Ollscoil na Gaillimhe University of Galway
Scoil na Fisice School of Physics

Laser Functionalisation of Flexible Polymer-Carbon Composites for Medical Sensing

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Manufacturing and Novel Materials

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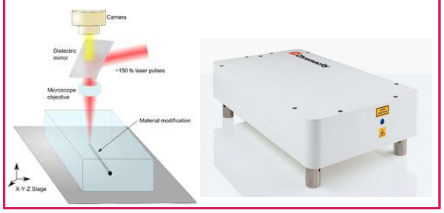
Direct Laser Writing (DLW)

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.

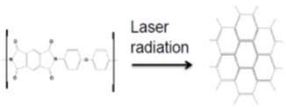


Process:

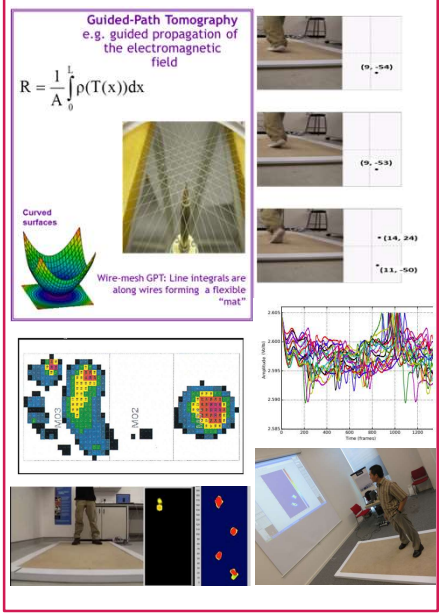
Photothermal process leads to conversion of Polyimide to Graphene.

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.



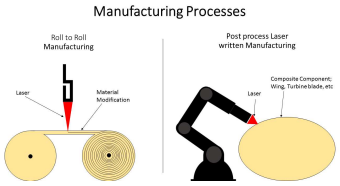
Sensor DAQ & Signal Analysis:



Scaling up to Manufacture:

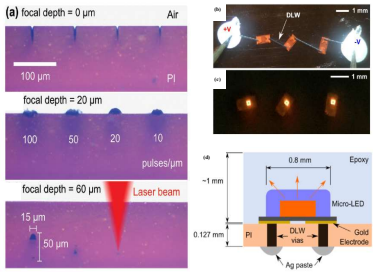
Automated manufacturing solution for integrated sensing technologies:

- 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.



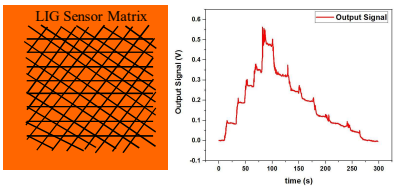
Demonstrations:

- **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.



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:

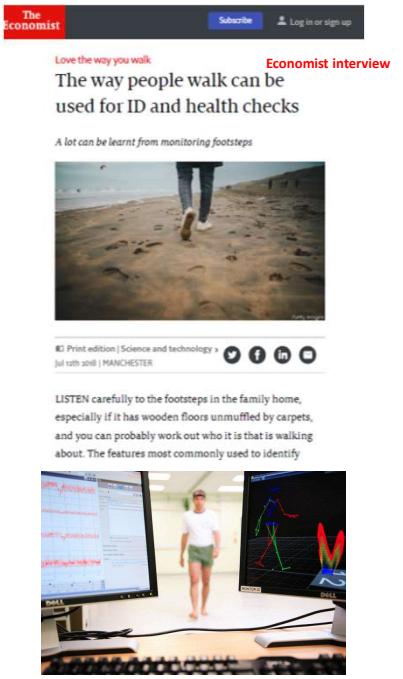
- Valuable biomechanical information.
- Identify position, locus and motion, plus balance and Centre of Mass (CoM).

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



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.

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