Metallic nanoislands on graphene as highly sensitive transducers of mechanical, biological, and optical signals

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Abstract: This work describes an effect based on the wetting transparency of graphene: the morphology of a metallic film (≤20 nm) when deposited on graphene by evaporation depends strongly on the identity of the substrate supporting the graphene. This control permits the formation of a range of geometries: tightly packed nanospheres, nanocrystals, and island-like formations with controllable gaps down to 3 nm. These graphene-supported structures can be transferred to any surface and function as ultra-sensitive mechanical signal transducers with high sensitivity and range (at least four orders of magnitude of strain) for applications in structural health monitoring, electronic skin, measurement of the contractions of cardiomyocytes, and substrates for surface-enhanced Raman scattering (SERS, including on the tips of optical fibers). These composite films can thus be treated as a platform technology for multimodal sensing. Moreover, they are low profile, mechanically robust, semitransparent, and have the potential for reproducible manufacturing over large areas.

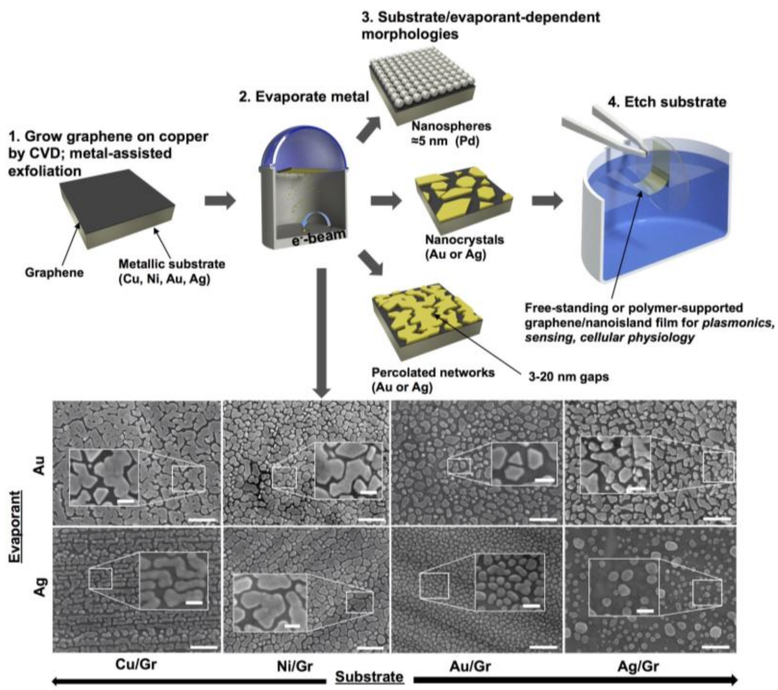

Fig. 1. Schematic diagram of the process used to generate nanoislands (top) and scanning electron micrographs of metallic nanoislands on various substrates obtained by electron beam evaporation of evaporant (y-axis) onto a graphene/metal substrate (x-axis) (bottom). 10 nm of gold (first row) and 10 nm of silver (second row) evaporated onto (left to right): graphene on copper foil (as grown), MAE-transferred graphene on nickel, MAE-transferred graphene on gold, MAE-transferred graphene on silver.

Each evaporant was deposited onto the substrates concurrently in the same chamber. Scale bars: 200 nm. Scale bars in insets: 50 nm.

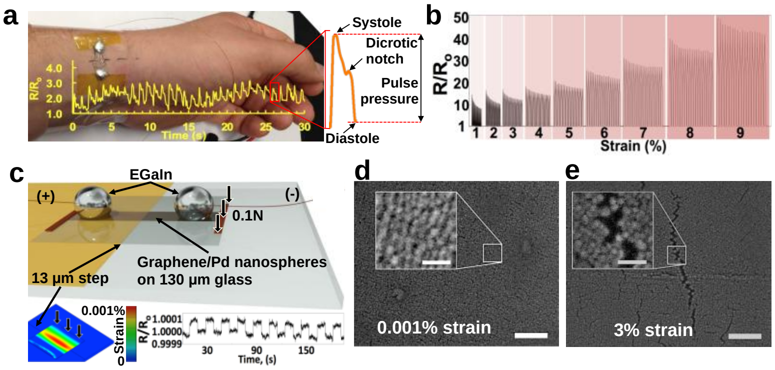

Fig. 3. Nanoisland strain sensors. a, Photograph of the PDMS/PdNI/graphene strain sensor placed atop the radial artery for detection of the pulse (overlaid in figure). Note the high resolution of the pulse pressure-waveform (in the blow-out) with distinguishable systolic and diastolic pressures, the dicrotic notch (aortic valve closure), and other cardiac cycle events. **b,** Normalized resistance plot of the PDMS/graphene/PdNI strain sensor stretched cyclically (20 cycles for each strain) to 1, 2, 3, … 9% strain. **c,** Schematic diagram of a graphene/PdNI strain sensor used to sense 0.001% tensile strain on the surface of the 130 µm-thick glass coverslip (used as a cantilever with the amplitude of deflection equal to 13 µm). Finite-element analysis (FEA) model of the strain on the cantilever surface (left inset). Normalized resistance plot of the graphene/PdNI strain sensor under cyclic tensile strain of 0.001% (right inset). **d,** Scanning electron micrograph of the glass/graphene/PdNI strain sensor under tensile strain of ~0.001%. Scale bar: 100 nm. Scale bar in inset: 25 nm. **e,** Scanning electron micrograph of the PDMS/graphene/PdNI strain sensor under tensile strain of ~3%. Scale bar: 100 nm. Scale bar in inset: 25 nm.

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