. (1) and specified in Table 1.

$$V_f = \frac{W_f}{W_f + W_m\left(\frac{\rho_f}{\rho_m}\right)} \quad (1)$$

where V_f is the volume fraction, W_f is the weight fraction, and ρ_f is the density of Cu particles, W_m and ρ_m are the weight fraction and density of PP matrix, respectively.

2.3.1 DENSITY

Theoretical density of the composites was calculated by the rule of mixtures (ROM) using the density of Cu 8.9 gcm^{-3} and of PP 0.905 gcm^{-3}. For theoretical density, it was assumed that there were no voids and no loss of constituents during processing. The ROM can be expressed as

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

$$\rho_{th} = \rho_m(1 - V_f) + \rho_f V_f \qquad (2)$$

where, ρ_{th} is the theoretical densityof the composite. The experimental density $\rho_{ex}$of the composites was determined by the Archimedes method using Eq. (3).

$$\rho_{ex} = \left[\frac{W_{air}}{W_{air} - W_{alcohol}}\right] X\ \rho_{alcohol} \qquad (3)$$

where W_{air} and $W_{alcohol}$ are the weight of the sample in air and alcohol medium, respectively. The $\rho_{alcohol}$ is the density of the alcohol used.

The porosity in the material was calculated using Eq. (4).

$$\%\ Porosity = \left[\frac{\rho_{th} - \rho_{ex}}{\rho_{th}}\right] X\ 100 \qquad (4)$$

2.3.2 HARDNESS

Hardness is defined as the resistance of a material to deformation, particularly permanent deformation, indentation or scratching. Hardness test was carried out using Vickers hardness tester Future Tech Corp FM-700, Tokyo, Japan.All samples were indented with a load of 100 g for dwell time of 15 seconds. Average microhardness of samples of six readings is used.

2.3.3. IMPACT STRENGTH

Impact tests are used to measure the value of strength of material under high rates of loading. Some ductile and brittle materials are weak under impact loads. Charpy tests are ordinarily conducted to assess impact strength. As with metals, polymers may exhibit ductile or brittle fracture under impact loading conditions, depending on the temperature, specimen size, strain rate and mode of loading. Many materials are prone to fracture in a brittle manner as very little plastic deformation takes place before failure. Crack growth during brittle fracture absorbs very little energy. It is also extremely rapid and occurs without any warning [13]. The Charpy test is used for testing the impact on specimens that are supported as a simple beam. Impact fracture energy is a significant parameter portraying toughness of materials. Impact values signify the total capability of the material to absorb impact energy, which is composed of two parts (a) energy required breaking bonds, and (b) energy consumed in deforming a certain volume of the material. It is a reasonable approximation to define the energy up to the peak load as the 'crack initiation resistance' [14-17]. Similarly, post-peak energy is also defined as the 'crack propagation resistance' of the material. A single-edge 45^0 V-shaped notch (tip radius 0.25 mm, depth 2 mm). Impact tests were carried-out by Fine Testing Machine, FIT-14, (least count 0.1 J)

III. RESULTS AND DISCUSSIONS

3.1 DENSITY OF PP/CU COMPOSITES

Density of composites increases with addition of Cu due to the higher density of Cu (8.9 gcm^{-3}) than that of pure PP (0.905 gcm^{-3}) Fig. 1. The experimental density and theoretical density of composite are closer at lower vol% (PP-0, 5and 10) concentration levels and at higher vol% (PP-20 and 30) it diverges due to the increased porosity which was estimated from an Eq. (1). It is observed that percent porosity increased particularly at higher concentration of Cu. This is due to the fact that when Cu particle loading is increased the interparticle distance decreases which in turn results in increased agglomeration of Cu particles. The penetration of molten polymer becomes difficult due to agglomerates leading to porosity. The porosity of the PP-40 composite is about 4.2%.

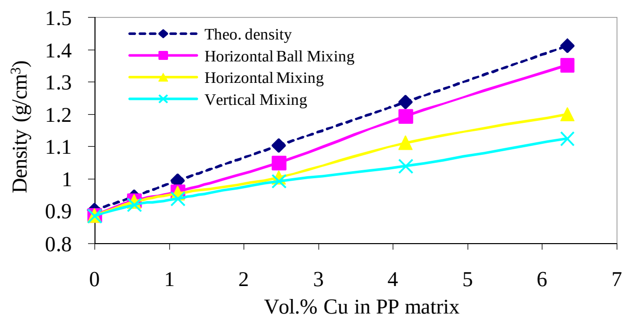
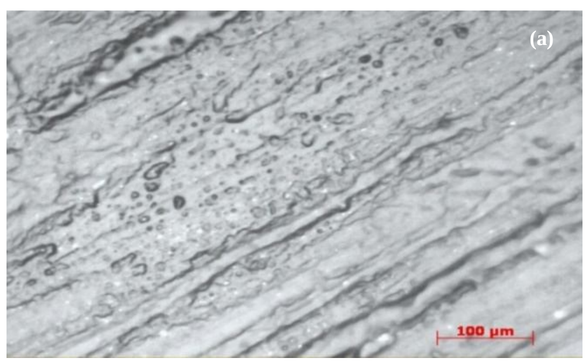
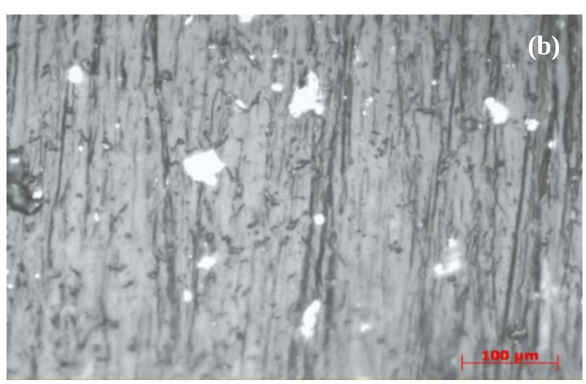


Fig. 1. Theoretical and experimental density for the PP/Cu composites.

Fig. 2 (a-f) shows the optical images of injection molded specimens PP-0, PP-5,PP-10, PP-20, PP-30 and PP-40 composites at 100X magnification. It can be seen that dispersion of Cu enhanced with increasing concentration. Fig. 2. b and c shows fine distribution of Cu in matrix it seems that Cu particles tends to form fine 3-dimensional network resulting in increasing the hardness, impact strength and conductivity of composite. Fig. 2. d shows the 30 wt% Cu with improper distribution of Cu in matrix unsettled to agglomeration of Cu particles the presence of porosity in the vicinity of Cu aggregates which might be the reason for decreased density and constant conductivity at higher Cu content the tendency for Cu aggregates was increased due to the decreased inter-particle distances between the Cu particles.

3.2 MORPHOLOGY OF PP/CU COMPOSITES





ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

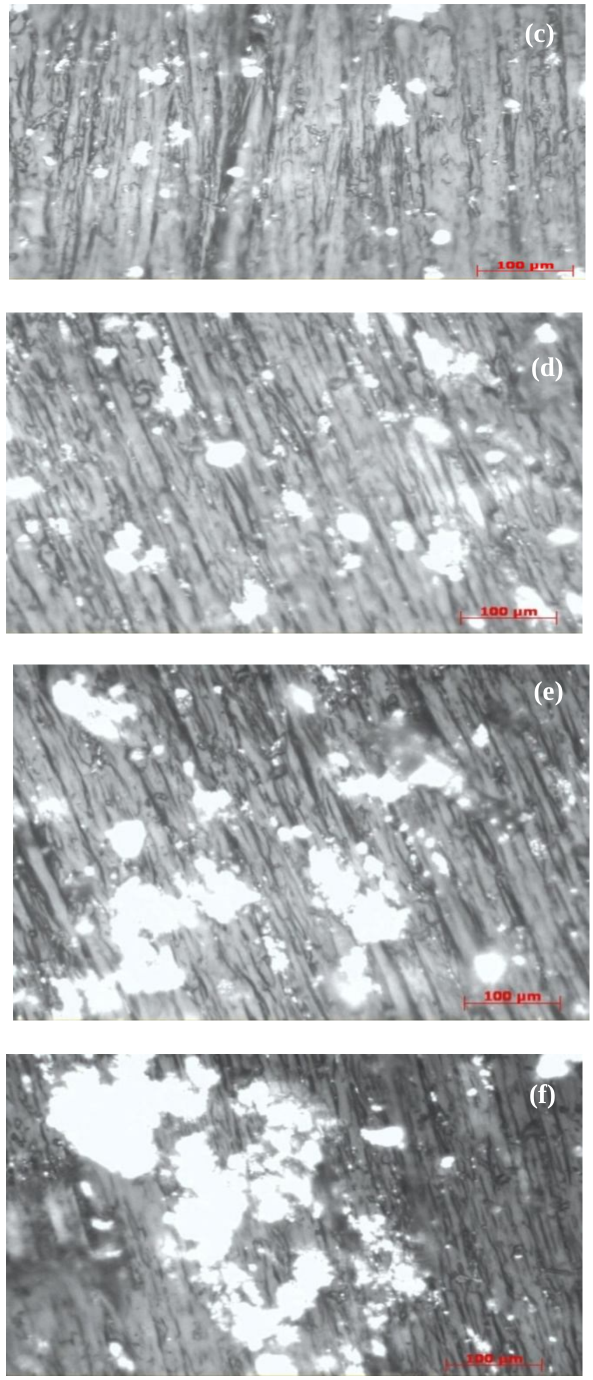


Fig. 2 (a-f) Optical microscopy (100X) images of composites containing (a) 0 wt%, (b)5 wt%,(c)10 wt%, (d) 20 wt%, (e) 30 wt%, (f) 40 wt%,Scale bar 100 µm

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

3.3 Microhardness of PP/Cu composites

Fig. 3 shows experimental and theoretical microhardness of composites as a function of Cu content. The theoretical values were predicted from the rule of mixtures (ROM). The ROM for micro-hardness can be expressed as; $H_c = H_m (1-V_f) + H_f V_f$, where H_c, H_m, and H_f represent microhardness of composite, matrix and Cu particles, respectively, and V_f is the volume fraction of the Cu particles. The micro-hardness of pure PP is 6.88 kgmm^{-2}. It can be seen that as Cu (microhardness of pure Cu varies from 39 kgmm^{-2}) content increases microhardness of composites increases with respect to pure PP matrix.

Goyal et al. [46] have reported that there is enhanced crystal nucleation and different local polymer chain conformation in the regions surrounding the reinforcing particles than that of away from the particles. Moreover, uniform dispersion of Cu particles in the matrix can well resist penetration of Vickers indenter resulting in significantly increased microhardnessof composites. Nevertheless, the microhardness can be further increased by reducing the porosity which is at present 4.2%. Moreover, porosities allow easy penetration of indenter and results in decreased microhardness compared to that of porosity-free samples.

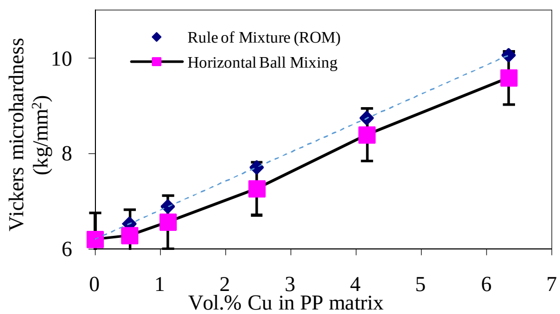


Fig. 3 Hardness as a function of vol% of Cu in PP matrix.

3.4 Impact testing for pure and reinforced epoxy

Fig. 4 shows Impact testing results have been obtained for pure and reinforced epoxy at room temperature with weight fraction 0, 5, 10, 20, 30, 40 Vol.%. Fracture energy and Impact strength increases for higher the concentration than that for pure epoxy with Cu powder as a result of Cu powder absorbs more energy than pure epoxy. But for reinforced epoxy with Cu powder, it can be noted that any increase in weight fraction leads to an increase in fracture energy and Impact strength by addition of Cu powder due to increase the number of Cu particles in unit volume which impede crack propagation, (i.e. increase in the absorb energy). Also, it can be noted that the fracture energy and Impact strength are increased as the particle size is decreased for each weight fraction due to increasing wettability of the Cu particles by epoxy resin which causes an increase in transmitting stresses from matrix to Cu particles. Also, higher the concentration it increases boundary grains of Cu in composite material, which leads to increase the strength of composite materials.

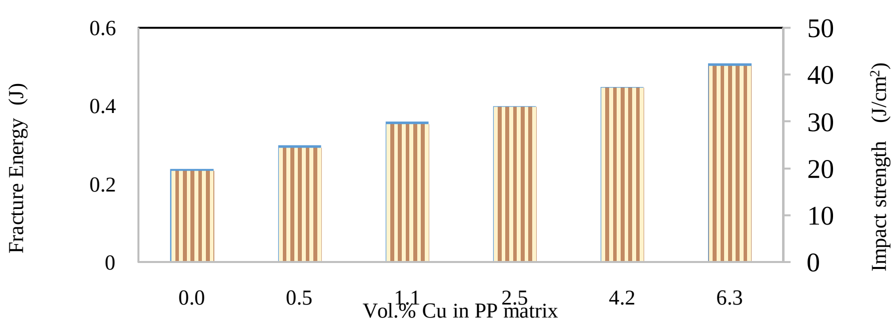


Fig. 4 Impact Strength and fracture energy as a function of vol% Cu in PP matrix

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

3.5 TENSILE STRENGTH

Addition of Cu decreases peak load, tensile strength, % elongation as compared to pure, PP Fig. 5(a, b, c).Pure PP has 36.4 mm elongation i.e., 104% elongation before breaking. Elongation at break values decreases with addition of Cu content due to indirect symptom that implies the bonding strength is poor [27, 40] i. e, interaction between PP and Cu composite is very small. Also, the filler added to polymer matrix restriction in the motion of polymer chains and thus lowers tensile strength to fracture sharply [26]. Similar trend results were observed by various authors [26, 27, 40]. illustrates the descending trends of elongation at break with addition of Cu filler. Pure PP is ductile in nature hence it is having 104% elongation, ductility decreases and hardness increases hence it behaves like brittle in nature. Elongation at 40 wt.% is just 21.97%. Reinforced Cu particles are randomly oriented and positioned in the PP matrix, under tensile loading they do not deform and operate as stress arising points and thus lowers the elongation resulting in brittle failure as compared to pure PP.

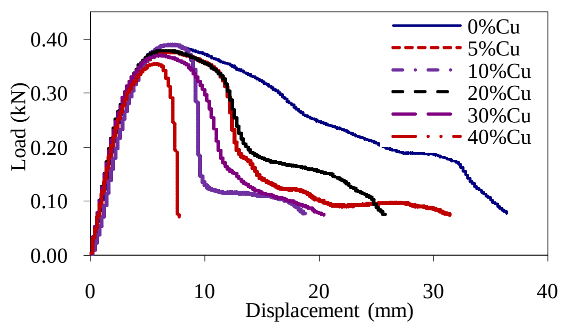


Fig. 5 (a) Stress strain diagram as a function of vol% Cu in PP matrix

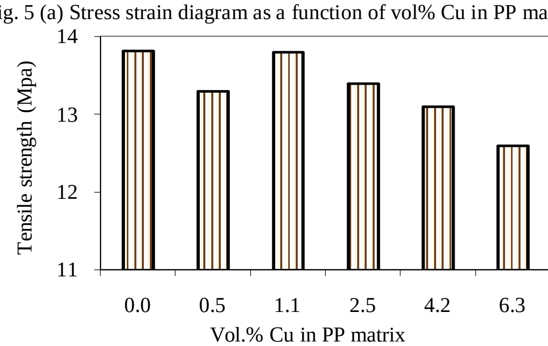


Fig. 5 (b)Tensile strength of PP as a function of vol.% Cu in PP matrix

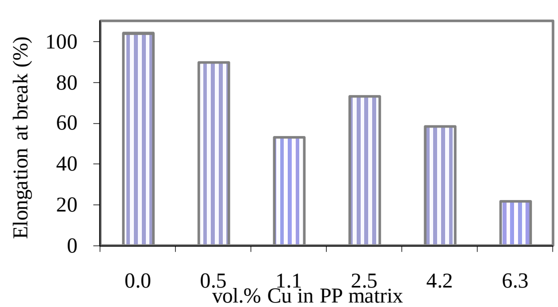


Fig. 5 (c)Elongation at break of PP as a function of vol.% Cu in PP matrix

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

IV. CONCLUSIONS

In this study, mechanical properties of micron sized copper (Cu) particles filled polypropylene (PP) composites prepared by mechanical mixing processed by injection molding are studied. PP/Cu composite mixed by horizontal ball mixing showed good results compared to those of prepared by horizontal mixing without balls. Experimental density of the composites prepared by horizontal ball mill was close to the theoretical density.Optical microscopy showed almost uniform dispersion of Cu particles in the composite prepared by horizontal ball mill at lower loading whereas agglomerates were observed in the composites containing higher Cu loading. Microhardness of composites increases with increasing Cu content, i.e., about 60 % microhardness was increased at 40 wt.% Cu. Fracture energy and impact toughness were increased nearly 50 % compared to pure PP matrix.The percentage elongation of the pure PP sample prepared by injection molding with water cooling was higher than the sample prepared without water cooling.Tensile strength decreased (from 13.8 to 12.6 MPa) with increasing Cu content, as bonding strength appears to be poor, and Cu behaves as stress arising points.By the addition of Cu in the matrix ductility decreases and brittle failure was observed at higher concentration.

ACKNOWLEDGEMENT

Authors would like to thank University Grant Commission (UGC), Delhi, India for funding this research work

REFERENCES

[1]. K. B. Cheng, S. Ramakrishna, K. C. Lee. *Electromagnetic shielding effectiveness of copper/glass fiber knitted fabric reinforced polypropylene composites. Composites*: *Part A 31* (2000) 1039–1045
[2]. D. D. L. Chung. *Materials for electromagnetic interference shielding. Journal of Materials Engineering and Performance*. 93 (2000) 350-354
[3]. X. Xia, S. Cai, C. Xie. Preparation, *structure and thermal stability of Cu/LDPE Nanocomposites. Materials Chemistry and Physics*. 95 (2006) 122–129
[4]. S. Moritomi, T. Watanabe, S. Kanzaki. *Polypropylene Compounds for Automotive Applications. Petrochemicals Research Laboratory*. I (2010) 2-14
[5]. C. Zwehen. Polymer Matrix Composites, chapter 12, *Advanced Materials by Design*. Contractor report prepared for OTA. (1985) 73-85
[6]. J. D. Idol, R. L. Lehman (Editor). Polymers. Chapter 12: *Materials, The CRC Handbook of Mechanical Engineering*, 2nd Ed., CRC Press. (2004) 8-22
[7]. J. P. Schaffer. (Editor). *Classification and selection of materials. The Science and Design of Engineering Materials'*, 2nd Ed., McGraw-Hill. (2000) 1-19
[8]. F. C. Campbell. (Editor). *Introduction to Composite Materials. Chapter 1, Structural Composite Materials*. (2010) 1-30.
[9]. B. A. Johnson. *Thermally and Electrically Conductive Polypropylene Based Resins for Fuel Cell Bipolar Plates. Michigan Technological University*. 1 (2009) 1-2
[10]. P. J. Jose, S. K. Malhotra, S. Thomas, K. Joseph, K. Goda, M. S. Sreekala. *Macro and Micro composites–State of the Art, New Challenges and Opportunities. Advances in Polymer Composites*. 1 (2012) 1-15
[11]. H. Ishida, J.L. Koenig. *Composite Interfaces. Journal of Polymer Science*. 17 (1979) 615-621
[12]. J. R. Davis. *Copper and Alloys.* ASM Hand Specialty Handbook, ASM International. (2001) 1-600
[13]. P. G. Georgopoulos, A. Roy, M. J. Yonone-Lioy, R. E. Opiekun, P. J. Lioy. *Copper: Environmental Dynamics and Human Exposure Issues*. The International Copper Association. 1 (2001) 27-35
[14]. D. Bikiaris. *Microstructure and Properties of Polypropylene/Carbon Nanotube Nanocomposites. Materials*. 3 (2010) 2884-2946
[15]. T. G. Nieh, W. D. Nix. *Embrittlement of Copper due to segregation of oxygen to grain boundaries. Metallurgical Transactions*. 12 (1981) 893-901
[16]. D. Anderson & H. T Michels. *Antimicrobial regulatory efficacy testing of solid copper alloy Metal Ions in Biology and Medicine*. 10 (2008) 185-190.
[17]. http://www.zeusinc.com/technicalservices/technicalbulletins/technicalnewsletters.aspx downloaded on 20/06/2012
[18]. C. E. Carraher, R. B. Seymour. *Polymer chemistry*. Marcel Dekker, Inc. 6th edition. (2003) 43–45
[19]. N. Patil, L. Balzano, G. Portale, S. Rastogi. *A study on the chain particle interaction and aspect ratio of nanoparticles on structure development of a linear polymer. Macromolecules.* 43 (16) (2010) 6749-6759
[20]. Kalpakjian, Schmid. *Polymer Properties. Manufacturing Processes for Engineering Materials*, 5th edition, Pearson Education. 2008 1-55
[21]. T. G. Río, A. Salazar, J. Rodríguez. *Effect of strain rate and temperature on tensile properties of ethylene–propylene block copolymers. Materials and Design*. 42 (2012) 301–307
[22]. M. S. Nurul, M. Mariatti. *Effect of thermal conductive fillers on the properties of Polypropylene composites. Journal of Thermoplastic Composite Materials.* (2011) 1–13
[23]. S. Y. Lee, I. A. Kang, G. H. Doh, W. J. Kim, J. S. Kim, H. G. Yoon, Q. Wu. *Thermal, mechanical and morphological properties of polypropylene/clay/wood flour Nanocomposites. Express Polymer Letters*. 2 (2008) 78–87

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

[24]. M. A. Mohammed. *Mechanical Behavior for Polymer Matrix Composite Reinforced By Copper Powder. Nahrain University*, College of Engineering Journal (NUCEJ). 14-2 (2011) 160-176
[25]. S. Sahin, P. Yayla. *Effects of testing parameters on the mechanical properties of polypropylene random copolymer. Polymer Testing*. 24 (2005) 613–619
[26]. A. Akinci. *Mechanical and structural properties of polypropylene composites filled with graphite flakes. Archives of Materials Science and Engineering*. 35 (2) (2009) 91-94
[27]. M. Altan, H. Yildirim, A. Uysal. *Tensile Properties of Polypropylene/Metal Oxide Nano Composites. Journal of Science and Technology*. 1 (2011) 25-30
[28]. M. N. Silberstein. Mechanics of Notched Izod Impact Testing of Polycarbonate. UG Thesis submitted to Massachusetts Institute of Technology. (2005) 2-21
[29]. T. Kimerling. Injection molding cooling time reduction and thermal stress analysis. ASME. (2012) 1-5
[30]. T. A. Siewert, M. P. Manahan, C. N. MCowan, J. M. Holt, F. J. Marsh, E. A. Ruth. The History and Importance of Impact Testing. Pendulum Impact Testing: A Century of Progress, ASTM STP, 1380 (1999) 1-16
[31]. J. A. Molefi, A. S. Luyt, I. Krupa. Comparison of the influence of Cu micro and nano particles on the thermal properties of polyethylene/Cu composites. Express Polymer Letters. 3-10 (2009) 639–649
[32]. M. Bilewicz, J. C. Viana, A. M. Cunha, L. A. Dobrzański. Morphology diversity and mechanical response of injection molded polymer Nanocomposites and polymer-polymer composites. Journal of Achievements in Materials and Manufacturing Engineering. 15 (1-2) (2006) 159-165
[33]. L. A. Dobrzański, M. Król, M. Bilewicz, J. C. Viana. Microstructure and mechanical properties of Polypropylene/Polycarbonate blends. Journal of Achievements in Materials and Manufacturing Engineering. 27 (1) (2008) 19-22
[34]. L. A. Dobrzański, M. Bilewicz, J. C. Viana. Polymer Nanocomposites reinforced with montmorillonite. Archives of Materials Science and Engineering. 53 (1) (2012) 5-28
[35]. J. C. Viana, L. A. Dobrzañski, M. Bilewicz. Mechanical approach of PP/MMT polymer nanocomposite. Archives of Materials Science and Engineering. 43 (2) (2010) 94-100
[36]. R. W. Evans. Design guidelines for shielding effectiveness, current carrying capability, and enhancement of conductivity of composite materials. NASA Report. (1997) 47-84.
[37]. Y. P Mamunya, V. V. Davydenko, P. Pissis, E. V. Lebedev. Electrical and thermal conductivity of polymers filled with metal powders. European Polymer Journal. 38 (2002) 1887–1897
[38]. A. Boudenne, L. Ibos, M. Fois, J. C. Majeste, E. GeHin. Electrical and thermal behavior of polypropylene filled with copper particles., Composites: Part A, 36 (2005) 1545–1554
[39]. D. L. Gaxiola. Characterization of thermal and mechanical properties of polypropylene–based composites for fuel cell bipolar plates and development of educational tools in hydrogen and fuel cell technologies. Ph. D Thesis submitted to Michigan Technological University. (2011) 26-42
[40]. A. S. Luyt, J. A. Molefi, H. Krump. Thermal, mechanical and electrical properties of copper powder filled low-density and linear low-density polyethylene composites. Polymer Degradation and Stability. 91 (2006) 1629-1636
[41]. Y. Li, S. Wang, Y. Zhang, Y. Zhang. Electrical Properties and Morphology of PP/Epoxy/Glass fiber composites filled with carbon black. Wiley Inter Science. 22-105 (2005) 1142-1149
[42]. M. P. Alvarez, V. H. Poblete, M. E. Pilleux, V. M. Fuenzalida. Submicron Copper-Low-Density Polyethylene Conducting Composites: Structural, Electrical and Percolation Threshold. Applied Composite Materials. 5 (2008) 375-379
[43]. H. Serkantekce, D. Kumlutas, I. H. Tavman. Effect of Particle Shape on Thermal Conductivity of Copper Reinforced Polymer Composites. Journal of Reinforced Plastics and Composites. 26 (2007) 113-121
[44]. J. Biagiotti, S. Fiori, L. Torre, M. A. L. Manchado, J. M. Kenny. Mechanical Properties of Polypropylene Matrix Composites Reinforced With Natural Fibers: A Statistical Approach. Plastic Engineering. 4 (1994) 2-31
[45]. M. M. Gauthier (Editor). Injection Molding in Engineered Materials. Handbook Desk Edition. (1995) 299-307
[46]. R. K. Goyal, K. R. Kambale, S. S. Nene, B. S. Selukar, Arbuj, U. P. Mulik. Fabrication, thermal and electrical properties of PPS/Copper composites. Materials Chemistry and Physics. 128 (2011) 114–120
[47]. M. G. Kulthe and R. K. Goyal. Microhardness and electrical properties of PVC/Cu composites prepared by ball mill. Advanced Material Letters. 3 (3) (2012) 246-249
[48]. N. Parvin, S. Ullah, F. Mina, A. Gafur. Structures and mechanical properties of talc and carbon black reinforced high density polyethylene composites: effects of organic and inorganic fillers. Journal of Bangladesh Academy of Sciences. 37 (1) (2013) 11-20
[49]. A. Belashi. Percolation modeling in polymer Nanocomposites. Ph. D Thesis submitted to University of Toledo. (2011) 55--95

BIOGRAPHY

Mahesh A Kori, Post Graduate student, Department of Metallurgy and Materials Science, College of Engineering, Pune(COEP), Has completed B. E degree in Mechanical Engineering, Visvesariah Technological University, Belgum, Karnataka, India in 2008. He is a Gold Medal reciepnt from National Design and Research Forum (NDRF)-2007, in Metallurgy and material science from IEI, Kolkatta, India and has won many prizes in International and national confernces. He has 4 yearsindustrial and 6 years of teaching experience. His area of research interest is in Tribology, polymer matrix, Mechanical Metallurgy.

IJIRSET

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

Manisha G. Kulthe obtained M.E. in Physical Metallurgy from Department of Metallurgy and Materials Science, College of Engineering, Pune, India in 2004. She obtained B. E. degree in Metallurgical Engineering, from Visvesvaraya Regional College of Engineering (Now, NIT), Nagpur, India in 2002. She joined Department of Metallurgy and Materials Science, College of Engineering, Pune (COEP), India as a Lecturer in 2005. She has also worked as a Research Associate in Tata Research Development and Design Centre (TRDDC), Pune for 1 year. She has published about 6 papers in national and international journals and conferences. She is Principal Investigator of research project sponsored by UGC, India. Herinteresting research area is polymer matrix micro- and nanocomposites.

Rajendra Kumar Goyal received Ph.D. in Materials Science from the Indian Institute of Technology Bombay, Mumbai, India in 2007. He was awarded Best Ph.D. Thesis Prize in Materials Science for the year 2007 by the Materials Research Society of India (MRSI). He obtained B.E. in Metallurgical Engineering from Malviya Regional Engineering College (now, NIT) Jaipur, University of Rajasthan, India in 1996. Presently, he is an Associate Professor in the Department of Metallurgy and Materials Science, College of Engineering, Pune (COEP), India. He also has research and industrial experience of more than 12 years. He has published over 70 papers in national and international peer-reviewed journals and conferences. His students have won several awards/prizes for the research work presented in international/national conferences. He is reviewer of many internationaljournals. He is Principal Investigator of research projects sponsored by ISRO and UGC, India. His main research area is polymer composites/nanocomposites, nanomaterials, characterization of materials, electronic materials, structure-properties relationship etc.