Dielectric properties of microwave assisted ABS/OMMT nanocomposite for fused deposition modelling

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Abstract:

Fused deposition modelling technique provides an economical platform to fabricate polymeric components. Any complex geometry can be easily fabricated with this technology as per the computer-aided-design model. However, the materials are limited for the process as compared with other polymer manufacturing techniques. The present papers present an approach to form a composite material. The dielectric properties were extracted for the developed material and also characterised using SEM and XRD techniques.

Introduction:

Additive manufacturing is a layer manufacturing technique which fabricates the desired part from bottom to top. The application of AM is not limited to production of mechanical parts, but it has also spread its domain in the area of surgical planning and biomedical implants. AM technology can be broadly classified based on their working principle as- Laser sintering, Adhesion, Lithography and Extrusion 1-8]. However extrusion based AM technology like Fused Deposition Modelling have an edge over others in terms of less material wastage, minimal post processing, safe and simple fabrication process. Fused deposition modelling (FDM) builds objects directly from a three dimensional computer aided design (CAD) models. The thermoplastic material is fed to the temperature controlled extrusion head, where it is heated to a semiliquid state; the extrusion head then deposits the material on the build platform, one layer at a time [9-15]. Each layer is bonded with the previous layer, as the temperature of the air surrounding the extrusion head is maintained below the melting point of the material [2]. Figure 1 shows the schematic diagram of FDM process.

The material properties of the available polymers is limited which hinders the application of 3D printed parts [16-19]. The present paper focuses on the extraction of dielectric properties of 3D printed parts via fused deposition modelling technique. The polymer filament was coated with the nanoparticles of organically modified montmorillonite (OMMT).

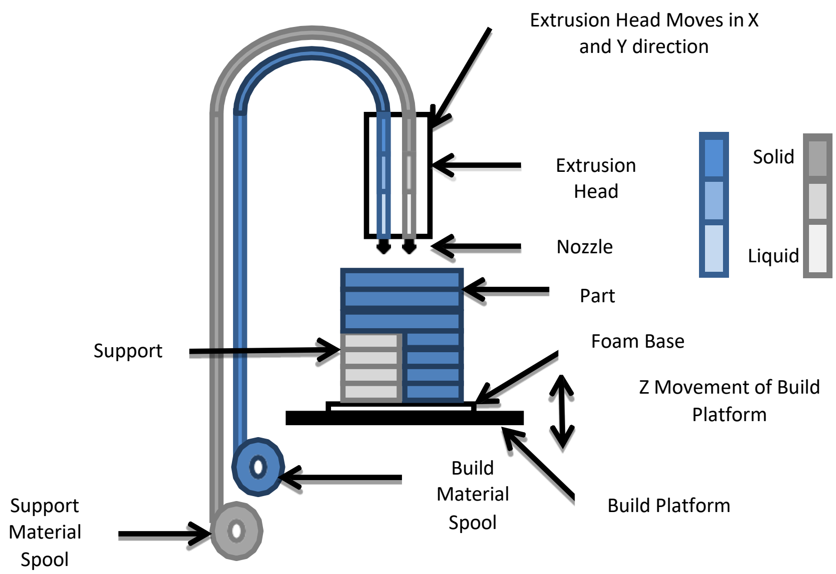

Figure 1 Schematic Diagram of FDM Process

Materials and Methods

Organically modified Montmorillonite (OMMT) was used for the preparation of nanocomposite with acrylonitrile butadiene styrene (ABS). The nanocomposite was prepared by dip coating method. The ommt solution was prepared and ABS filament was dip coated over it [20-27].

Results and discussions

Extraction of Dielectric Properties

The dielectric properties were extracted by fabricating microstrip tee resonator [28-29]. The effective permittivity was calculated as follows:

$$\varepsilon_{eff} = \left(\frac{(2n-1)c}{4f_o(l+\Delta l)}\right)^2$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}(1+12(^h/_w))^{-0.5}$$

$$Q_L = f_o/(f_h - f_l)$$

$$Q_u = Q_L \Big/ \sqrt{1 - 2 * 10^{-(l_a/10)}}$$

$$\alpha_0 = \frac{8.686\,\pi\, f_0\,\sqrt{\varepsilon_{eff}}}{cQ_u}$$

Increment in relative permittivity was observed for the nanocomposite along with the loss tangent (figure 3).

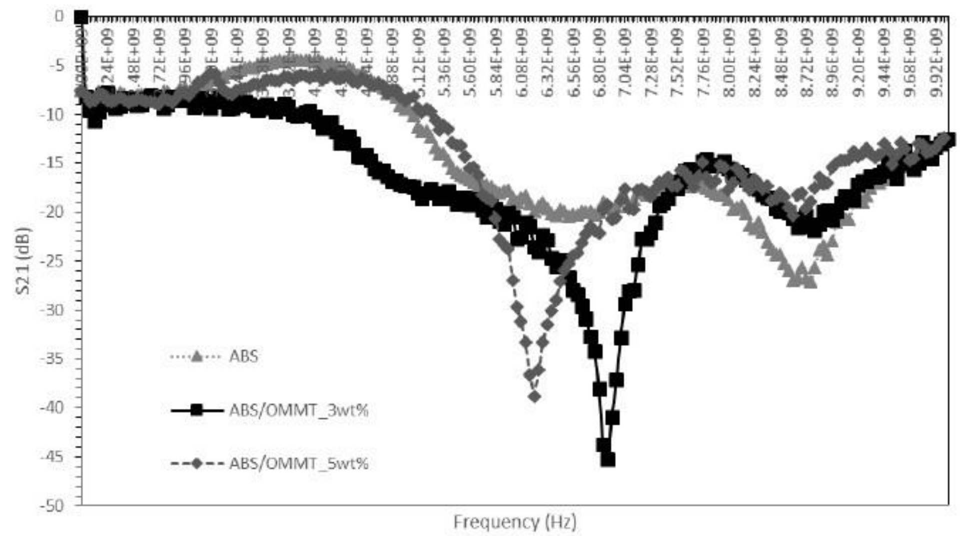

Figure 2 S21 vs frequency plot for tee resonator

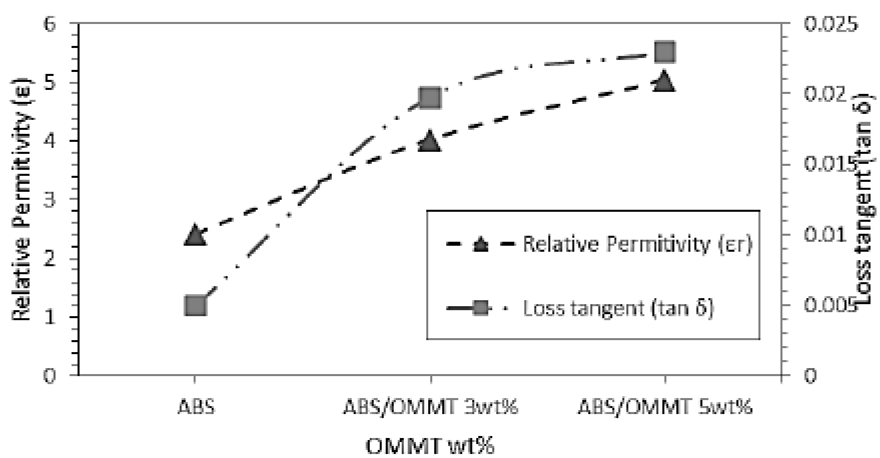

Figure 3 relative permittivity and loss tangent

Material characterization

Scanning electron microscopy and X-ray diffraction were performed to characterize the nanocomposite. In the developed nanocomposite the characteristic peak of nanoclay was reduced which can be an indication of possible exfoliation Figure 4.

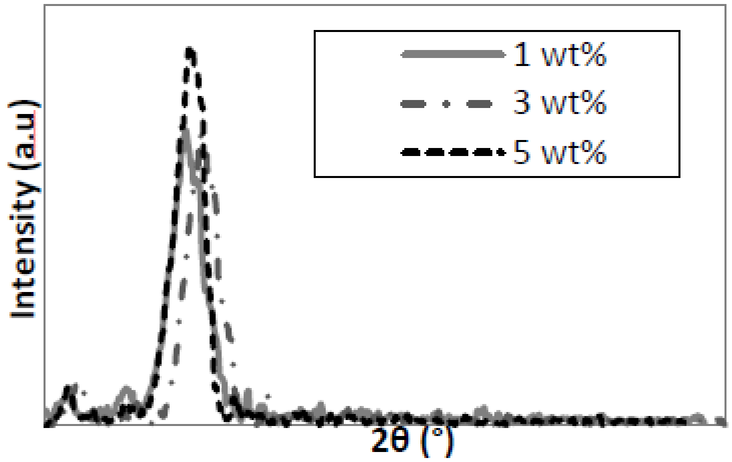

Figure 4 XRD of nanocomposite

The SEM images revealed the presence of nanoclay on the surface of the fabricated parts. Figure 5 shows the bright clay particles in the SEM images.

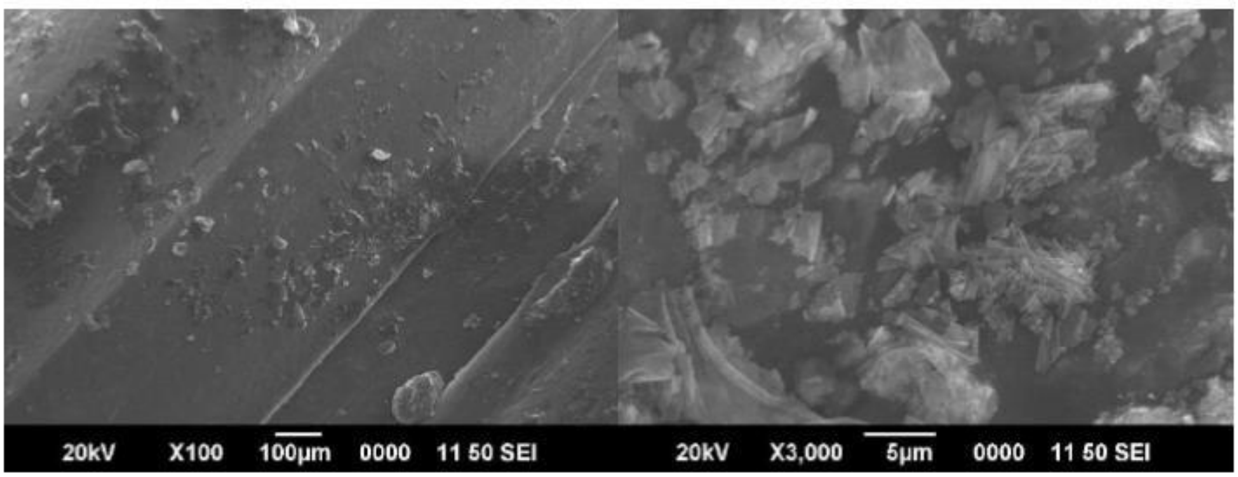

Figure 5 SEM image of nanocomposite

Conclusion

Microwave assisted ABS/OMMT nanocomposite was prepared for FDM process. The developed nanocomposite demonstrated increment in relative permittivity along with the loss tangent. The XRD analysis and SEM analysis showed evidence of formation of nanocomposite. The presented approach can be effectively used to coat the polymer filament with nanoparticles in order to enhance their material properties.

References

[1] Bellehumeur Céline, Longmei Li, Qian Sun, P.G., 2004. Modeling of Bond Formation between Polymer Filaments in the Fused Deposition Modeling Process. Journal of Manufacturing Processes, 6(2), pp.170–178.

[2] Belter, J.T. & Dollar, A.M., 2015. Strengthening of 3D Printed Fused Deposition Manufactured Parts Using the Fill Compositing Technique. PLoS ONE, 10(4), pp.1–19.

[3] Chua C.K., Leong K.F., L.C.S., 2003. Rapid prototyping principles and Applications 2nd ed., Singapore, world scientific.

[4] Francis, V. & Jain, P.K., 2015. Advances in nanocomposite materials for additive manufacturing. International journal of rapid manufacturing, 5(3/4), pp.215–233.

[5] Francis, V. & Jain, P.K., 2016. Experimental investigations on fused deposition modelling of polymer-layered silicate nanocomposite. Virtual and Physical Prototyping, 11(2), pp.109–121.

[6] Gurrala, P.K. & Regalla, S.P., 2016. Part strength evolution with bonding between filaments in fused deposition modelling Part strength evolution with bonding between filaments in fused deposition modelling, 9(3), pp.141–149.

[7] Jain, P.K., Pandey, P.M. & Rao, P.V.M., 2009. Selective Laser Sintering of Clay-Reinforced Polyamide. Polymer Composites, 31, pp.732–743.

[8] Jain, P.K., Pandey, P.M. & Rao, P.V.M., 2010. Tailoring material properties in layered manufacturing. Materials & Design, 31(7), pp.3490–3498. Available at: http://dx.doi.org/10.1016/j.matdes.2010.02.029.

[9] Kontopoulou, M., 1998. The role of viscoelasticity in polymer sintering. rheol Acta, 37, pp.270–278.

[10] Kumar, A., Ohdar, R.K. & Mahapatra, S.S., 2009. Improving dimensional accuracy of Fused Deposition Modelling processed part using grey Taguchi method. Materials and Design, 30(10), pp.4243–4252. Available at: http://dx.doi.org/10.1016/j.matdes.2009.04.030.

[11] Lederle, F., Meyer, F. & Christian, G.B., 2016. Improved mechanical properties of 3D-printed parts by fused deposition modeling processed under the exclusion of oxygen. progress in additive manufacturing, 1(3).

[12] Masood, S.H. & Song, W.Q., 2004. Development of new metal/polymer materials for rapid tooling using Fused deposition modelling. Materials and Design, 25(7), pp.587–594.

[13] Nikzad, M., Masood, S.H. & Sbarski, I., 2011. Thermo-mechanical properties of a highly filled polymeric composites for Fused Deposition Modeling. Materials and Design, 32(6), pp.3448–3456. Available at: http://dx.doi.org/10.1016/j.matdes.2011.01.056.

[14] Ning, F. et al., 2015. Additive manufacturing of carbon fi ber reinforced thermoplastic composites using fused deposition modeling. Composites Part B, 80, pp.369–378. Available at: http://dx.doi.org/10.1016/j.compositesb.2015.06.013.

[15] Pegoretti, A. et al., 2016. Fused deposition modeling with ABS-graphene nanocomposites. Composites Part A, 85, pp.181–191.

[16] Rocha, C.R., Perez, A.R.T. & Roberson, D.A., 2014. Novel ABS-based binary and ternary polymer blends for material extrusion 3D printing. journal of materials research, 29(17), pp.1859–1866.

[17] Singh, H. garg and rupinder, 2016. Investigations for melt flow index of Nylon6-Fe composite based hybrid FDM filament. Rapid Prototyping Journal, 22(2), pp.338–343.

[18] Singh, P. & Ghosh, A.K., 2014. Torsional , tensile and structural properties of acrylonitrile – butadiene – styrene clay nanocomposites. , 55, pp.137–145.

[19] Singh, R. & Singh, S., 2014. Development of Nylon Based FDM Filament for Rapid Tooling Application. Journal of The Institution of Engineers (India): Series C, 95(2), pp.103–108.

[20] Sinha Ray, S. & Okamoto, M., 2003. Polymer/layered silicate nanocomposites: A review from preparation to processing. Progress in Polymer Science (Oxford), 28(11), pp.1539–1641.

[21] Siqueiros, J.G. et al., 2016. ABS-maleated SEBS blend as a 3D printable material. virt, 11(2), pp.123–131.

[22] Skorski, M.R. et al., 2016. The chemical , mechanical , and physical properties of 3D printed materials composed of TiO 2 -ABS nanocomposites. Science and Technology of Advanced Materials, 6996(June), pp.89–97.

[23] Sun, Q. et al., 2008. Effect of processing conditions on the bonding quality of FDM polymer filaments. Rapid Prototyping Journal, 14(2), pp.72–80.

[24] Taufik, M. & Jain, P.K., 2016. A Study of Build Edge Profile for Prediction of Surface Roughness in Fused Deposition Modeling. Journal of Manufacturing Science and Engineering, 138(6), p.061002.

[25] Turner, B.N. et al., 2014. A review of melt extrusion additive manufacturing processes : I . Process design and modeling. Rapid prototyping, 20(3), pp.192–204.

[26] Weng, Z. et al., 2016. Mechanical and thermal properties of ABS/montmorillonite nanocomposites for fused deposition modeling 3D printing. Materials & Design, 102, pp.276–283.

[27] Zhong, W. et al., 2001. Short fiber reinforced composites for fused deposition modeling. , 301, pp.125–130.

[28] M. Kirschning, R.H. Jansen, and N.H.L. Koster, Accurate model for open-end effect of microstrip lines, Electron Lett 17 (1981), 123–125.

[29] Y.H. Chou, M.J. Jeng, Y.H. Lee and Y.G. Jan, Measurement of RF PCB Dielectric Properties and Losses, Progress In Electromagnetics Research Letters, 4 (2008), pp. 139-148.