CARBON 2019
LEXINGTON, KY

MOSQUITO BITE PREVENTION THROUGH GRAPHENE BARRIER LAYERS

Cintia J. Castilho[1]*, Dong Li[1], Muchun Liu[1,2], Yue Liu[1], Huajian Gao[1], Robert H. Hurt[1]

[1]School of Engineering, Brown University, Providence, USA.
[2]Department of Chemistry, Brown University, Providence, USA.

*Presenting author's e-mail: c_barbosadecastilho@brown.edu

Introduction

Graphene-enhanced fabrics are being explored in wearable technologies for various applications including environmental sensing, biomonitoring, and chemical toxicant barriers(1, 2). An unexplored application area for graphene-enhanced smart fabrics is protection against infectious diseases. Mosquitoes are vectors for infectious diseases affecting millions of people every year. Here we hypothesize that graphene films could also be engineered to serve as barrier layers in fabrics to prevent mosquito biting. Our hypothesis is assessed using a combination of live mosquito experiments on human skin and mechanical penetration tests.

Materials and Methods

Live mosquito experiments. The mosquito experiments were conducted by exposing human skin patches of defined area to the interior of the mosquito containment chamber. One hundred *Aedes Aegypti* female mosquitoes were purchased per batch. Experiments were performed in the morning (9am – 12 pm) with randomized sequences of tests and controls to minimize behavioural effects. The control experiments were performed by exposing a small defined area of live human skin (hand or lower forearm), with or without cheesecloth, within the containment chamber. For the test experiments, graphene films were placed on the skin patches using a cheesecloth covering to minimize air gaps, and the edges were taped to control the active area of the test. Experiments with wet films were conducted by addition of nanopure water/sweat to the top of the graphene/cheesecloth patch. All the experiments were recorded with a Canon EOS Rebel T6S camera and all graphene films were inspected for pin holes and cracks using a Zeiss Stemi 2000-C optical microscope.

Results and Discussion

In the presence of water/sweat, we observed the mosquitos to land, stay, and actively probe, but for reduced graphene oxide (rGO) films not to successfully bite (Fig. 1). This suggests rGO films are capable of resisting fascicle penetration. An unexpected finding of our study was the ability of mosquitos to bite through graphene oxide (GO) films in the wet state (Fig. 1). The bite frequencies are lower than controls but are non-zero and reproducible. Graphene oxide is known to be a hygroscopic material(3) and upon water absorption, swell, and form hydrogels. Our wet GO films are easily destroyed upon handling. In contrast, rGO films with reduced oxygen functionality do not absorb water or swell, and likely retain their mechanical properties.

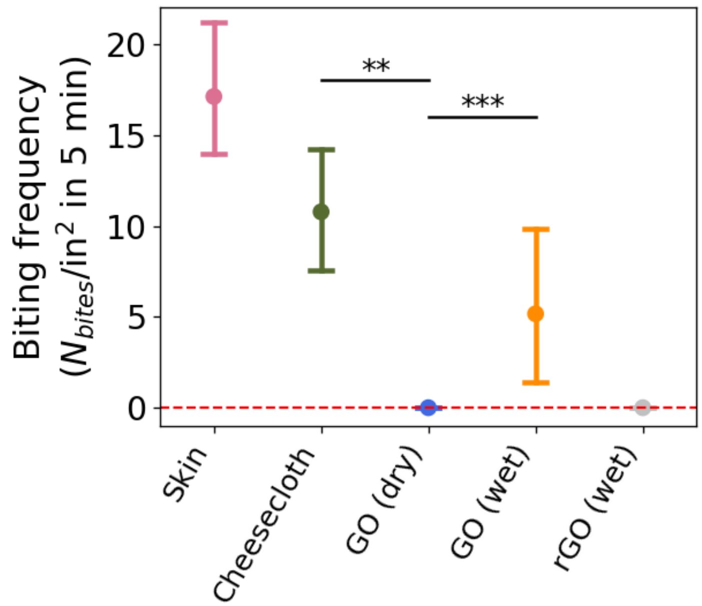

Figure 1. Effect of graphene films on mosquito biting behaviour. Experimental statistics on mosquito contact frequency on dry and wet graphene films compared to control experiments. Data presented as mean +/- s.e.m. *** P < 0.05. **P < 0.01.

Conclusions

Graphene-based films applied to wearable technology also offers mosquito bite protection. Graphene films (GO and rGO) offer full protection when in dry state. The primary mechanism of protection is the interruption of the mosquito sensing system through a molecular barrier effect. On the other hand, when water/sweat is introduced on the external film surface only those graphene films with sufficient mechanical puncture resistance offer bite protection -- i.e. rGO with surface water, but not GO hydrogel.

References

1. Karim N, *et al.* (2017) Scalable Production of Graphene-Based Wearable E-Textiles. *ACS Nano* 11(12):12266-12275.
2. Spitz Steinberg R, Cruz M, Mahfouz NGA, Qiu Y, & Hurt RH (2017) Breathable Vapor Toxicant Barriers Based on Multilayer Graphene Oxide. *ACS Nano* 11(6):5670-5679.
3. Lian B, *et al.* (2018) Extraordinary water adsorption characteristics of graphene oxide. *Chemical science* 9(22):5106-5111.