**Electronic supplementary information**

# Green synthesis of copper nanoparticles and conducting nanobiocomposites using plant and animal sources

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**Experimental details**

Henna leaves were obtained from Chennai, Tamilnadu and washed in distilled water and dried at room temperature. The extract from henna leaves was prepared by heating 5 g dried leaves in 100 ml distilled water at 90$^{o}$C for 10 min. The boiled solution was cooled and centrifuged to obtain henna leaf extract. 30 ml of leaf extract was mixed with 100 ml of 10 mM copper sulphate pentahydrate solution and heated at 100$^{o}$C for 15 min. The pH of the solution was adjusted to 11 using 1M NaOH and heated at 100$^{o}$C for another 30 min. The change of color of copper sulphate solution from blue to reddish brown indicates the formation of copper nanoparticles. The formed copper nanoparticles were separated by centrifugation at 10,000 × g for 20 min followed by washing with distilled water, twice with ethanol and dried at room temperature. The synthesized copper nanoparticles were calcined at different temperatures (200, 300, 400, 500 and 600$^{o}$C) for 1 h in argon atmosphere to increase the electrical conductivity. Temperature was increased at the rate of 5˚C/min during the calcination process. Trimmed waste from cowhide was obtained from a local tannery, cleansed and processed into powder.[1,2] Collagen was extracted from the powder using acetic acid.[2] Varying amount of calcined copper nanoparticles was added (0, 0.5, 1, 2, 5 and 10 wt.%) to the 10 mg/ml collagen solution and stirred for 1 h. The homogenous solution was poured in Petri dish and dried at room temperature to obtain a nanobiocomposite film of 40±10 μ thick. The prepared copper nanoparticles and henna leaf extract were characterized using a UV-visible spectrophotometer (UV 1800, Shimadzu). The prepared copper nanoparticles, henna leaf extract and nanobiocomposite were analyzed using X-ray diffraction (Rigaku miniflex II, Desktop model with a $Cu_{K\alpha}$ radiation source, λ=0.15405 nm) and Fourier transformed infrared spectroscopy (Perkin Elmer). The high resolution scanning electron microscopic analysis and

energy dispersive X-ray analysis were carried out using a Quanta 200 FEG (FEI) scanning electron microscope equipped with energy dispersive X-ray analyser. Gold sputter coating was carried out for 60s using a Edwards E306 sputter coater. High resolution transmission electron microscopic (JEOL 3010) analysis of as-synthesized copper nanoparticles was carried out. Electrical resistance of calcined copper nanoparticles and nanobiocomposite films was measured using a two probe 4.5 digit micro-ohm meter (Model no. PE-16R, Prestige Electronics, Mumbai, India). Conductivity was calculated using the below equation.

$$\sigma = \frac{1}{R} \times \frac{l}{a}$$

Where σ = Conductivity ($Sm^{-1}$); $l$ = Thickness (cm); $R$ = Resistance (Ω); $a$ = area ($cm^2$)

**Fig. S1** UV-visible spectrum of $CuSO_4$. $5H_2O$ solution; inset shows a vial containing blue color $CuSO_4$. $5H_2O$ solution.

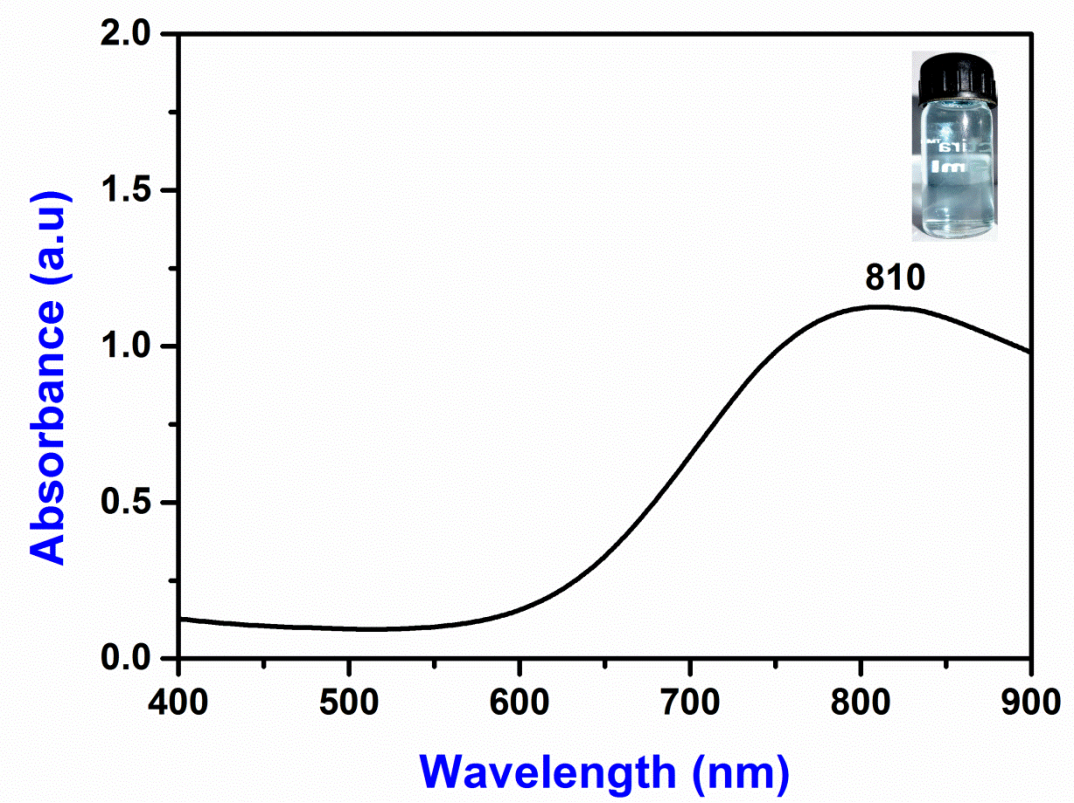


**Fig. S2** UV-visible spectrum of calcined Cu nanoparticles at (a) 400˚C, (b) 500˚C and (c) 600˚C.

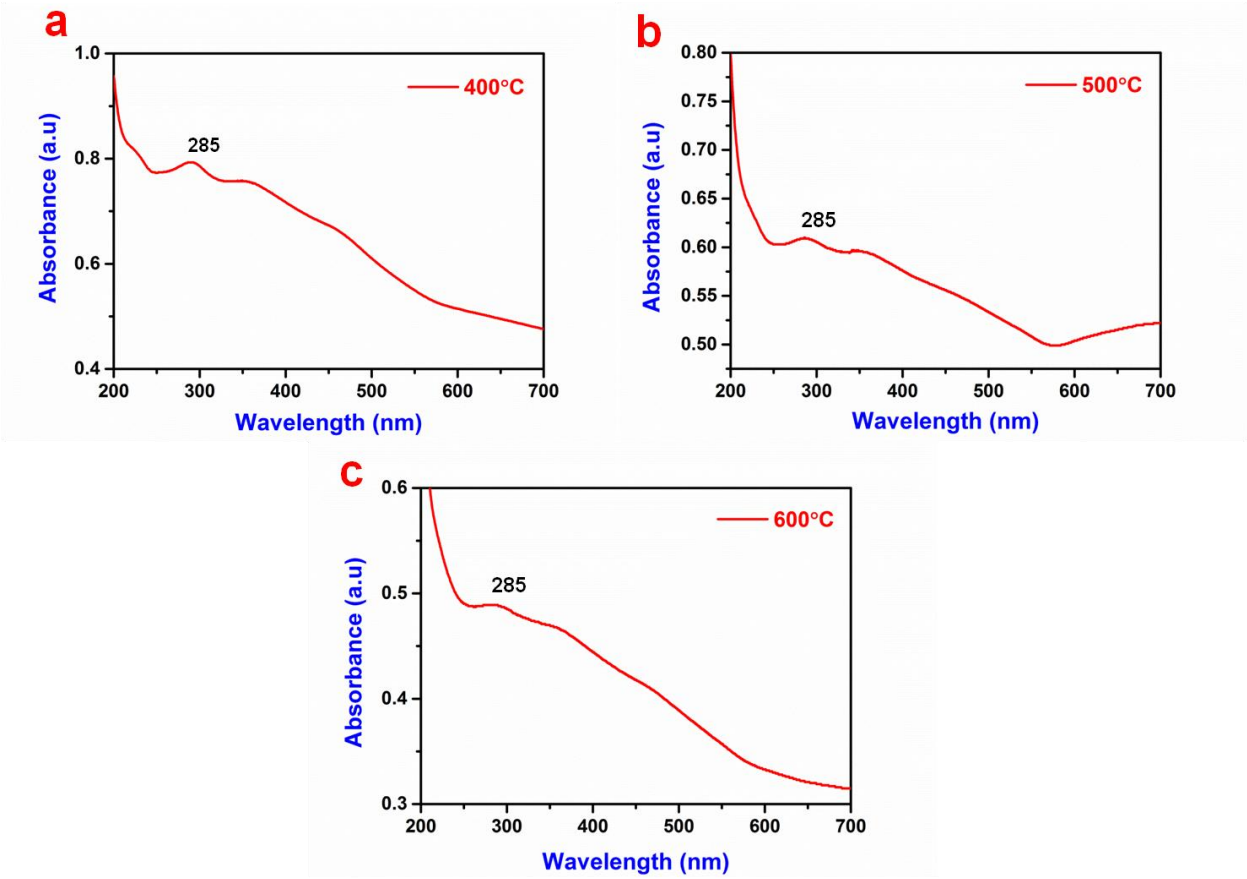


**Fig. S3** FT-IR spectra of (a) henna leaf extract and (b) as-synthesized Cu nanoparticles.

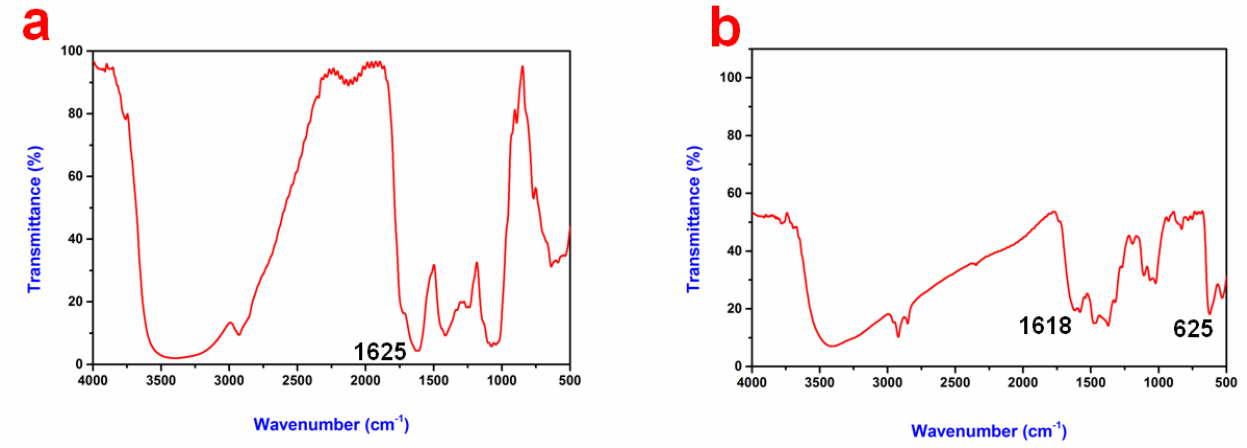


**Fig. S4** FT-IR spectra of Cu nanoparticles calcined at (a) 400˚C, (b) 500˚C and (c) 600˚C.

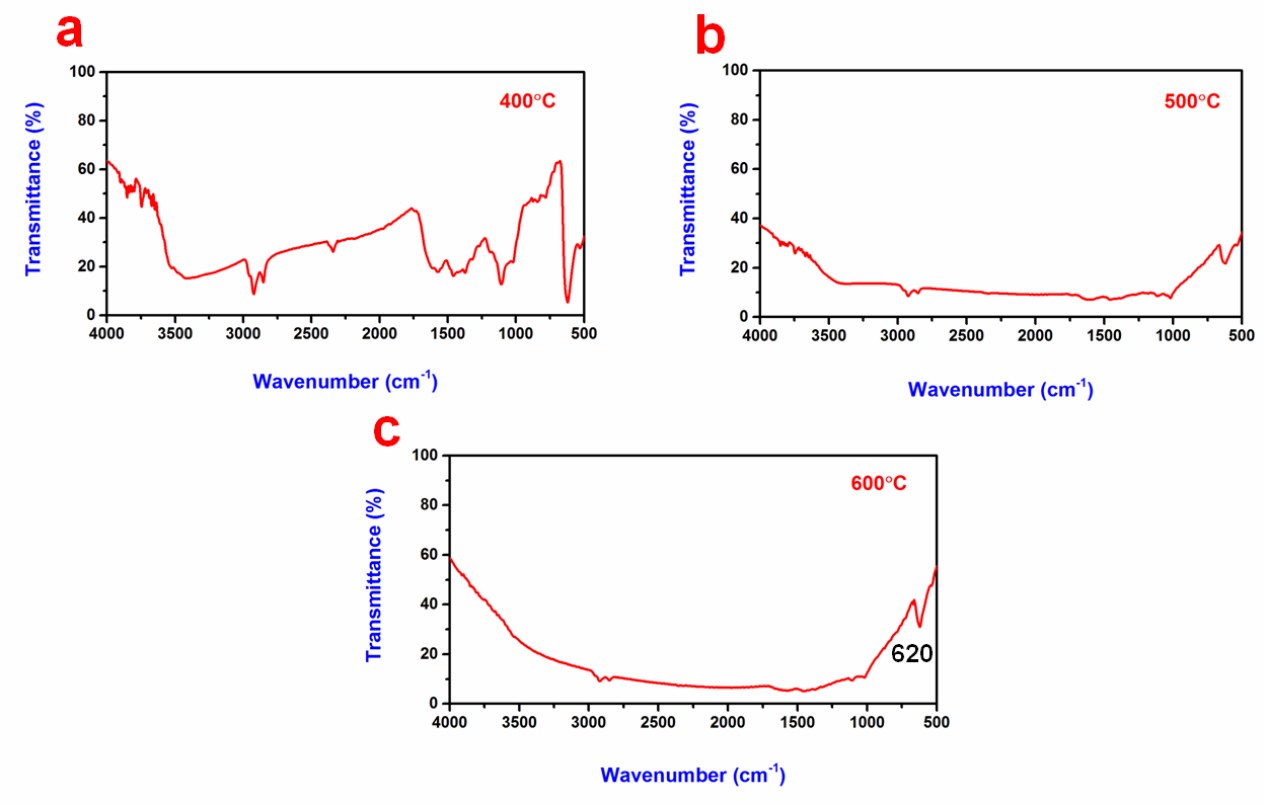


**Fig. S5** HRSEM image of as-synthesized Cu nanoparticles at lower magnification; inset shows EDAX data.

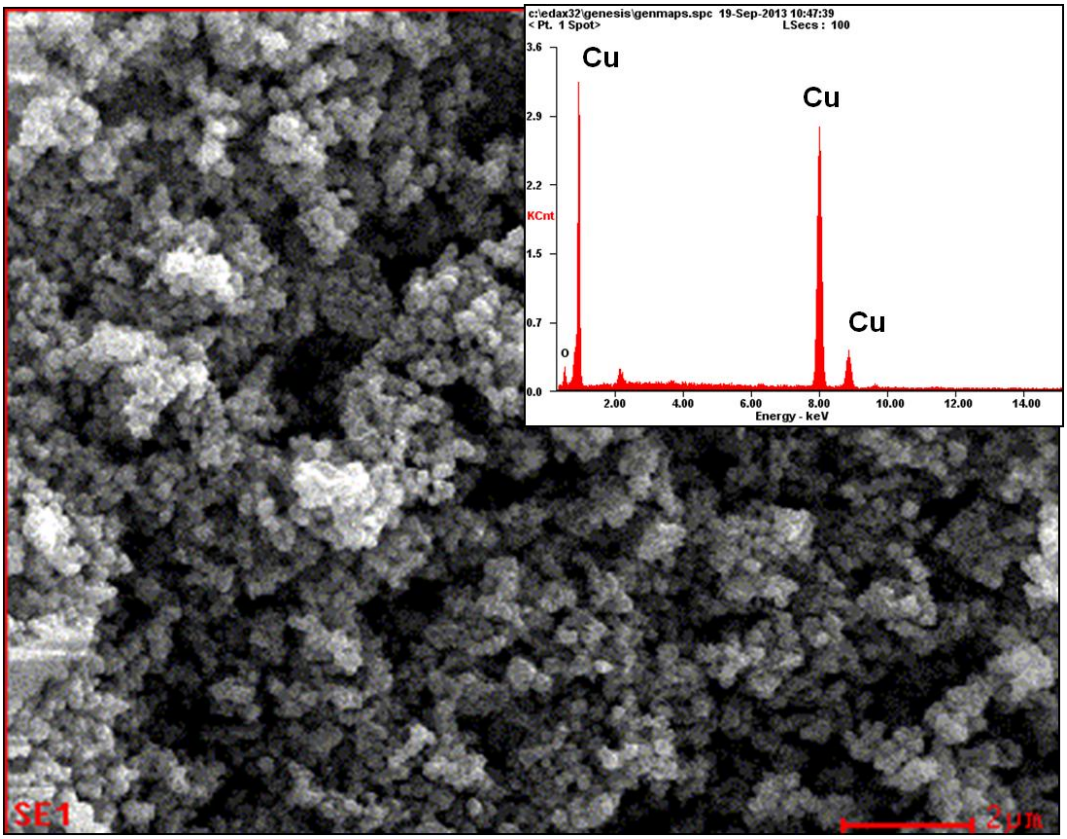


**Fig. S6** Particle size distribution of (a) as-synthesized and (b) calcined Cu nanoparticles derived from HRSEM images shown in Fig. 3a and 3b, respectively (please refer main paper).

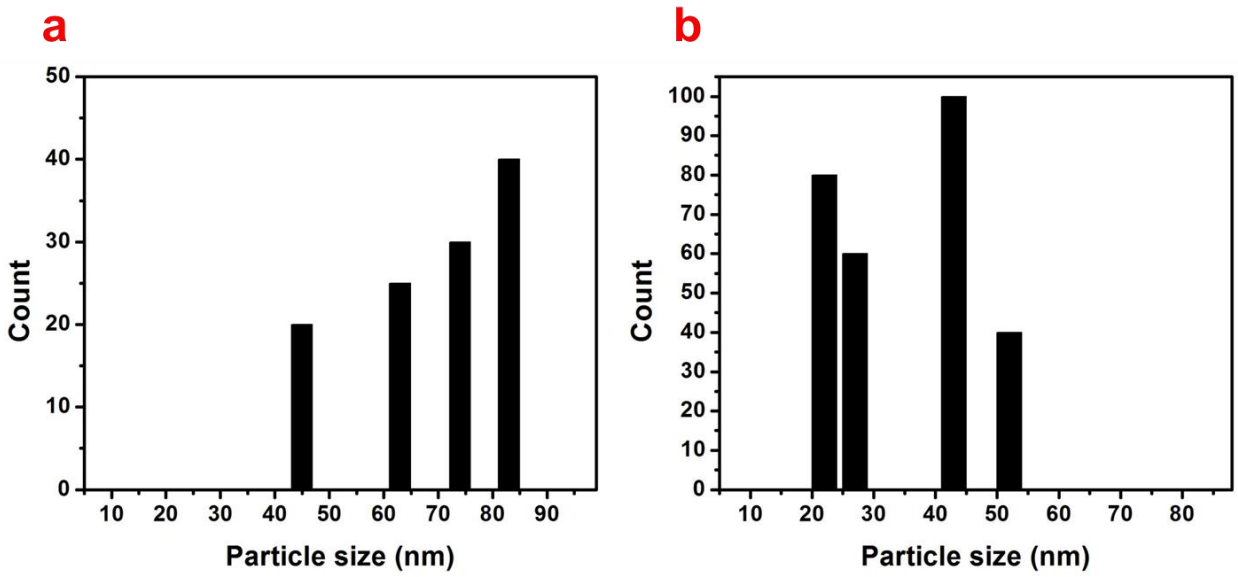
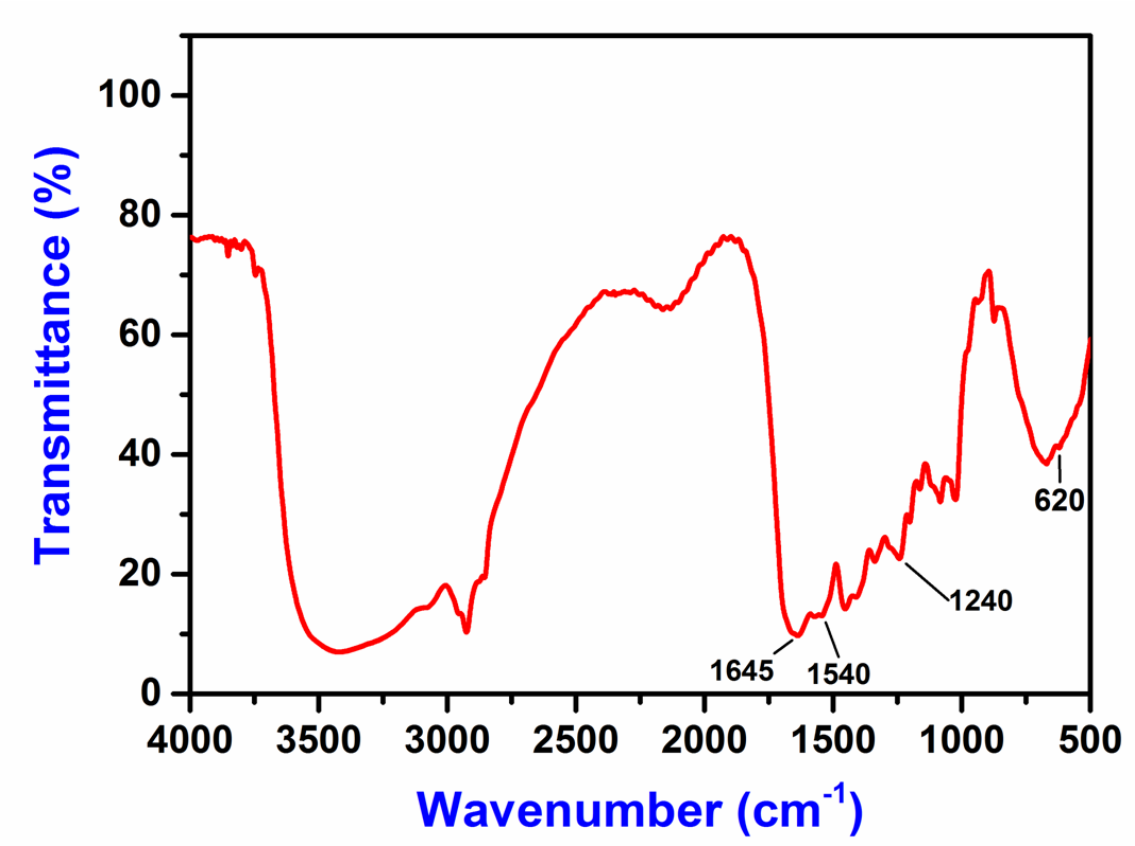


**Fig. S7** FT-IR spectrum of nanobiocomposite thin film containing 10 wt.% calcined Cu nanoparticles.



**Notes and references**


1 S. Saravanabhavan, R. Aravindhan, P, Thanikaivelan, J. R. Rao and B. U. Nair, *Green Chem*., 2003, **5**, 707.

2 A. Anumary, P, Thanikaivelan, M. Ashokkumar, R. Kumar, P. K. Sehgal and B. Chandrasekaran, *Soft Mater.*, 2013, **11**, 181.