Bio-inspired Silicon Nanospikes Fabricated by Metal-Assisted Chemical Etching for Anti-bacterial, Wearable Systems

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***Abstract*— Researchers have recently discovered that the nano-structures found on cicada wings can mechanically kill bacteria upon contact. Reported here is a simple, fast, low-cost, and scalable nanofabrication method based on metal-assisted chemical etching using a single crystal silicon substrate, to create biological inspired anti-bacterial surfaces. We evaluated the effect of etch time, the anti-bacterial surface coverage, and speed of incubation on bacterial growth rate. We discovered that a 6 minute etch time, an anti-bacterial surface coverage greater than 0.5 cm^2, and a static incubation environment generated the greatest rate of reduction in bacterial growth over time, and lysed all bacteria in 3 hours. These findings suggest these nano-spikes may be a useful anti-bacterial surface for use in wearable systems.**

I. INTRODUCTION

Antibacterial surfaces can limit bacterial growth and inhibit infection, and are useful in wearable devices such as contact lens and medical implants [1]. To fabricate biomimetic nano-structures similar to cicada wings, researchers have relied on non-lithographic methods such as reactive ion etching and glancing angle deposition, which are expensive and require a vacuum environment. Here, we proposed to create nano-spikes using a low-cost metal-assisted chemical etching method (MacEtch) that uses two common chemicals: hydrofluoric acid and silver nitrate to etch a single crystal silicon in minutes at room temperature [2].

II. MAIN RESULTS

To determine if the rapid MacEtch method can generate the optimal pitch of 200 nm that has been reported to be critical in the bactericidal property [3], silicon nano-spike samples were prepared at 2.5, 6, and 10 minute etch times and their anti-bactericidal activity evaluated (data not shown). We found that at 6 minutes, the height of the nano-spikes is ~1.1 µm, with an average pitch of 220 nm (Figure 1 (a) and (b)). Figure 1 (c) shows a helium ion microscope image of a lysed *E. coli* bacterium on a 6 minute etched nano-spike sample.

We evaluated the effect of surface area and speed of incubation on bacterial growth rate. We discovered that the a nano-spike coverage larger than 0.5 cm^2 can lyse all bacteria in 3 hours at a starting $OD_{600} = 0.1$ (Figure 2 (a)). Interestingly, a nano-spiked sample incubated in a static environment is more effective at reducing bacterial growth compared to a same sized sample rotated at 100 rpm (Figure 2 (b)). We hypothesize a sample in a static condition would allow more time for *E. coli* to attach to the surface and get lysed by the nano-spiked surface. In contrast, in a rotation condition, it is more difficult for the bacterium to attach to the surface, and therefore less likely to get lysed.

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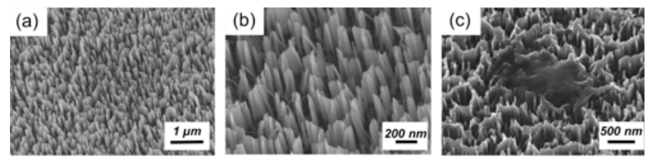

Figure 1. SEM images of silicon nanospikes formed by MacEtch at 6 minutes at (a) 1 µm and (b) 200 nm resolution. (c) Helium Ion Microscope image of a lysed *E.coli* bacterium on a nano-spiked surface.

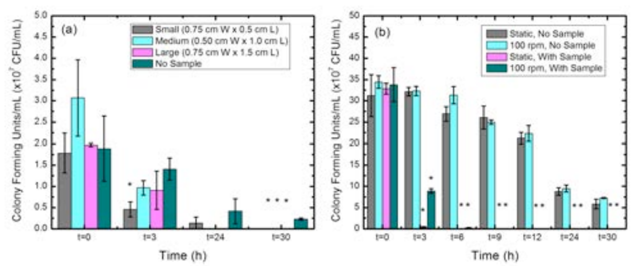

Figure 2. *E. Coli* bacterial colony growth at different time points as a function of (a) different MacEtch surface coverage, and (b) in a static or rotational environment. Error bars are s.d values of triplicate plates. Statistical significance was determined by a one-tailed t-test against control.

III. CONCLUSIONS

We presented a novel, low-cost, and scalable MacEtch method for creating anti-bacterial surfaces useful for wearable and medical sensor applications. Using the MacEtch method, we demonstrated that a 6 minute etch time, with an anti-bacterial surface greater than 0.5 cm^2, in a static environment is most successful at eliminating bacterial growth in 3 hours, with a starting $OD_{600} = 0.1$.

REFERENCES

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