High-resolution gravure printing of graphene for biomedical applications

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INTRODUCTION

- Objectives:
  - Roll-to-roll printing of graphene electrodes on large-area polymer foils
  - Apply biofunctional coatings (e.g. proteins) on printed graphene structures
  - Fabrication of biosensors for impedimetric or electrochemical measurements

EXPERIMENTAL

- Ink composition
  - Basis: graphene ink for screen printing
  - Various solvents and solvent concentrations
  - Modified milling of graphene flakes
- Fabrication of printing cylinders
  - Masking and chemical etching
  - Alternatively direct engraving with ultrashort pulse laser
- Gravure printing with graphene ink
  - PET foil (50 µm)
  - Corona activation of PET foil (600 W)
  - Printing speed 20 – 30 m/min
- Electrical characterization of printed graphene electrodes (sheet resistance measurements)
- Cell adherence and cell growth
  - Cytotoxicity testing according ISO 10993 with MRC5 (human fibroblasts)
  - Further tests with TZM-bl cells (human cervical carcinoma)

CONCLUSION / OUTLOOK

- Roll-to-roll gravure printing of graphene ink with line width < 60 µm on PET foils
- Sheet resistance of gravure printing graphene ink similar to conventional screen printing ink
- Good compatibility with biological cells
- Parameters to be optimized for smaller line widths and more homogeneous structures
- Patterning of proteins to be established

CONSORTIUM / PROJECT FUNDING

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RESULTS

Printing cylinder

- Customized cell geometry for graphene ink
- Line width and orientation influence etching behaviour
- Small lines at high depth for sufficiently high ink transfer

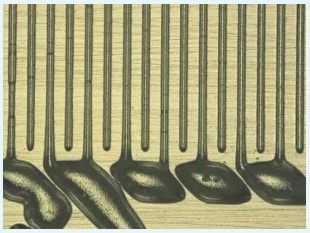

Figure 1. Biosensor structure on printing cylinder (40 µm lines)

Gravure printed graphene electrodes on PET film

- Thickness of printed structures: 2 – 5 µm
- Minimum line width < 60 µm
- Structure quality depends on cell depth, grid width and orientation (angle) relative to printing direction

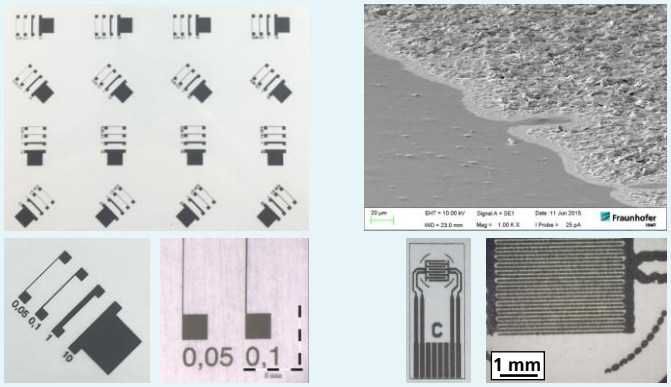

Figure 2. Left: Printed graphene patterns on PET foil (web width: 200 mm), top right: SEM image of graphene surface, bottom right: biosensor with IDA electrodes.

Sheet resistance (gravure vs. screen printing)

- Adapted inks show similar values compared with original screen printing ink
  - Screen printing ink: 12 – 15 Ω/sq. (at 25 µm)
  - Adapted gravure printing ink: 15 – 20 Ω/sq.

Cell adherence and cell growth

- Graphene gravure printing inks are not toxic to cells
- Reduced cell adherence on pure graphene structures
- Adherence proteins on graphene improve cell adhesion

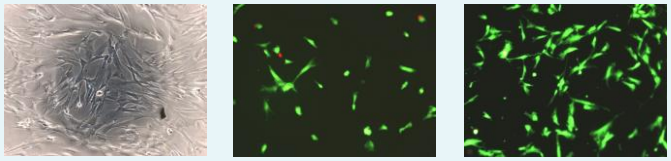

Figure 3. Left: Bright-field image of adhered cells on pure graphene structures, middle and right: fluorescent cells on graphene without (middle) and with (right) adherence protein.