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# Copper-Based Functional Nanomaterials and Printed Devices for Advanced Biosensing, Bioimaging, and Health Monitoring Applications

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The growing demand for affordable, portable, and continuous health monitoring technologies has accelerated research into functional nanomaterials that combine optical, electrical, and electrochemical versatility and biocompatibility. This work focuses on developing copper-based nanostructures and conductive inks as sustainable alternatives to noble metal systems for biosensing, bioimaging, and printed electronic applications.

Oxide-free copper nanoparticles (Cu NPs) were synthesized below 10 nm using controlled surface engineering strategies with L-serine, curcumin, glutathione (GSH), and polyethylene glycol (PEG)to prevent oxidation and agglomeration. The resulting nanostructures exhibit size-dependent optical characteristics, with surface modified CuNPs showing tunable plasmonic activity (600-800 nm) and GSH stabilized Cu nanoclusters (1-2 nm) demonstrating pH-dependent fluorescence suitable for intracellular imaging and environmental sensing. Curcumin-functionalised Cu NPs were further employed to fabricate a paper-based colorimetric $Na^+$ sensor with high selectivity and sensitivity.

In parallel, the electrochemical functionality of copper-based nanostructures was exploited for enzyme-free biosensing of homocysteine molecules. A novel CuS-based conductive nanoink was developed to enable screen-printed electrodes and photodetectors on flexible substrates, exhibiting excellent conductivity, stability, and visible-light photoresponse. This ink is currently being optimized for printed electrochemical biosensors targeting specific biomarkers, with the long-term vision of integrating these into wearable diagnostic systems for real-time health monitoring.

Together, these advances establish a comprehensive material-to-device framework, linking nanoscale copper surface engineering with scalable printed electronics, paving the way toward multifunctional, low-cost, and wearable biosensing technologies for next-generation personalized healthcare.