

Supplementary information

Title-Polyaromatic hydrocarbon based carbon copper composites for suppression
of electromagnetic pollution

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Fig.1S: The crystallographic structure of nano-crystalline Cu coated HTPAHs powder (batch B (Cu:C = 0.5)) was determined by TEM and HRTEM images as shown in Fig. 1S(A) and 1S(B), respectively. The low magnification TEM image (Fig. 1S (A)) depicts a dense network of Cu nano-particles coating on HTPAHs. The observed particle size of Cu nano-particle is ~ 30nm. The HTPAHs layers of carbon can be seen clearly in Fig. 1S (A). The selected area electron diffraction (SAED) pattern, shown inset of Fig. 1S (A) reveals poly-crystalline form of Cu nano-particles with 111 plane. The Fig.1S (B) shows HRTEM of nano-crystalline Cu coated HTPAHs powder, showing inter-planer spacing of Cu ~ 0.24nm. The random arrangement of carbon atoms in different directions can be seen in zoomed image of highlighted region shown in inset of Fig. 1S(B), indicating the amorphous nature of HTPAHs. Overall microscopic results show an ultrafine coating of nano-crystalline Cu on HTPAHs¹.

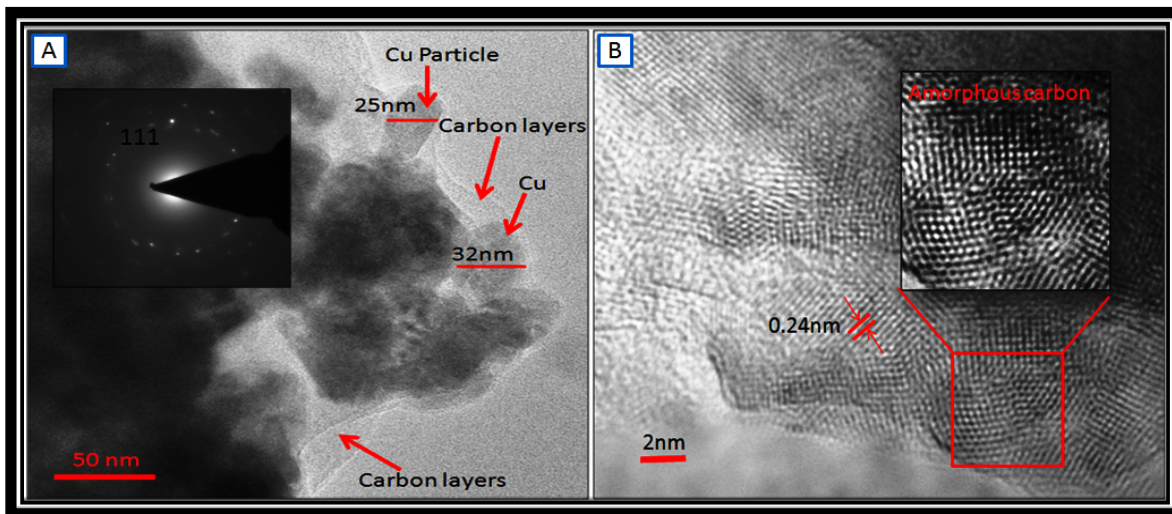


Fig.1S: (A) TEM and (B) HRTEM images of nano-crystalline Cu coated HTPAHs powder (batch B, Cu:C = 0.5). The inset of (A) shows selected area electron diffraction (SAED) pattern with 111 plane and (B) zoomed image of highlighted region.

Fig. 2S: (A) Shows FTIR spectra of HTPAHs and nano-crystalline Cu coated HTPAHs powder (batch B (Cu:C = 0.5)) after 500°C heat treatment. The peak positions at 1218, 1361, 1439 and 1737 cm^{-1} , correspond to the aromatic ether (C-O), aromatic nitro (NO_2) compound, aromatic C=C (sp^2) ring and cyclic ether with conjugation ring, respectively². On coating of HTPAHs by Cu nano-particles, low intensity peaks are observed in respect of HTPAHs. The FTIR spectra of batch B (Cu:C = 0.5) has also been plotted separately as shown in Fig. 2S (B). Very low intensity Peaks at 664, 733, 886, 992, 1070, 1541, 1700, 2447, 2635 and 2864 cm^{-1} have been observed³. The peaks observed in the region $\sim 600\text{-}1000\text{cm}^{-1}$ may be attributed to interaction of Cu nano-particles with different functional groups present in HTPAHs⁴.

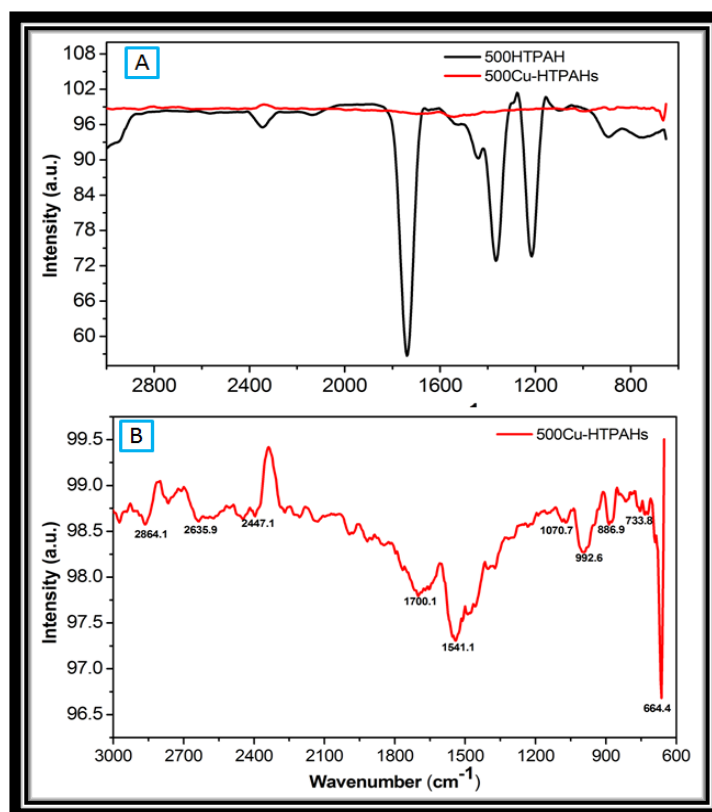


Fig. 2S: (A) Fourier Transform Infra-Red Spectroscopy (FTIR) analysis for HTPAHs and nano-crystalline Cu coated HTPAHs (batch B (Cu:C = 0.5)); (B) FTIR of batch B (Cu:C = 0.5) plotted separately

Fig. 3S Shows the SE_T , SE_A and SE_R observed for the batch C (Cu:C = 1.28) as a function of thickness. The thickness was varied from 0.5 to 2.0mm. The total EMI SE (SE_T) of composite is found to increase from ~ 20 dB to ~ 58 dB as the thickness is changed from 0.5 mm to 2.0 mm, respectively. The trend in reflection loss (SE_R) indicates that the variation in thickness has minor influence, as it varies from 8 dB for 0.5mm to 12 dB for 2.0 mm thick sample. However, significant change has been observed in the absorption (SE_A) of the composite which enhances from 12 dB for 0.5mm thick sample to 46 dB for 2.0mm thick sample. The overall result explicitly shows that the SE(dB) is enhanced with increase in thickness and further stresses the point that SE_A dominantly contributes towards SE_T . The minimum thickness (t) for this sample that can satisfy the minimum requirement ($SE \sim 30$ dB) for techno-commercial applications lies in the range $0.5\text{mm} < t < 1.0\text{mm}$.⁵

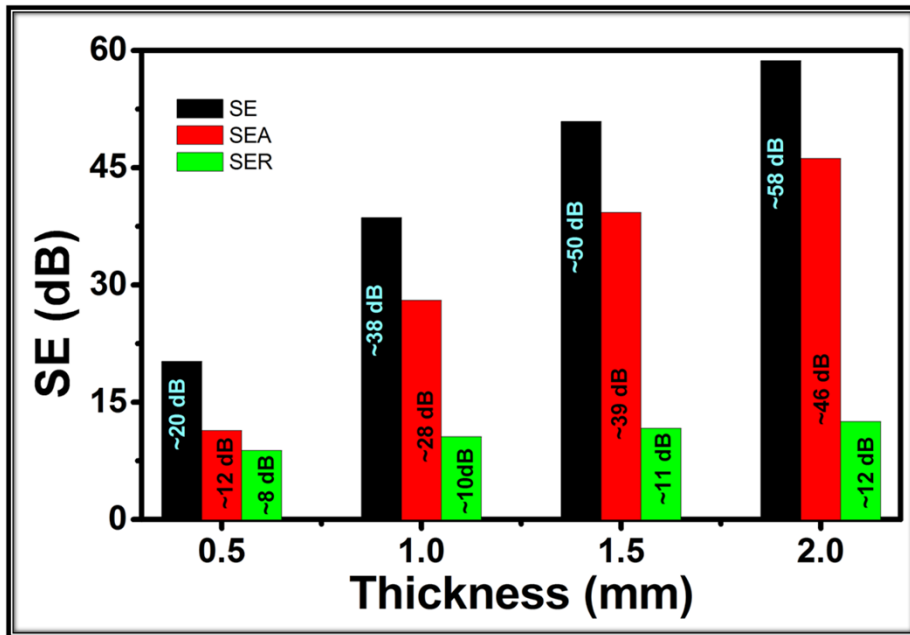


Fig. 3S: Total EMI SE_T , due to absorption (SE_A) and reflection (SE_R) are plotted for C-Cu nano-composite (batch C, Cu:C = 1.28) as a function of thickness

Fig 4S Shows a relative plot of mechanical (flexural strength), electrical and EMI SE for batches A, B and C. HTPAHs (Batch A) posses a very low EMI SE ($\sim 29\text{dB}$) with high electrical resistivity ($4.62\text{m}\Omega\text{cm}$) and flexural strength of 83MPa . However, C-Cu nano-composite batch B and C shows low resistivity with high flexural strength and EMI SE. For instance, batch C (Cu:C = 1.28) exhibit electrical resistivity of $0.14\text{m}\Omega\text{cm}$, mechanical strength of 109MPa and enhanced EMI SE $\sim 58\text{dB}$. EMI shielding in metals is known to be governed by reflection rather than absorption with high conductivity. On the other hand, hybrid conducting nano-composite, developed in present study, shows that EMI shielding occurs predominantly due to absorption owing to the presence of electric dipoles and scattering centers.

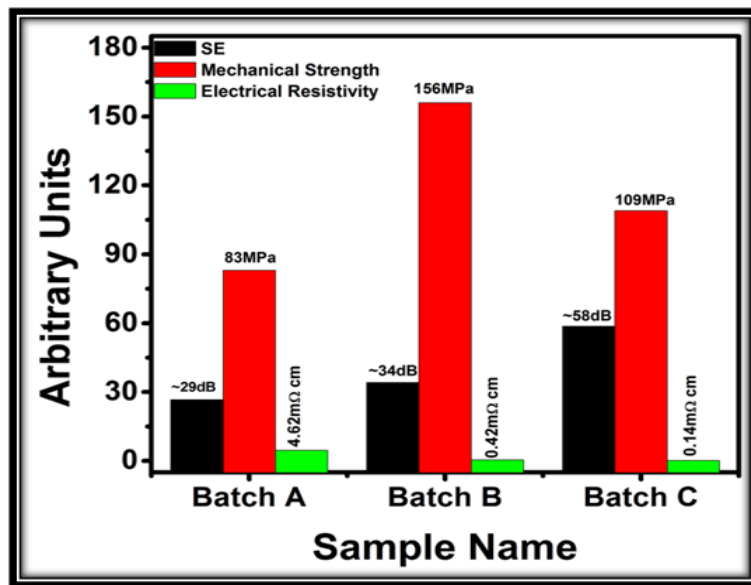


Fig. 4S: EMI SE, mechanical (flexural) strength and electrical resistivity comparison of HTPAHs and C-Cu nano-composite for batch A, B and C

The X-ray diffraction patterns of C-Cu nano-composite (batch C) aged six month in atmosphere is shown in Fig.5S. The main peaks corresponding to Cu appear at $2\theta = 43.4^\circ$, 50.61° and 74.14° representing (111), (200) and (222) planes, respectively. The characteristic peaks for CuO are not visible in six-month aged C-Cu nano-composite which is due to the HTPAHs making a protective layer around the nano-crystalline Cu, which inhibits its conversion to CuO. This is further with the fact that the resistivity of the 6-month aged sample does not show any change in its value.

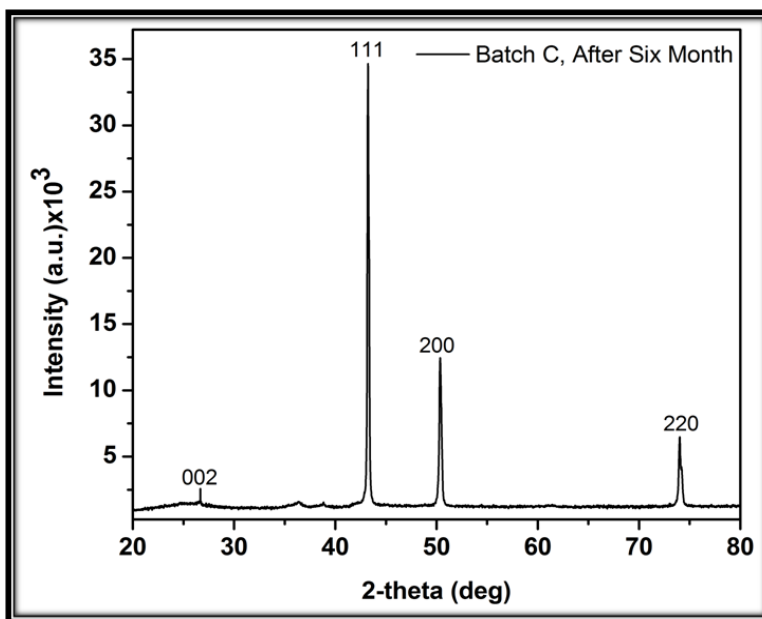


Fig. 5S: XRD pattern of C-Cu nano-composite batch C (Cu: C=1.28) after six month

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