NC STATE UNIVERSITY
Wilson College of Textiles
Department of Textile Engineering, Chemistry and Science

Fabricating 3D Printed Nanocomposites Using Continuous CNT Filaments by Modified Fused Deposition Modelling (FDM) Technology

Patrapee Kungsadalpipob, Mostakima Mafruha Lubna, Philip Bradford

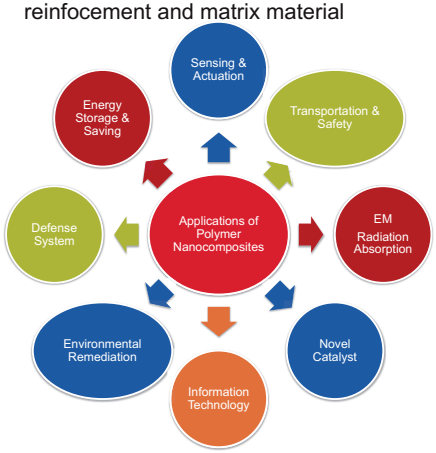
BRADFORD RESEARCH GROUP
Advancing Carbon Nanotube Textiles

Abstract

- We develop and modify a commercial desktop 3D printing process capable of printing continuous carbon nanotube (CNT) filament reinforced nanocomposites. In the initial state of research, we impregnated dry-CNT filament in-situ with polymer (PLA) filament. To solve printability issues, our approaches are: 1) to investigate the CNT-polymer interface incompatibility, 2) to modify the machine for co-extrusion and 3) to incorporate fusion design in the heating zone of the machine. This research will characterize continuous CNT 3D printed structure's printability, morphology and fiber orientation using SEM, as well as its thermal properties using DSC and TGA.

Why Nanocomposites?

- High aspect ratio
- Large surface area
- High interfacial adhesion between reinfocement and matrix material

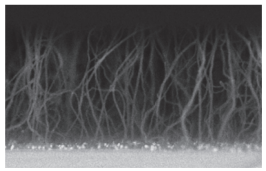


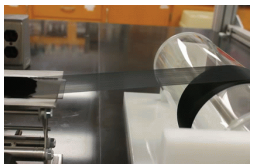
- TiO_2, graphene nanoplatelets, and carbon nanotubes (CNTs) are the top selection for reinforcing nanomaterials due to the improvement in mechanical strength of composites parts. Moreover, they may show unique functionality properties.

Core Objective: Develop and modify a commercial desktop 3D printing process suitable for printing continuous carbon nanotube (CNT) filament reinforced nanocomposites.

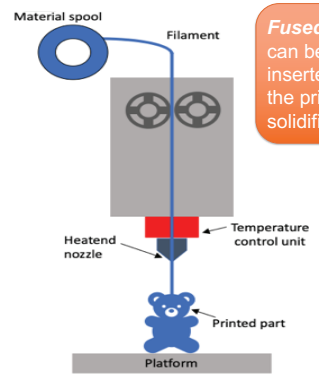
What is "Spinnable CNTs" ?

We grow vertically aligned multiwalled carbon nanotubes (CNTs) using the Chemical Vapor Deposition process (CVD). This CNTs is called "Spinnable CNTs" because it can be spun continuously as yarns/sheets/fibers which can be incorporated in other matrices





3D printed Nanocomposites using FDM



Fused deposition modeling (FDM) also called Fused filament fabrication (FFF) can be categorized as an extrusion-based process where thermoplastic filament is inserted into the machine which has been pre-heated by the heating zone inside the printer. The molten polymers are then extruded through the nozzle and solidified on the substrate or previously printed surface

☺ Advantages

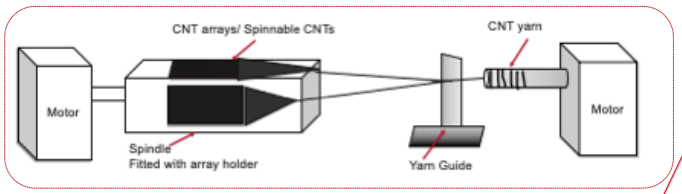
- Yield component with complex gerometries and functionalities
- High level of control of the processing conditions
- Wide range of scalability

☹ Limitations

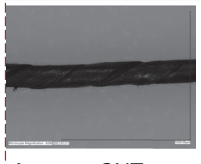
- Lower mechanical strength compared with conventional fabrication technique
- Challenging to incorporate additive materials espacially continuous fiber reinforced structure

Materials and Methods

CNT Yarn Preparation

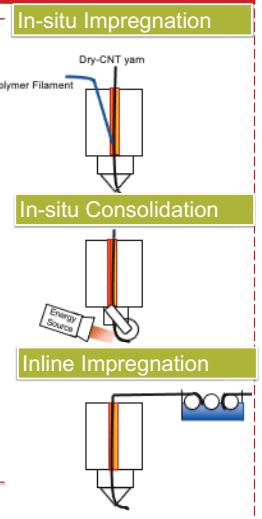


Fabrication of 3D printed CNT/Polymer Nanocomposites



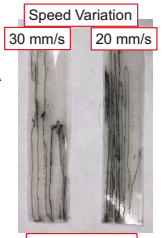
As-spun CNT yarns and 1.85 mm. diameter commercial PLA filament is fabricated by ROBO 3D™ R1 plus FDM printer

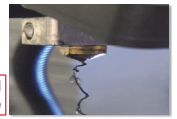
Machine Modification



Results

- We successfully impregnated dry-CNT filament in-situ with the PLA filament. Initial results indicated some problems associated with the continuity of the CNT filaments/yarns. A few possible reasons are 1) viscosity drag of molten polymer, 2) pulling rate mismatch and 3) surface incompatibility between dry CNTs and polymer





Conclusions

- The 3D printed CNT yarns/PLA nanocomposites have been in-situ impregnated, but need further machine modification to reach better printability

Discussion of possible future research

- Investigate the CNT-polymer interface incompatibility
- Modify the machine design for co-extrusion
- Incorporate fusion design in the heating zone of the machine

Acknowledgement

- Dr. Philip Bradford's Carbon Nanotube Research group members
- Judy Elson, for the use of Stereo Microscope
- Hai Bui, for the use of machining equipment

References

Zhao, H., Zhang, Y., Bradford, P. D., Zhou, Q., Jia, Q., Yuan, F., & Zhu, Y. (2010). Carbon nanotube yarn strain sensors. *Nanotechnology, 21*(30), 305502. doi:10.1088/0957-4484/21/30/305502