Laser Functionalisation of Flexible Polymer-Carbon Composites for Medical Sensing
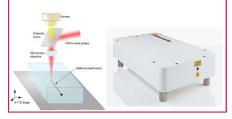
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Direct Laser Writing (DLW)

Laser induced pyrolysis of flexible polymers generates carbonized conductive tracks on or within a flexible polymer, that can wire together embedded devices, or act as intrinsic sensor elements, changing resistance with applied strain or temperature.

Computer controlled translation stage translates the focal position of a laser to induce carbonised tracks on the surface or inside a flexible polymer substrate, to form a distributed sensing surface to measure spatial changes in pressure or deformation, or temperature.
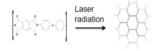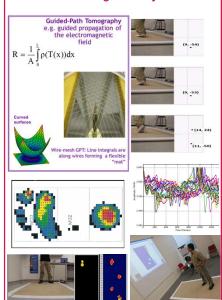

Process:

Photothermal process leads to conversion of Polyimide to Graphene.
Alternative to complex manufacturing methods needed for Graphene, such as:

- Molecular assembly.
- Mechanical/ electrochemical shearing.
- Chemical vapour deposition (CVD).
- Lithography-requiring process liquids/gases, clean rooms and controlled atmospheres.
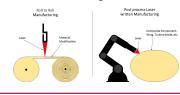

Sensor DAQ & Signal Analysis:

Guided-Path Tomography
e.g. guided propagation of the electromagnetic field

$$R = \frac{1}{A}\int_0^L \rho(T(x))dx$$

Curved surfaces

Wire-mesh GPT: Line integrals are along wires forming a flexible "mat"

Scaling up to Manufacture:

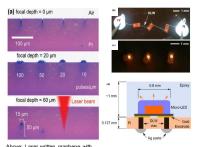**Automated manufacturing solution** for integrated sensing technologies:

- Prints multiple sensor units.
- Facilitates large area sensitisation using Roll-to-Roll manufacturing or robotic arm laser processing of a sprayed polymer coating on an existing substrate.
- Creates building blocks for new devices, via a single step, digitally controlled process.
- Enables fast, scaleable, green, roll-to-roll manufacturing; providing massive scale-up in speed and volume; and reduced manufacturing costs.
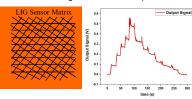
Manufacturing Processes

Roll to Roll Manufacturing

Post process Laser written Manufacturing

Demonstrations:

- **3D laser wiring of micro-nano devices** (µLEDs & Ag nanowires) embedded in polymers.

Above: Laser written graphene with
(a) Varying Writing Depths [Journal of Materials Chemistry C, Issue 20, 2017]
(b,c) configuration of µ-LEDs with DLW contacts viewed from back/front.
(d) Encapsulation of u-LED and DLW fabrication. [Applied Physics A (2018) 124:340]

- **Laser inscribed Strain & Temp Sensors** in flexible polymers for wearables, smart skin & wound monitoring, and catheters/implants.

LIG Sensor Matrix

Above: Laser written graphene with
LHS: LIG sensor matrix drawn at various depths inside Polyimide.
RHS: Sensor output from one LIG channel upon bending and unbending.

- **Smart Mats** for footfall, gait, identity, security, detecting falls, Alzheimers & Parkinson's, balance & sway, animals.
- **Signal analysis** for extracting features /deformation/ pressure/ biometrics:

  - Locus & Real-time tracking
  - Data Analysis to classify human motion
  - Distinguish changes in gait for a single person performing 10 different walks.
  - Identify age & sex from walking signal.
  - Identify individual from gait for security applications.

Applications: Smart deformable surfaces:

Biometrics: Unobtrusive or ambient data collection from individuals walking on a smart surface. as a behavioural biometric:

- Valuable biomechanical information.
- Identify position, locus and motion, plus balance and Centre of Mass (CoM).

Mobility: Remote monitoring/analysis of patients affected by mobility and balance problems:

- Requiring rehabilitation, following exercise regimes.
- Tracking degenerative conditions such as musculo-skeletal diseases (MSD), Parkinson's & arthritis.

Cognitive function: Identifying gait/mobility as markers of preclinical dementia:

- Detection of early onset of dementia affects executive brain function & mobility
- Improved diagnostics & new preventive strategies
- Effectiveness of treatment/interventions
- Early detection of mobility abnormalities

The Economist — Economist interview

Love the way you walk
The way people walk can be used for ID and health checks

A lot can be learnt from monitoring footsteps

LISTEN carefully to the footsteps in the family home, especially if it has wooden floors unmuffled by carpets, and you can probably work out who it is that is walking about. The features most commonly used to identify

Deep and Frequent Phenotyping Study

- Establish database of people at risk of Alzheimer's disease: Brain scans, cognitive and memory testing, retinal imaging, blood tests & movement/gait.
- Do early interventions work? .
- £6.9M to identify biomarkers, to detect early onset Alzheimer's disease - when a person has no obvious symptoms.