Development of cohesive Exfoliated h-BN-CuS Nanosheets through Ultrasonic Approach for Hybrid Supercapacitors

Dhamodharan Krishnamoorthy[a], Richa Chaudhary[b], Varun Chaudhary[b], Abhishek Kumar Singh[a*]

[a]Department of Physics, School of Advanced Sciences, Vellore Institute of Technology, Vellore-632014, Tamil Nadu, India.

[b]Industrial and Materials Science, Chalmers University of Technology, SE-41296, Gothenburg, Sweden

*Corresponding author E-mail: abhishek.kumar@vit.ac.in

1. Synthesis Procedure

1.1. Preparation of exfoliated hexagonal boron nitride nanosheets

To begin with, a boron nitride powder was well granulated over 25 minutes employing mortar and pestle. These grainy powders were shifted into a glass tube, including distilled water and isopropyl alcohol in a 1:4 ratios, subsequently sonicated for 12 hrs from an ultrasonic bath. Following that, a dispersed solution was collected that was centrifuged to acquire a supernatant, which dried in the temperature of 80 °C through an oven for across 12 hrs to generate exfoliated h-BN nanosheets. This kind of process, known to be the LPE approach, makes certain to layer separation from a bulk boron nitride.

2. Characterization analysis

2.1. Raman analysis

Fig. S1 illustrates the Raman spectroscopy studies of bulk h-BN, CuS, exfoliated h-BN, and exfoliated h-BN-CuS NCs which provides their existed vibrational modes. An emergence of two modes in exfoliated h-BN-CuS NCs ascribes to S-S stretching vibration and the E_{2g} mode, wherein the stretching vibration (S-S) implies the presence of CuS and the E_{2g} mode connotes the existence of exfoliated h-BN in the exfoliated h-BN-CuS NCs, which affirms the creation of nanocomposites.

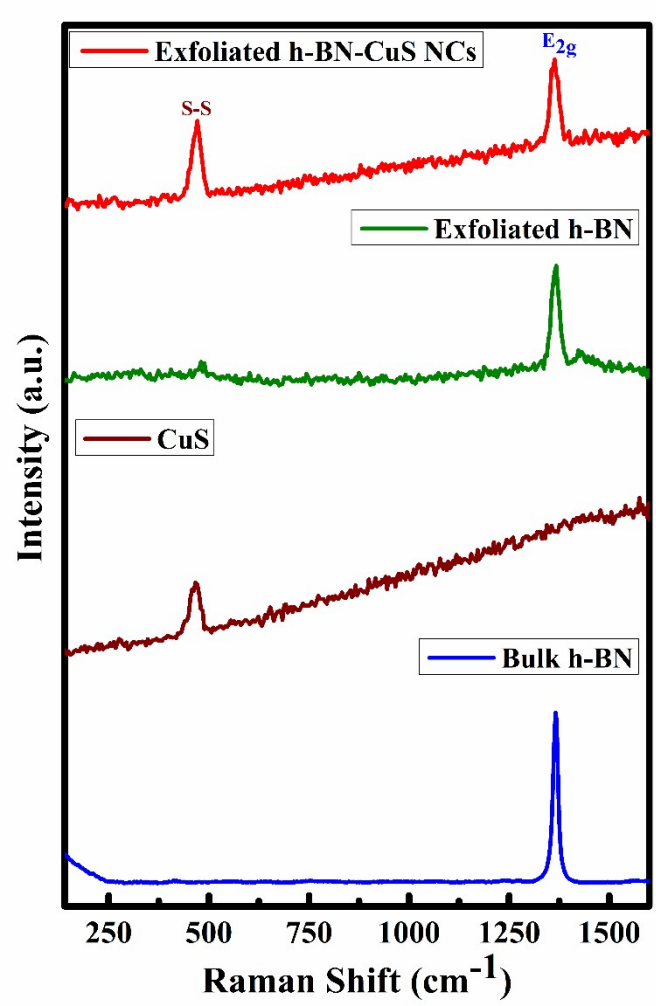

Figure S1. Raman spectra of prepared materials.

XRD and FESEM of bulk h-BN

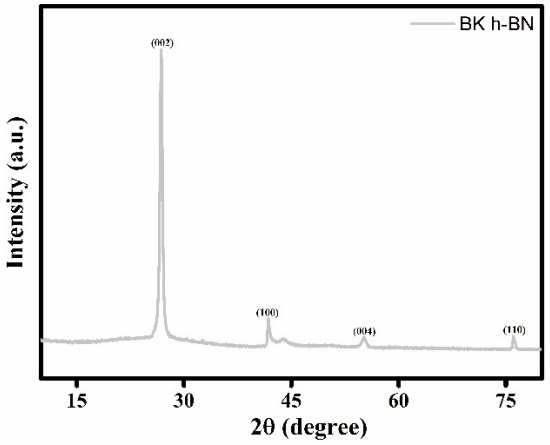

Figure S2. XRD for Bulk h-BN (BK h-BN)

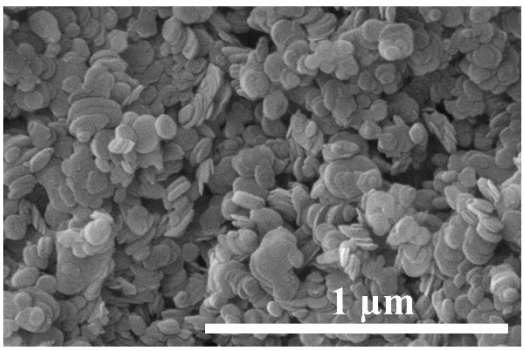

Figure S3. FESEM for BK h-BN

BET analysis of Exd h-BN

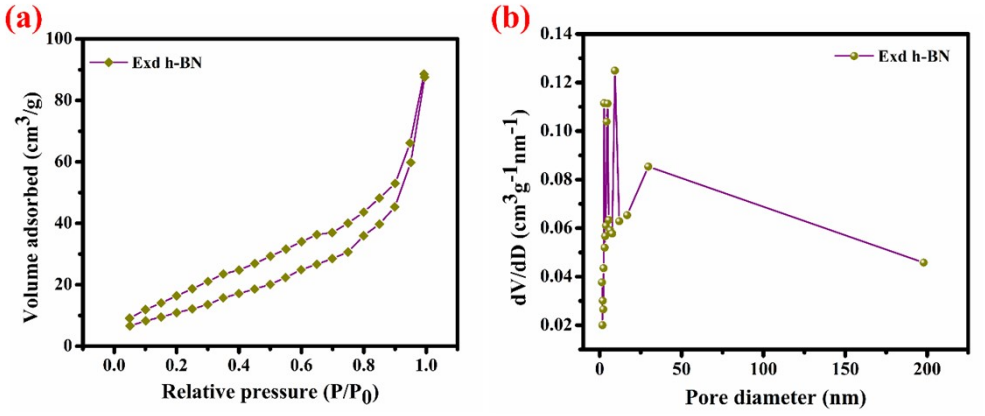

Figure S4. BET analysis for Exd h-BN: (a) Nitrogen adsorption and desorption, and (b) pore size distribution

2.2. Electrochemical analysis in three Electrode system

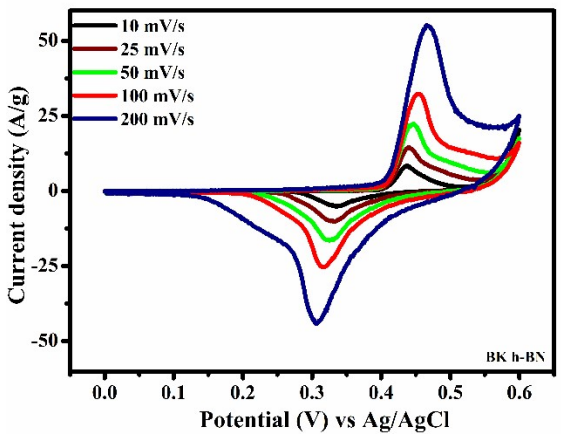

Figure S5. CV for BK h-BN

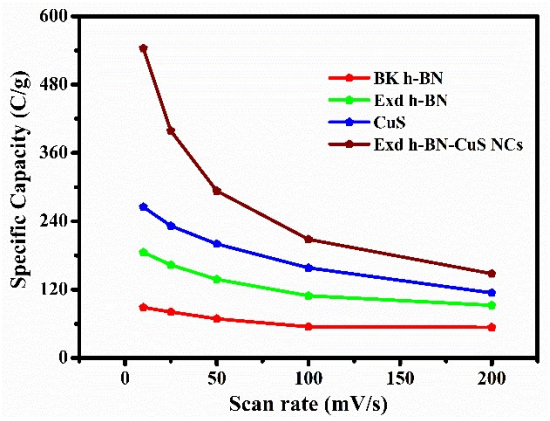

Figure S6. Plot for distinct scan rate with Specific capacity.

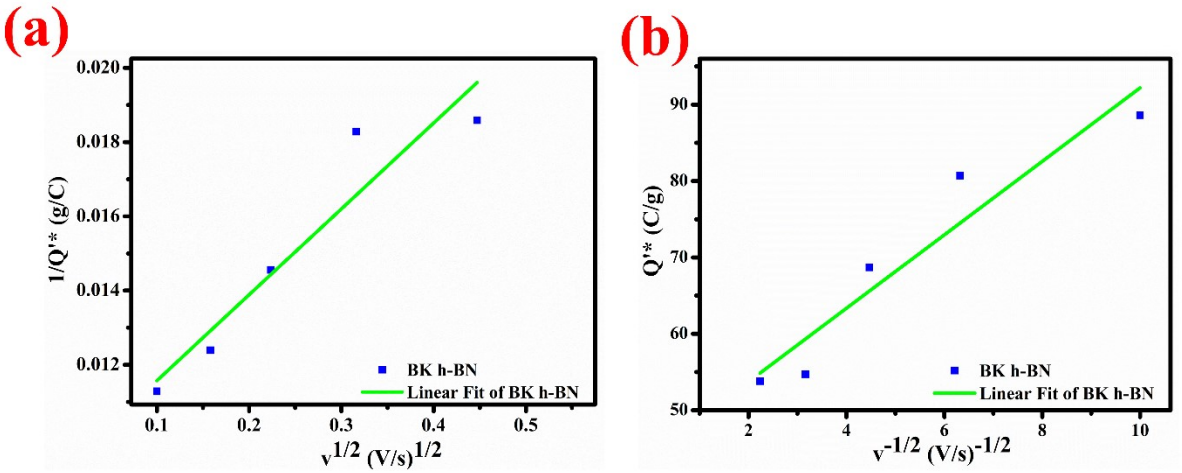

Figure S7. Trassati plot: (a) [$v^{1/2}$ vs $1/Q'^{*}$], and (b) [$v^{-1/2}$ vs Q'^{*}] for BK h-BN.

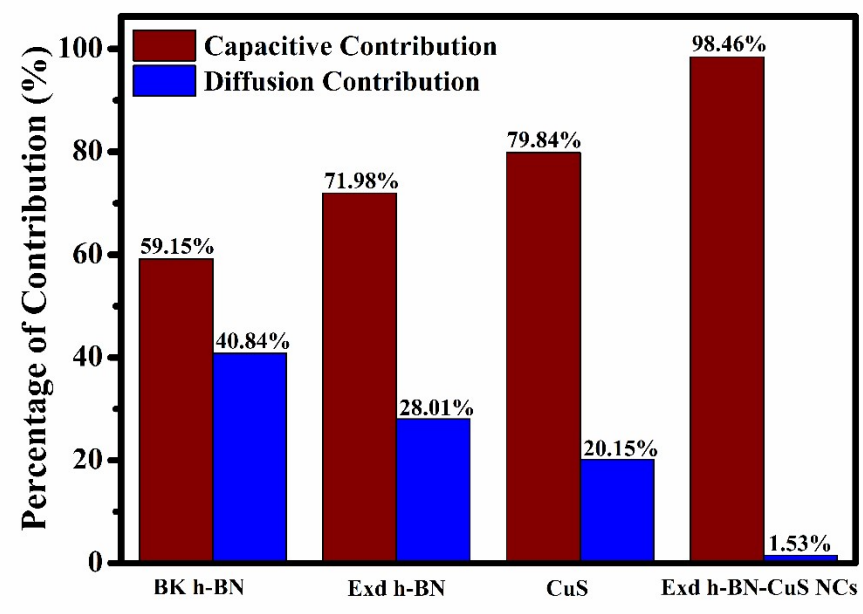

Figure S8. Capacitive-diffusion contribution of active electrodes.

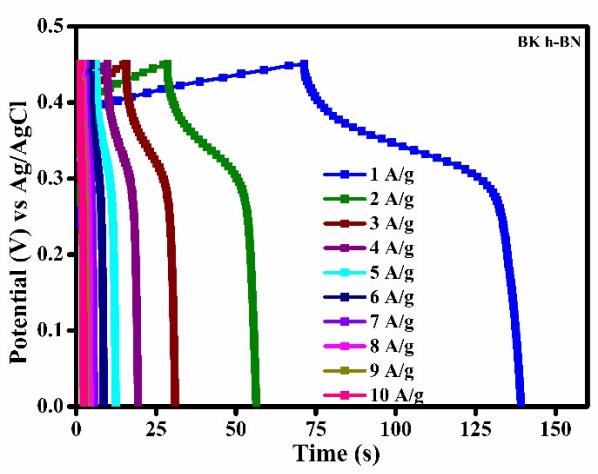

Figure S9. GCD for BK h-BN

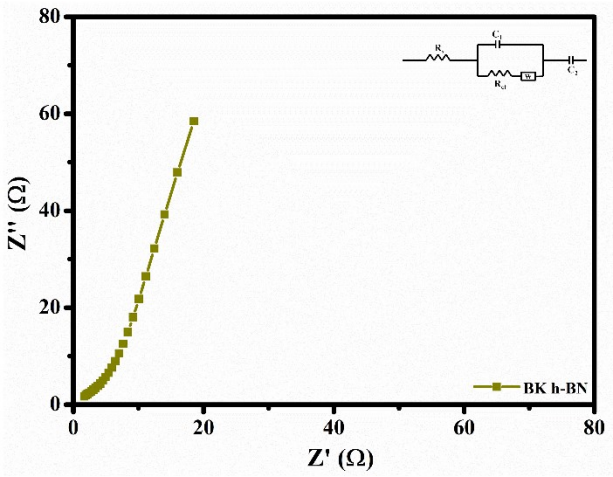

Figure S10. EIS for BK h-BN

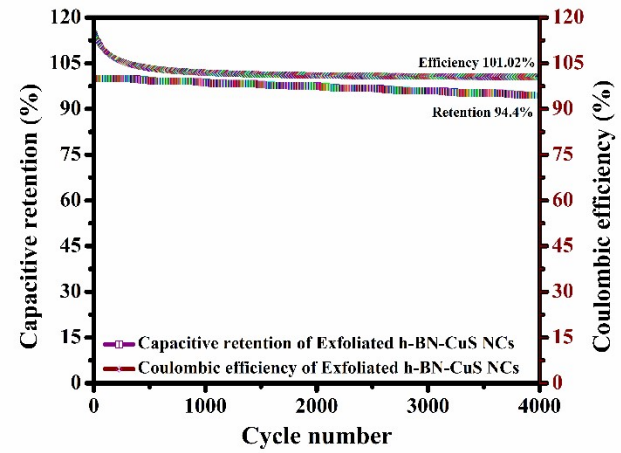

Figure S11. Cyclic stability of Exd h-BN-CuS NCs.

3. After cyclic stability of Exd h-BN-CuS NCs

3.1. XRD

The exfoliated h-BN-CuS NCs were examined in an XRD study after the cyclic test, which disclosed the hkl planes of (002), (101), (102), (110), and (108) that confirm the Exd h-BN-CuS NCs, and additionally two diffraction peaks exist because of the nickel foam substrate deployed. An XRD image was zoomed as displayed in Fig. S12 due to the nickel foam's higher intensity peak.

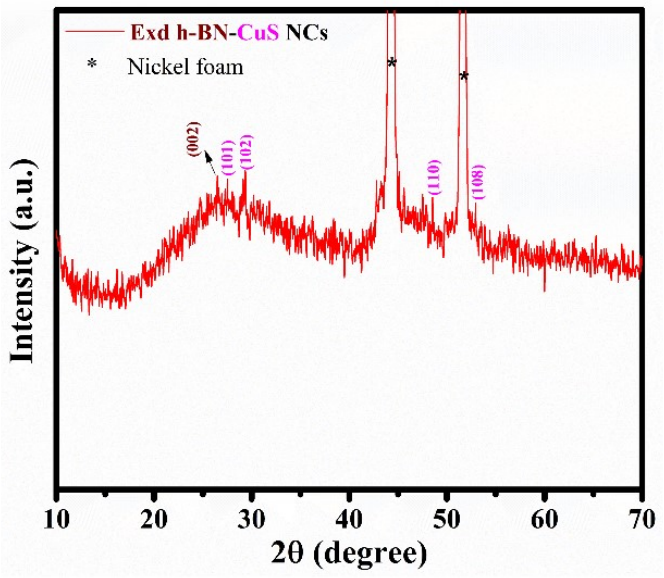

Figure S12. XRD analysis after cyclic stability of Exd h-BN-CuS NCs.

3.2 FESEM

After cyclic stability, an Exd h-BN-CuS NC was analyzed for FESEM to reveal a morphology, as shown in Fig. S13, which displayed combined nanosheets of Exd h-BN and CuS, and also observed that there were minimal changes in morphology after the cyclic test.

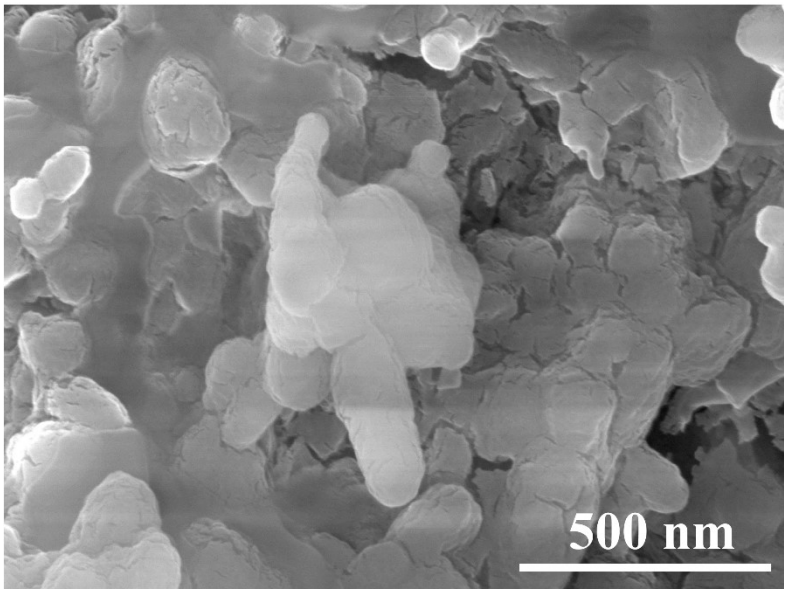

Figure S13. FESEM analysis after cyclic stability of Exd h-BN-CuS NCs.

Table S1. The observed surface area of Exd h-BN-CuS NCs was compared with previous reported articles.

Materials	Morphology	Surface Area (m^2/g)	References
CuS	Nanospheres	65	[1]
Copper molybdenum sulfide	Rounded hollow cube	102.54	[2]
CuS	Nanosheets	169.4	[3]
Nickel/cobalt/copper sulfide	Dodecahedral hollow multi shell	145.5	[4]
CuS	Nanoflowers	150.6	[5]
CuS/C-120	Dense spatial cloud structure	41.3709	[6]
Exfoliated h-BN-CuS NCs	Nanosheets	314.538	This work

References

1. H. Heydari, S.E. Moosavifard, M. Shahraki, and S. Elyasi, *J. Energy Chem* 2017, **26**, 762-767.

2. B.V. Krishna, O.R. Ankinapalli, R.R., Ayyaluri, and J.S. Yu, *J. Energy Storage* 2025, **118**, 116148.
3. M. Naveed, W. Younas, Y. Zhu, S. Rafai, Q. Zhao, M. Tahir, N. Mushtaq, and C. Cao, *Electrochim. Acta* 2019, **319**, 49-60.
4. Z. Andikaey, A.A. Ensafi, B. Rezaei, and J.S. Hu, *Electrochim. Acta* 2022, 420, 140437.
5. A.M. Patil, A.C. Lokhande, N.R. Chodankar, P.A. Shinde, J.H. Kim, and C.D. Lokhande, *J. Ind. Eng. Chem.* 2017, **46**, 91-102.
6. Q. Liu, S. Zhang, and Y. Xu, *Nanomaterials*, 2020, **10**, 1034.