Energy Harvesting Using High-Strength and Flexible 3D-Printed Cellulose/Hexagonal Boron Nitride Nanosheet Composites

Anjali Jayakumar[1,2]
Rushikesh S. Ambekar[2], Preeti Lata Mahapatra[2], Appu Kumar Singh[2], Tarun Kumar Kundu[2], Sreeram P R[2], Rahul R. Nair[1] and Chandra Sekhar Tiwary[2]
[1]*The University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom*
[2]*Indian Institute of Technology Kharagpur, West Bengal 721302, India*
anjali.jayakumar@postgrad.manchester.ac.uk

As a natural polymer, cellulose is abundant, low-cost, robust, and biodegradable and can be chemically modified. This work [1] explores the enhancement of mechanical, thermal, and flexoelectric properties of three-dimensional (3D)-printed carboxymethyl cellulose (CMC) due to the addition of mechanically exfoliated hexagonal boron nitride (hBN). hBN was observed to act as a rheology modifier, and CMC reinforced with 2% hBN exhibited the maximum apparent viscosity of 12.24 Pa·s at a shear rate of 100 s^{-1}. The 0.5% hBN/CMC film exhibited the highest mechanical and thermal stability. A flexoelectric energy harvester was fabricated out of 3D-printed hBN/CMC composites to test the effectiveness of strain-induced charge production. By varying the load resistance and applied pressure, we were able to measure the voltage and current flowing through the device. We found that a load resistance of 180 kΩ connected across a 2% hBN/CMC device resulted in the highest power delivery of 5.5 nW. When mechanical strain is applied, a charge state fluctuation and spontaneous polarization in the hBN/CMC matrix are seen. This phenomenon can be explained based on the flexoelectric energy-harvesting mechanism, supported by density functional theory (DFT) calculations.

References

[1] Anjali Jayakumar, Rushikesh S. Ambekar, Preeti Lata Mahapatra, Appu Kumar Singh, Tarun Kumar Kundu, Sreeram P R, Rahul R. Nair, and Chandra Sekhar Tiwary. ACS Applied Nano Materials. 6 (2023) 14278-14288.

Figures

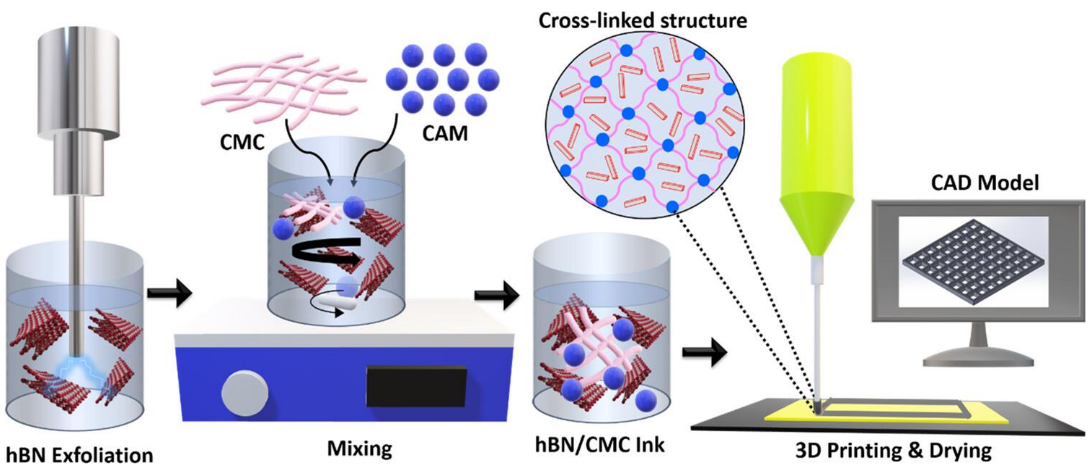

Figure 1: 2D hBN/CMC Composite Ink Formulation with citric acid monohydrate (CAM) as cross-linker and 3D printing process of model generated using a Computer-aided design (CAD) software [1]