Flexible urea sensor fabrication by localized laser - induced pyrolysis of Kapton

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Introduction

We present a fabrication method of enzymatic urea sensor employing new, low-cost, lithography free, one-step process of laser-induced carbonization [1-4] and compare it to glassy carbon [5]. Here, we report fabrication of two types of enzymatic urea sensors by immobilization of urease:

- directly on carbon;
- via intermediate biopolymer (chitosan) layer.

Carbon electrode fabrication and characterization

Fabrication:

- Kapton®HN 125x13μm;
- CO2 laser, wavelength 10.6μm;
- Power 4.8 W, speed 10 cm/s.

Properties:

- High porosity:
  - BET surface area – 255 m2/g;
  - Surface porosity – 15.2%.
- Composition:
  - XPS: C – 76.1%, N – 1.0%, O – 23.0%;
  - Combustion analyzer: C – 93%, N–0.9%, H – 0.4%;
- Conductivity – 7.1±0.7 S/cm;
- d-spacing – 3.48Å; Lp = 4.0nm; Lc = 7.1nm;
- Raman ratio (Ip/Ic) = 0.8;
- Hydrophilicity (contact angle 70°).

Carbonate electrode deposition and process optimization

- Chitosan preparation: chitosan solution 1 % w/v, pH 5.5 A in diluted HCl (0.2 M) and filtered,
- Improvement of hydrophilicity
- Oxygen plasma treatment at 100 W for 120s
- Contact angle <10°;
- Retention over 5 days;
- Highest deposition quantity at current direction perpendicular to laser patterning;
- Optimal deposition duration is 15 min at 4 A/m2.
- Increase of the time leads to chitosan self-peeling;
- Chitosan film thickness ~2 μm after drying.

Urea sensor fabrication and analysis

- Urea from Jack Beans (Canavalia ensiformis):
  - Covalently coupled to chitosan with glutaraldehyde (Sigma Aldrich 25% in water) [6];
  - All sensors were immobilized in 1 mg/ml urease solution overnight;
  - Activity tested by urea hydrolysis and ammonia release [7,8].

Conclusions

Material exhibits electrical, mechanical and physical properties different from glassy carbon.

- Simplicity, flexibility and versatility of such method enable:
  - fabrication of the patterns of various designs;
  - variation of the properties depend on applied laser parameters;
  - electrodeposition of chitosan can be utilized for immobilization of other enzymes;
  - determined urea detection limit at 10⁻⁴ M, which is in two orders below risk values for a healthy human;
  - integration with other biomedical devices, e.g. in catheter tube (4 mm diameter tested).

References


Fig. 1: Flow chart of the process.