COMPARISON OF DIELECTRIC BARRIER DISCHARGE MODES FUNGICIDAL EFFECT ON CANDIDA ALBICANS GROWTH

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Filamentary and quasi-homogeneous mode of dielectric barrier discharge (DBD) was investigated as a plasma source with fungicidal effect on *Candida albicans* yeast inoculated on Sabouraud agar wafers. As compared with the filamentary DBD mode, the quasi-homogeneous mode had significantly better results: shorter exposition time needed for inhibiting *C. albicans* yeast, moreover the quasi-homogeneous mode had gentle influence on the agar surface structure.

PACS: 52.25.Mq, 52.80.Hc, 87.50.C-, 87.19.xg

INTRODUCTION

Low current atmospheric pressure discharges (LCAPD) are known as sources of low temperature plasma with many technological, agricultural [1] and biological [2] applications. Dielectric barrier discharge (DBD) as one of LCAPD is suitable for noninvasive surface treatment, e.g. polyethylene powder surface modification [3] and polyamide fibers improvements [4] causing change of surface stress, which can be observed as a material wettability change as well [5]. Along with DC corona discharge in point to plane configurations, we have focused on DBD used as a fungicidal tool inactivating the *Candida albicans* yeast growth. The *C. albicans* was used as a fairly good resistant organism model [6]. Thee are two modes of DBD – filamentary and homogeneous acting as planar (surface) DBDs [7] and volume DBDs (e.g. used in [3]). Using modified electrode – barrier positioning, we can compare two DBD modes and their influence on *C. albicans* growth.

1. APPARATUS

Apparatus (Fig. 1) consisted of an electrode system and power source. A high voltage power source was realized by a voltage measuring transformer (VMT) with transformation ratio 35000/100 V. The VMT was fed by variable auto transformer (VAT) 0…250 V/50 Hz. The input voltage on VMT input and current on the output as a portrait of voltage on shunt 10 Ω resistor was measured by the 200 MHz OWON PDS 8102T oscilloscope (OSC).

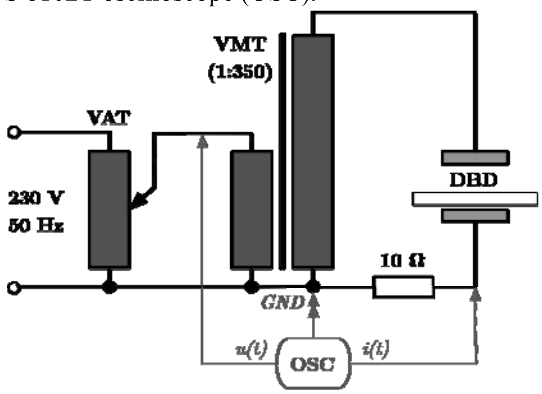

Fig. 1. Apparatus

The electrode system (Fig. 2) was realized as an electrode pair with one grounded electrode made as planar circular electrode of approximately 36 mm diameter (GND) and a high voltage electrode (HV) placed above the GND. The high voltage electrode consisted of 7 spikes placed into a triangular array. The step of the grid was 5 mm; the spike in the center was dropped for about 1 mm [8]. The inter electrode distance was constantly held on $D = 20$ mm. In between there was placed dielectric barrier of thickness $T = 0.1$ mm made of polyethylene terephthalate foil ($\varepsilon_r = 2.3$ [9]) of dimensions 105×105 mm.

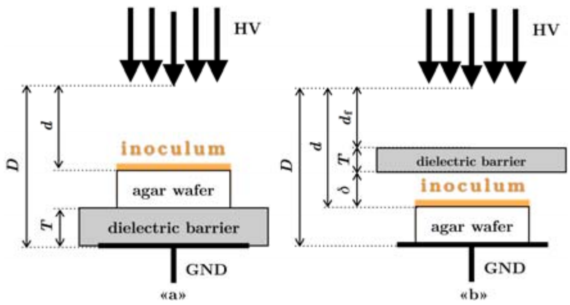

Fig. 2. Electrode set-ups with filamentary «a» and with dominant quasi-homogeneous «b» DBD mode

2. EXPERIMENTS

Sabouraud agar wafers of cylindrical shape (22 mm in diameter and approximately 4 mm in thickness) were used as a cultivating medium. The upper face of each wafer's sides was inoculated with 50 µl of *Candida albicans* suspension forming 10^4 cfu/cm^2 (colony forming unit per square centimeter). Contrary to usually used cultivation media (i.e. agar spilled into Petri dish) the agar wafers are independent mechanically controllable objects without any fixed underlay, e.g. Petri dish. The absence of any underlay gives us an opportunity to configure electrical circuit by dielectric barrier position.

In the case «a», the DB was laid on the grounded electrode GND on which was placed the inoculated agar wafer. In the case «b», the inoculated agar wafer was placed directly on the grounded electrode, the DB was located concurrently in equidistance δ ~ 1…2 mm from upper inoculated agar wafers surface (Fig. 2).

Two DBD burning modes depending on electrodes/barrier configuration were observed. In both configurations «a» and «b» the filamentary mode (FIL) appeared in space under the HV electrode (distance d, resp. d_f). The quasi-homogeneous mode (QH) emerged in the configuration «b» in space between the barrier and the agar wafer (distance δ).

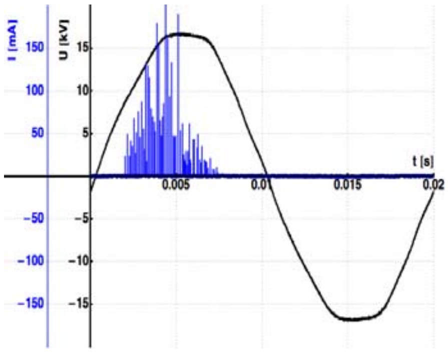

Fig. 3. FIL DBD mode voltage and current waveforms

Typical voltage and current waveforms (U_{RMS} = 12.5 kV, inter electrode distance D = 15 mm) are shown in Fig. 3 (configuration «a») and Fig. 4 (configuration «b»). The positive current peaks in both waveforms correspond to filamentary DBD mode. The negative current peaks (significant in configuration «b» only) are apparently caused by quasi-homogeneous DBD mode.

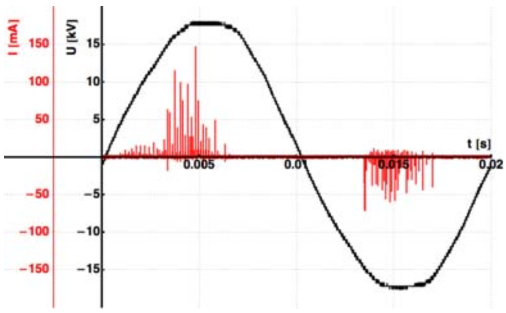

Fig. 4. QH DBD mode voltage and current waveforms

The electrode system (HV and GND electrode) was powered by sine high voltage U_{RMS} = 14 kV/50 Hz. The effective (RMS) current values given by the PDS 8102T oscilloscope were I_{RMS} = 100…140 mA in case of filamentary DBD and I_{RMS} = 100…180 mA in case of quasi-homogeneous DBD.

The filamentary DBD treatment caused visible macroscopic changes on agar surface. Immediately after the plasma exposition of the wafers surface, there were noticeable small hollows in accordance with HV spike positions. In contrast, the quasi-homogeneous DBD exposure did not visibly affect the treated surface. This effect was verified by measuring mass loose using an analytical balance (sensitivity of 0.1 mg).

Nevertheless, the main experimental effort was focused on fungicidal effect of filamentary vs. quasi-homogeneous DBD plasma on *C. albicans* as a model organism. For each electrode-barrier configuration, there was prepared two identical sets of six inoculated agar wafer samples (see paragraphs above). The plasma exposition times (t_{exp}) of inoculated surface were 6, 3, 1.5, 1, 0.5 and 0.25 min.

3. RESULTS

The results for mass loss Δm during plasma exposition t_{exp} = 0…20 min are shown on Fig. 5. The influence of the filamentary DBD on agar mass drop is significantly (up to 10 times) higher then the influence of the quasi-homogeneous DBD.

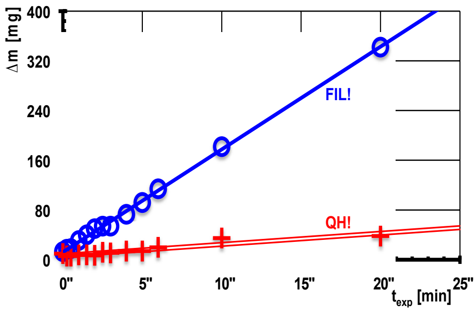

Fig. 5. Agar wafer's mass loss time dependence

Showing in Fig. 6, surface treatment using the filamentary mode of DBD had weak fungicidal effect. Satisfying treatment result can be find on samples marked by number "6" (t_{exp} = 6 min). On agar wafers with t_{exp} < 6 min after 24 hours of cultivation there was found huge amount of *C. albicans* colonies.

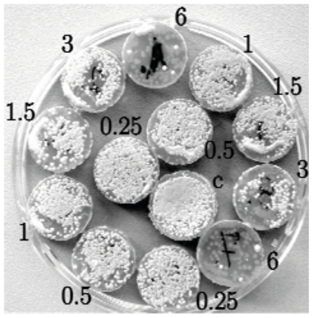

Fig. 6. Results after FIL DBD treatment (marked by exposition times [min], "c" is the control sample)

Results of quasi-homogeneous DBD mode treatment are shown in Fig. 7. Samples with totally inhibited agar wafer surface are those with exposition time $t_{exp} \geq 0.5$ min. (The samples for 6 and 3 minutes in upper part of Fig. 7 with few remaining colonies are affected by error probably caused by agar surface roughness.)

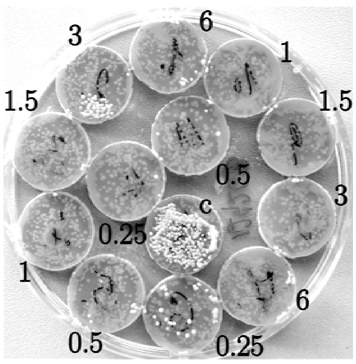

Fig. 7. Results after QH DBD treatment (marked by exposition times [min], "c" is the control sample)

CONCLUSIONS

• Quasi-homogeneous DBD plasma surface treatment acts significantly less invasive compared to filamentary DBD. Homogenized DBD acts gently on agar surface structure, does not drain the agar wafer.

• If the discharge ignited above the GND electrode, significant current peaks for positive voltage alternation only were observed (case «a»). Whereas configuring barrier with air gaps above and below, current peaks were observed in both voltage alternations (case «b»).

• Fungicidal effect on *Candida albicans* growth was increased significantly compared the filamentary and the quasi-homogeneous DBD mode. The quasi-homogeneous DBD mode seems to be a promising type of discharge for not only biological applications and is an object of further research interests.

ACKNOWLEDGEMENTS

This research has been supported by the Czech Technical University in Prague grant № SGS10/266/OHK3/3T/13, by Research Program PRVOUK – P25/LF1/2 *and by a personal gift from Petr Boreš.*

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Article received 25.10.12

СРАВНЕНИЕ ФУНГИЦИДНОГО ВОЗДЕЙСТВИЯ РЕЖИМОВ ДИЭЛЕКТРИЧЕСКОГО БАРЬЕРНОГО РАЗРЯДА НА РОСТ *CANDIDA ALBICANS*

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Нитевидный и квазигомогенный режимы диэлектрического барьерного разряда (ДБР) были исследованы в качестве плазменного источника с фунгицидным воздействием на дрожжи рода *Candida albicans*, которые были высеяны на тонкие диски агара Сабуро. Квазигомогенный режим показал значительно лучшие результаты по сравнению с нитевидным режимом ДБР: для ингибиции дрожжей *C. albicans* потребовалось более короткое время экспонирования. Кроме того, воздействие квазигомогенного режима на структуру поверхности агара было незначительным.

ПОРІВНЯННЯ ФУНГІЦИДНОГО ВПЛИВУ РЕЖИМІВ ДІЕЛЕКТРИЧНОГО БАР'ЄРНОГО РОЗРЯДУ НА ЗРОСТАННЯ *CANDIDA ALBICANS*

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Ниткоподібний та квазігомогенний режими діелектричного бар'єрного розряду (ДБР) були досліджені в якості плазмового джерела з фунгіцидним впливом на дріжжі виду *Candida albicans*, які були висіяні на тонкі диски агара Сабуро. Квазігомогенний режим показав набагато кращі результати порівняно з ниткоподібним режимом ДБР: для інгібіції дріжжів *C. albicans* був потрібний менший час експонування. Крім того, вплив квазігомогенного режиму на структуру поверхні агара був незначний.