Ulva settlement on surface topographic gradients

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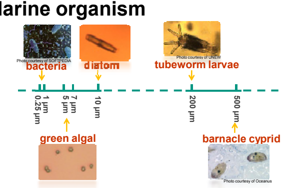
ABSTRACT

Surface microtopography has been found to influence the settlement of cells and larvae [1]. Here the influence of surface topographic features on the biofouling process was studied. Honeycomb gradient structures, inspired by the pattern found on the skin of the pilot whale [2], were obtained by a hot embossing process [3], and the effect on the density of spores of the green alga *Ulva* that attached in laboratory assays was quantified. Spore settlement density was higher on the microstructured gradients than the smooth background. The highest density of spores was found when the size of the microstructures was similar to or larger than the size of a spore. With decreasing size of the honeycombs, spore settlement decreased to a level similar to that on the smooth background. In line with the results from the Brennan group [4], spore settlement closely correlated with Wenzel roughness factor.

INTRODUCTION

Marine organism



Hierarchical surface topographies should be more promising while targeting a wide ranges of species.

Ulva zoospores

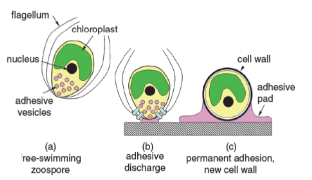


Fig. Cartoon depicting the course of events involved in the settlement and adhesion of *Ulva spores* (*The Ulva Spore Adhesive System*, ed. by A.M. Smith and J.A. Callow)

TECHNIQUE

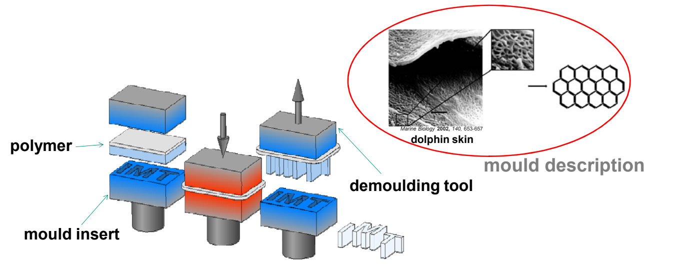


Fig. Schematic view of the hot embossing process. (Image from *DTIP of MEMS & MOEMS* **2008**, 9-11 April)

Hot Embossing Lithography is a microreplication process by stamping the pattern by a mould insert into a soften polymer with controlled process parameters (e.g. temperature, pressure, time). A variety of polymers such as PMMA, PC, PSU, etc. can be used.

SURFACE ANALYSIS

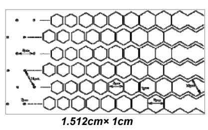


Fig. sketch of honeycomb gradient microstructures.

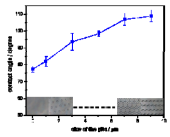


Fig. Surface contact angles across the gradient.

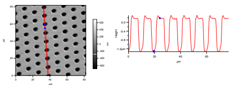
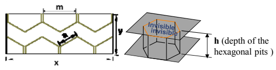


Fig. AFM test of the honeycomb gradient microstructures fabricated on the surface of PMMA.

The depth of the features across the gradient is ***1.57±0.08 µm****.*

Wenzel roughness factor



(**x** and **y** are fixed across the gradient, while **m** and **a** change according to the size of the feature.)

$$\mathbf{x}=30.00\mu m,\quad \mathbf{y}=11.58\mu m,\quad \mathbf{a}=\frac{\sqrt{3}}{3}\mathbf{m}$$

For hexagonal structures,

$$S_{geometric}=S_{projected}=347.40$$

$$S_{actual}=S_{geometric}+S_{wall}=347.40+18\mathbf{ah}=347.40+18\times\frac{\sqrt{3}}{3}\mathbf{m}\times\mathbf{h}=347.40+6\sqrt{3}\,\mathbf{mh}$$

$$R_{Wenzel}=\frac{S_{actual}}{S_{geometric}}=\frac{347.40+6\sqrt{3}\,\mathbf{mh}}{347.40}=1+\frac{10\sqrt{3}}{579}\mathbf{mh}$$

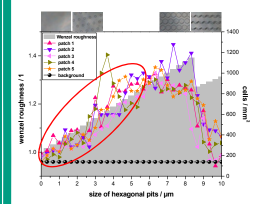
For "Zig-zag" structures,

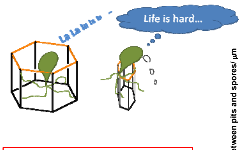
$$S_{geometric}=S_{projected}=347.40$$

$$S_{actual}=S_{geometric}+S_{wall}=347.40+12\mathbf{ah}=347.40+12\times\frac{\sqrt{3}}{3}\mathbf{m}\times\mathbf{h}=347.40+4\sqrt{3}\,\mathbf{mh}$$

$$R_{Wenzel}=\frac{S_{actual}}{S_{geometric}}=\frac{347.40+4\sqrt{3}\,\mathbf{mh}}{347.40}=1+\frac{20\sqrt{3}}{1737}\mathbf{mh}$$

Smallest pits for spores





The minimum size of the pits for spores to fit in is around ***2.6 µm****.*

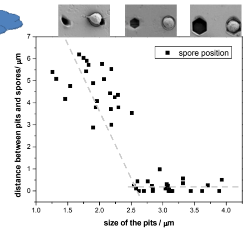
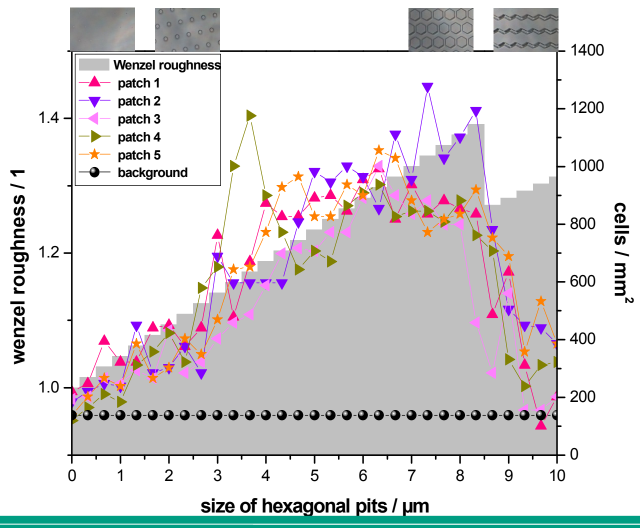


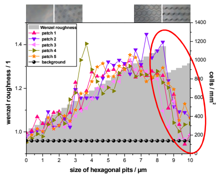
Fig. Distance between pits and spores at different positions

SPORE SETTLEMENT

Wenzel roughness & Ulva spore settlement



"Kink site" effect



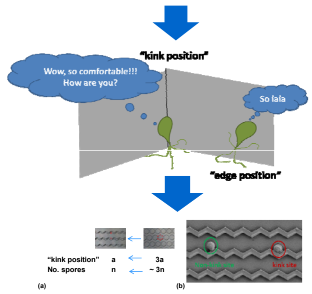


Fig. (a) sketch of "kink site" effect; (b) SEM images of kink site and non-kink site

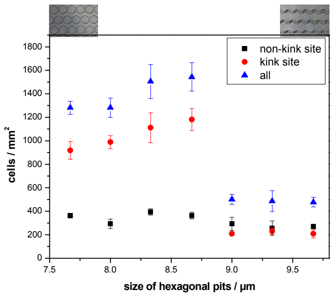


Fig. Mean cell counts for spores at different positions while going from hexagon to zigzag

The decreasing of spore settlement from hexagon to zigzag structures is mainly caused by the reduction of spores at kink sites.

CONCLUSION

Nearly linear correlation was found between Wenzel roughness factor and spore settlement on honeycomb gradients. During settlement, the "kink position" was preferred, which influenced the effect of Wenzel roughness factor on spore settlement while the structure changed from hexagon to zigzag. The smallest size of the pits where spores could fit in on the gradient is around 2.6 µm.

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