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Examination of dielectric strength of thin Parylene C films under various conditions

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Abstract: The breakdown voltage of the biocompatible polymer Parylene C was determined after storage in 60°C saline solution and treatment by autoclave. It occurred that both, storage at 60°C in saline solution and autoclaving, lead to distinct decrease of dielectric strength by approximately 50%.

Keywords: dielectric strength; encapsulation; implant; insulation; Parylene C.

1 Introduction

Parylene C is an established polymer for encapsulation of medical implants due to its manifold advantageous properties as chemical robustness, biocompatibility, sterilizability [1]. Its proprietary vacuum deposition process allows a thin contiguous conformal coating that reaches into almost all crevices and gaps, thus ensures a defect and void free coverage of any geometries [2]. Additionally, it is hydrophobic, has high electrical insulation capability also in wet conditions, and exhibits a very low water uptake and swelling behavior, which makes it attractive also for coatings of assembled electronics on printed circuit boards [3]. Micro machined flexible neural interfaces can be realized with Parylene as substrate material [4, 5].

In these contexts, properties of the used polymer strongly determine the properties of the implant. The Young's Modulus, insulation resistance and crystallinity were investigated by [1, 6].

It is known that properties as crystallinity and elongation at break alter massively with time and treatment [1]. In this work the dielectric strength of Parylene C in wet conditions is investigated after storage in 60°C PBS (phosphate buffered saline) and autoclaving.

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2 Material and methods

The samples used for measurements were built on square glass substrate of $(49\ \text{mm})^2$ size. On this substrate 200 nm of titanium were deposited using DC sputtering.

A polymer cylinder of approx. 1 cm height was glued on the substrate surrounding the fields in the centre (UHU plus schnellfest, UHU GmbH & Co KG, Germany). Some space was masked for contacting using adhesive tape.

These samples were coated with Parylene C, using a unique coater that consists of a combination of a Parylene deposition unit by PPS (Plasma Parylene Systems GmbH, Germany) and a PECVD unit by Plasma Electronic, Germany. Parameters of all depositions: Pressure 8 Pa, pretreatment with argon and oxygen plasma, adhesion agent A-174, realized sheet thickness 1.9 µm.

Sheet integrity was checked after deposition. Therefore, the cylinders were filled with PBS in which an electrode was placed using a standard wire. The second contact was realizing with an alligator clip to the masked titanium contact pad. Five volts were applied and if no hydrolysis was observed, the sample was considered as usable.

For the measurement, the same contacting was used. An alternating voltage of 50 Hz rose linearly to 2 kVrms within 45 s, and stopped when the current exceeded 20 mA.

For analyses only those measurements were taken into account were the breakdown could be linked to a visible formation of bubbles and destruction of the Parylene layer to exclude faulty measurements caused by leakage currents (Figure 1).

3 Results

For the samples measured directly after fabrication with a Parylene thickness of 1.9 µm a mean breakdown voltage

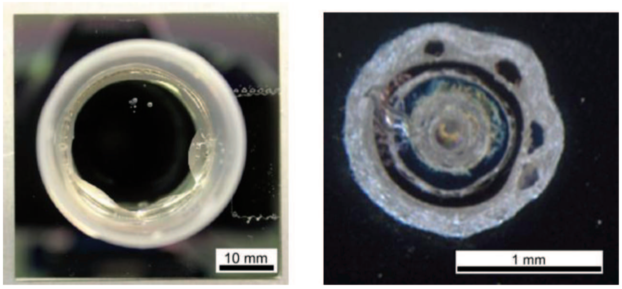

Figure 1: Sample after measurement, left: substrate and plastic cylinder in top view, right: close up of a defect in the Parylene C layer where the breakdown appeared.

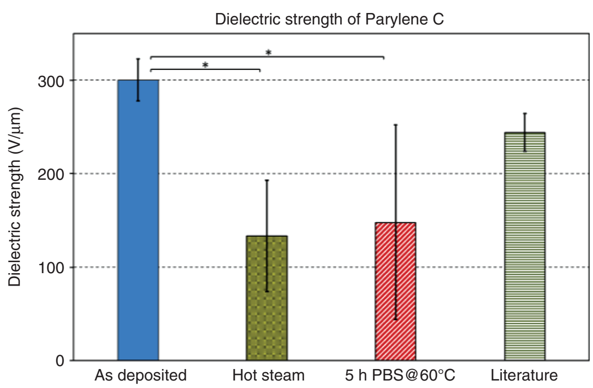

Figure 2: Dielectric strength of Parylene C sheets under wet condition and different pretreatments: as deposited, autoclaved and stored 5 h in PBS at 60°C (mean and standard deviation), *$p < 5\%$.

of 561 V was received, equivalent to a dielectric strength of 300 V/µm, standard deviation 22.5 V/µm ($n = 6$).

After autoclaving the mean value for the dielectric strength decreased to 133 V/µm, standard deviation 59.5 V/µm ($n = 6$). Besides the decrease of the breakdown voltage the results of different samples showed higher variance than the samples measured directly after fabrication.

The autoclaving obviously also changed the adhesion of the Parylene. This could be observed when the adhesive tape used for covering some area for contacting was removed.

A third group of samples was stored at 60°C for 5 h, with the cylinders on the samples were filled with PBS.

After this short storage the dielectric strength decreased to 148 V/µm mean value ($n = 4$).

All results are summarized in Figure 2.

4 Discussion

With 1.9 µm Parylene C, the theoretical breakthrough voltage is approximately 500 V. An area of about 6.2 cm^2 roughly exhibits a capacity of 9.2 nF, thus resulting in an impedance of 360 kΩ@50 Hz, approximated with a plate capacitor with the Parylene as dielectric. The resistance of that area is theoretically 270 TΩ. Therefore, the current due to the capacity should in the range of 1.4 mA for 500 V at 50 Hz.

The received values for the dielectric strength are in good agreement with the values found in literature and on datasheets 244 V/µm, where different values can be found.

Albeit there is large variance in the values for the samples after storage or autoclaving the impact of those treatments is obvious and devastating. The influence cannot be explained by delamination or chemical transformation of Parylene C. Further investigations must be undertaken to fathom this effect out.

5 Conclusion

The observed strong decrease of dielectric strength due to autoclaving or storage in saline solution at 60°C have to be considered when Parylene C is used in electrical active implants.

The short storage at 60°C could be seen as time-lapse test for a longer storage at body temperature. However 5 h were a short time causing such strong changes.

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