Microelectrode Array system for neuron-muscular applications

Ali Parsapour, Farnoosh Vahidpour, Milos Nesladek

Hasselt University Institude for Materials Research (IMO), Wetenschapspark 1, B-3590 Diepenbeek, Belgium

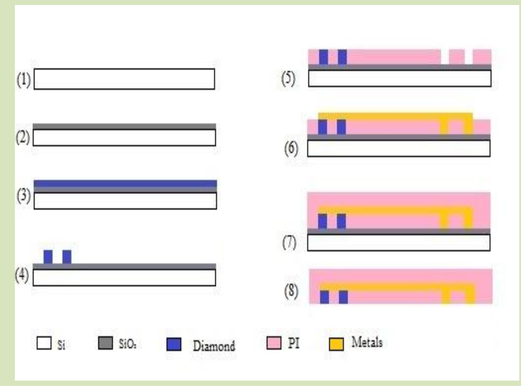
universiteit hasselt | IMO - IMOMEC INSTITUUT VOOR MATERIAALONDERZOEK

Introduction

Neural devices have mostly been used to restore and modulate neural behaviour in neuronal diseases. In the regime of neural device manufacturing, Polyimide (PI) has been reported for its successful use in device fabrication, benefiting from its mechanical flexibility and biocompatibility, low dielectric constant, and relative ease of processing as films using spin- coat [1,2]. On the other hand, Boron-doped Diamond as a conductive material, has been used in neural devices due to its superior properties such as long term physical and chemical stability, wide electrochemical potential window, biocompatibility, etc. [3,4]. In this study, Boron-doped Nano Crystalline Diamond (BNCD) is used as electrode material and conductive interface in combination with Gold connecting lines and insulated by PI. Surface treatment of polyimide has been successfully applied for improving the adhesion of metal layer on PI films. The surface of diamond, metal and PI is investigated and fully characterized in every step of fabrication using different characterizations techniques such as Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Energy Dispersive X-ray Spectroscopy (EDX) and contact angle measurements. The flexible EMG electrodes can be eventually used for human neuro-muscular measurements with the advantage of diamond biocompatibility and beneficial electrical characteristics for EMG recording.

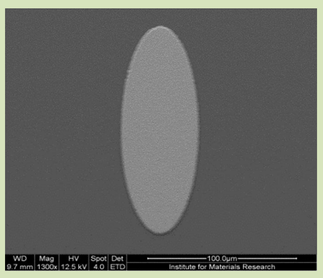
Materials & Methods

- ❖ Silicon substrate preparation: RCA1, RCA2 cleaning
- ❖ Deposition of SiO_2 layer as a sacrificial layer > 300nm
- ❖ Substrate Preparation for diamond growth
- ❖ Boron-doped diamond growth: ~ 200 nm
- ❖ Photolithography using negative lift off resist
- ❖ Deposition of 300 nm Chromium
- ❖ Lift off in Acetone
- ❖ Reactive Ion Etching (RIE) of BNCD in O_2 plasma
- ❖ Coating, pattering and curing of polyimide
- ❖ KOH treatment of polyimide surface
- ❖ Photolithography using negative lift off resist
- ❖ Deposition ~ 100 nm of Gold
- ❖ Lift off in Acetone
- ❖ Oxygen treatment of polyimide surface
- ❖ Coating, pattering and curing of polyimide
- ❖ Release the electrodes in diluted HF solution



Results &Discussion

Surface characterization of diamond electrode as neural interface

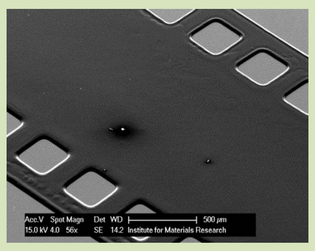


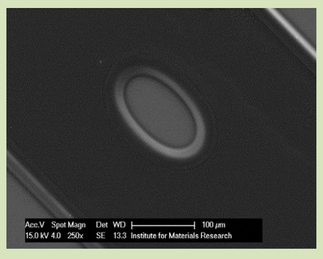
SEM image of the BNCD-active electrode area

Microscopic image of patterned BNCD

These images demonstrate the successful pattering of BNCD electrode of 50 µm x 150 µm on silicon dioxide substrate, using photo lithography and metal deposition technique.

Surface characterization of Polyimide as insulating layer

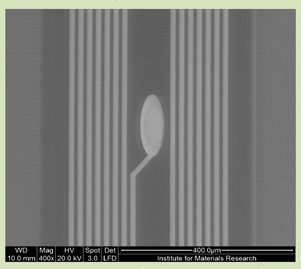


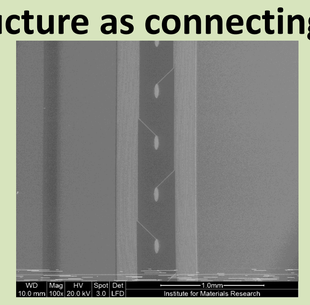


SEM images of the polyimide micro-structure in the electrodes

SEM measurement was performed on polyimide patterned on BNCD electrodes. It showed successful fabrication of PI by means of photo lithography, and optimization of UV exposure time and dip development time of polyimide. It can be clearly seen that there is no defect on the surface even after curing.

Pattering of metallic structure as connecting lines





SEM images of the metal micro -structure in the electrodes. Each BNCD ellipse is connected to a square contact by a metallic connecting line with the thickness of 10µm, in 16-channel electrodes.

Flexibility of diamond /PI EMG electrodes

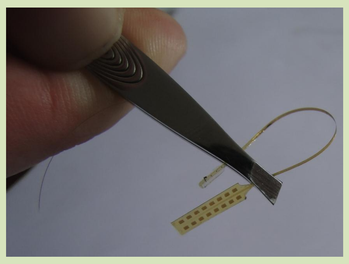


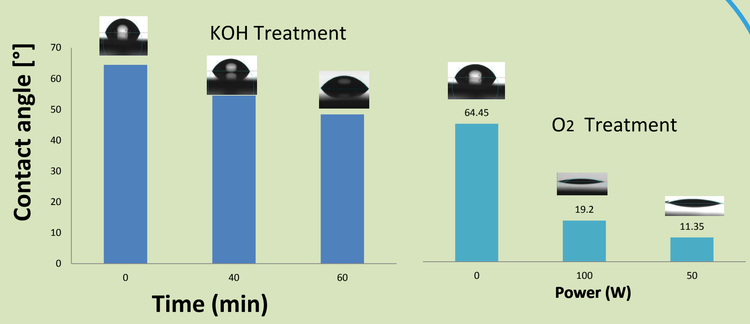
Image of the flexibility and fabricated electrodes

Image of the fabricated and successfully released electrodes. The final released electrodes have the thickness of about 25um and show extremely good flexibility. The newly-designed diamond and polyimide EMG electrodes can be eventually used as implants for human electromyography monitoring, recording and healing.

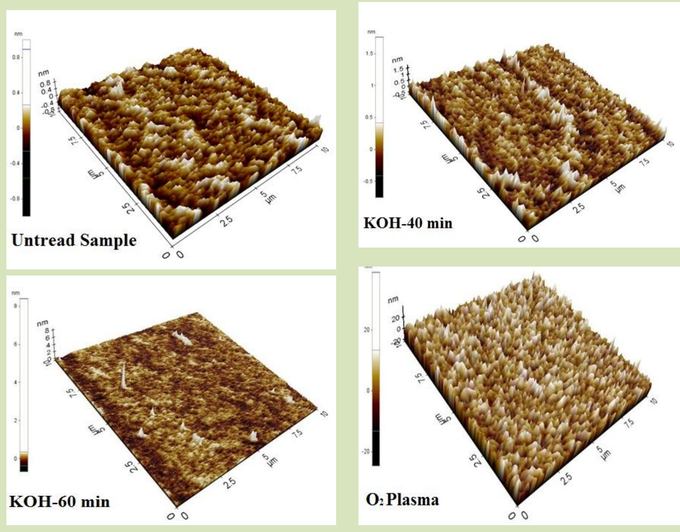
Surface treatment of polyimide for the adhesion of metal

The surface treatment of polyimide, prior to metal deposition, is found to be necessary to activate the surface of PI by promoting various surface oxygen complexes and increasing the surface roughness of PI. It offers an improvement in the adhesion of metal to the PI surface for fabricating the EMG electrodes. Without these surface treatments, the metal film detaches from the PI.

This methods makes the surface of PI more hydrophilic than untreated sample, which is confirmed by contact angle measurement. The roughness of the treated and untreated PI surface is measured by AFM technique. The atomic composition of the surfaces is acquired by EDX technique. The results show the positive effect of PI surface treatment and successful attachment of metal to the PI surface.



Contact angle as function of time of treatment for KOH and O_2 Treatment



Three-dimensional AFM image of untreated and treated of polyimide surface by KOH and O_2 plasma

Wt.%	Control Sample	KOH treatment at 40 min	KOH treatment at 60 min	O_2 Plasma
C	72.37	69.82	69.82	70.72
O	16.18	19.94	20.35	19.07
N	11.45	10.24	9.83	10.21
O/C	0.224	0.285	0.291	0.270

Atomic composition of treated and untreated PI surfaces, obtained by EDX technique

Conclusion

- ➢ Design, preparation and fabrication of flexible `diamond /PI EMG electrodes have been successfully accomplished. Patterning of 11 µm polyimide with the resolution of 50 µm was a success in thick polyimide fabrication using photolithography and dip development.
- ➢ Applied innovative treatment method for Polyimide makes the surface of PI active by promoting various surface oxygen complexes and increasing the surface roughness of PI, offering an improvement of adhesion for fabricating the EMG electrodes.

References

1] B. Ghane-motlagh and M. Sawan, “Design and implementation Challenges of Microelectrode Arrays : A Review,” pp. 483–495, 2013.
[2] C. Hassler, T. Boretius, and T. Stieglitz, “Polymers for neural implants,” J. Polym. Sci. Part B Polym. Phys., vol. 49, pp. 18–33, 2011.
[3] M. Dankerl, et al. Adv. Funct. Mater. 19, 2915-2923 (2009).
[4] J. M. Halpern, M. J. Cullins, H. J. Chiel, and H. B. Martin, “Chronic in vivo nerve electrical recordings of Aplysia californica using a boron-doped polycrystalline diamond electrode,” *Diam. Relat. Mater.*, vol. 19, no. 2–3, pp. 178–181, 2010.