MosBracelet: A Mosquito Repelling Bracelet

Kevin (Won June) Cho, Christine Hwang, Jiwon Min, Stephen Park
Department of Chemical and Biomolecular Engineering
Johns Hopkins University

Motivation

Mosquitoes are the deadliest animals to humans – they kill about a million people every year because of mosquito-borne diseases, such as malaria and dengue fever. Moreover, mosquitoes are often huge nuisances in the summer for people who are not even at risk of mosquito-borne diseases. Therefore, we are proposing an idea of a mosquito-repelling bracelet, or MosBracelet. MosBracelet is a Poly Lactic-co-glycolic acid, or PLGA, nanofiber bracelet loaded with citronella oil, or CO. MosBracelet has 95.8% effectiveness in repelling mosquitoes and is biodegradable. Lastly, because we use an electrospinning method to form core-sheath nanofibers to encapsulate CO, MosBracelet has a sustained and extended release of CO to effectively repel mosquitoes for up to 9 days.

Market



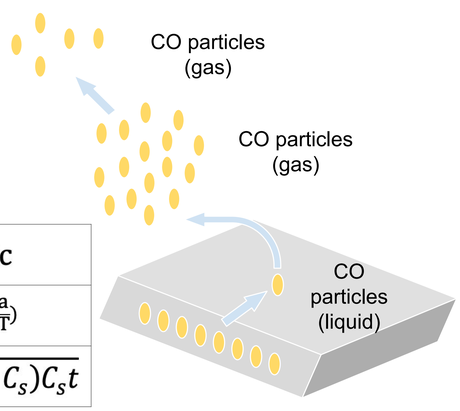
	Bugslock[1]	Kinven[2]	MosBracelet
Repellent Type	Essential oil	Essential oil	Essential oil
Design	Chamude; adjustable strap	PU leather; adjustable strap	Nanofiber; adjustable strap
Price	$4.99 per unit	$2.25 per unit	$3.00 per unit
Release	Burst	Burst	Sustained

To understand the current competitive field, we compared our product with top products in the mosquito bracelet market, Bugslock and Kinven. For all three bracelets, many of the features, including repellent type, design, and price, are similar. However, one key advantage of MosBracelet is that the repellent has a sustained release, whereas the other two brands have a burst release. Bracelets with burst release of repellent material may be highly effective in the beginning but rapidly lose effectiveness with time. On the other hand, bracelets with sustained release, like MosBracelet, are steadily effective for a long period. This advantage will give MosBracelet a competitive edge in the mosquito repellent bracelet market.

Product Model

As seen in the figure below, the release model of CO can be divided in three different steps. We used the Higuchi equation[3] to model the liquid-to-liquid diffusion of the CO from the center of the fiber to the surface of the fiber. Then, we used the Arrhenius equation to model the evaporation of the CO from the surface of the fiber to the air.

Lastly, we used Fick's Law of Diffusion to model the gas-to-gas diffusion of the CO further out to the atmosphere, which is important as the CO needs to further diffuse to repel mosquitoes. The equations used are listed below:

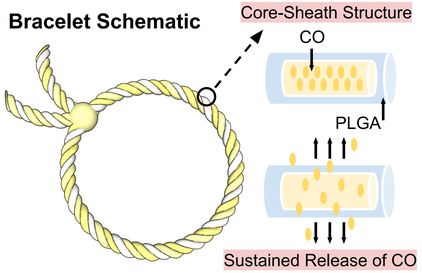


Fick's Law of Diffusion	$N = -D\nabla c$
Arrhenius Equation	$k = Ae^{(-\frac{Ea}{RT})}$
Higuchi's Equation	$Q = A\sqrt{D(2C - C_s)C_s t}$

By using Fick's Law of Diffusion to calculate the target CO concentration on the surface and using Arrhenius Equation to calculate the evaporation rate, we were able to use both numbers to calculate the required amount of CO loaded per bracelet and the total weight of the bracelet as well.

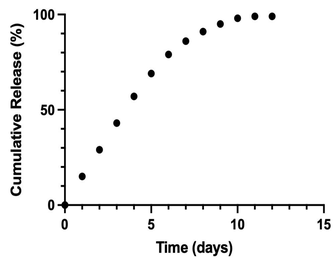
Product Specification

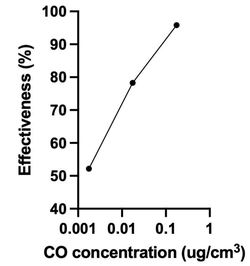
Bracelet Schematic



Bracelet Dimensions	
Total Length (cm)	20
Radius (cm)	2 ~ 3
Thickness (diameter, cm)	0.5
Weight (g)	3.6
Surface Area (cm^2)	31.4

Nanofiber Properties	
Nanofiber Diameter (nm)	750
Nanofiber Porosity (%)	70
PLGA-CO Volume Ratio (V_{sheath} / V_{core})	1/9





MosBracelet is comprised of core-sheath-shaped nanofibers, loaded with CO as a core strand and PLGA as a sheath layer. Slit-surface electrospinning, which is suitable for large-scale production of electrospun nanofibers without electrical interference, is used to fabricate the structured nanofibers.[4] The primary advantage of having a core-sheath morphology is the sustained release of the citronella oil. Unlike other repellents with typical burst release of oil, MosBracelet steadily releases the oil until complete depletion. Overall, MosBracelet is expected to maintain a constant release profile until day 9 with 95.8% repellent effectiveness.

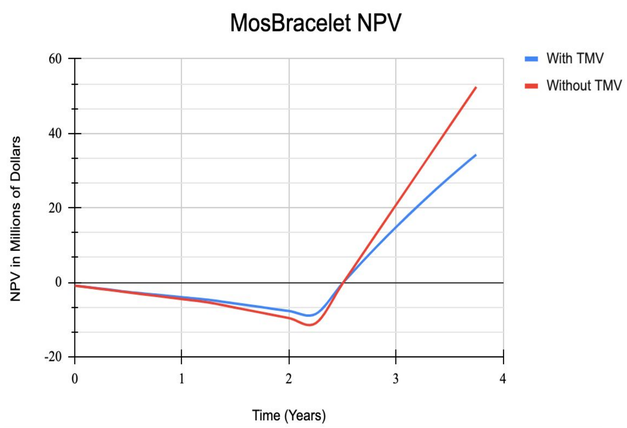
Manufacturing

Purchasing Materials | Slit-surface Electro-spinning | Post-processing (Bracelet Manufact-uring) | Quality Inspection | Packaging and Distribution

Our manufacturing process can be divided into five main parts as shown in left. Once the product materials are purchased, the core-sheath structured nanofibers will be fabricated using Inovenso StreamSpinner1000 with customized slit-surface spinnerets and rotating collectors for nanofiber yarns.[5] The fiber yarns are then braided, cut, and tied in post-processing step to make bracelets. At the end of the manufacturing stage, there will be a quality inspection. A deep learning will be used to detect any physical deformities and a programmed robotic arm will pick out the defective ones. MosBracelet will be packed and distributed in plastic vacuum bags to prevent the evaporation of the CO. Sorbent Systems vacuum bags and PAC Machinery vacuum sealer will be used.

Electrospinning Operation Parameters	
PLGA Content in Sheath Solution (wt%)	20
Sheath Solution Solvent	Dimethylformamide
CO Content in Core Solution (wt%)	70
Core Solution Solvent	Acetic Acid
Feed Solution Input Flowrate (mL/hr)	1200
Production Rate (bracelets/hr)	199

Financials



Looking at the graph on the left, we expect MosBracelet to break even in Year 2, around Q2. This is around the time that MosBracelet begins making revenue. We expect to make around 19 million bracelets in our first year in the market, with each bracelet being priced at 3 USD. We expect our revenue to increase as we make more bracelets.

Development Costs

We estimate our development costs to be around 3.6 million USD. Our development costs include personnel costs for our three development teams. Other costs pertain to development tasks such as prototyping and generating commercials. We expect to spend our development costs up to Year 2, Q2.

Capital Costs

We estimate our capital costs to be around 1.9 million USD, based on the production of 19 million bracelets. Our capital costs mostly pertain to equipment used for electrospinning and quality inspection. Other costs include off-site costs for delivery and storage. We expect our 1.9 million USD of capital costs to be spent before Year 2, Q2. However, we allot around 0.1 million USD each year after Year 2, Q2, mainly for purchasing more equipment as we produce more bracelets.

Operating Costs

We estimate our operating costs to be around 16.1 million USD, based on the production of 19 million bracelets. Our operating costs mostly pertain to materials and labor. As we produce more bracelets, we expect our operating costs to increase.

Conclusions

MosBracelet has

- A hopeful stance in the current market
- A scientifically-based design
- Projected financial stability

With these strengths and its mission to help those around the world, we believe that MosBracelet will help combat mosquitoes and the negative impacts they bring, one bracelet at a time.

References

1. *#1 genuine Bugslock mosquito repellent bracelet*. Amazon. (2016). Retrieved April 24, 2022, from https://www.amazon.in/Genuine-Bugslock-Mosquito-Repellent-Bracelet/dp/B01NALJB36
2. Walmart. (2020). *Kinven Original Mosquito Insect Repellent Bracelet*. Walmart. Retrieved April 24, 2022, from https://www.walmart.com/ip/Kinven-Original-Mosquito-Insect-Repellent-Bracelet-Waterproof-Natural-DEET-Free-Insect-Repellent-Bands-Gold-nbsp/977426325
3. Paarakh, Padmaa, et al (2019). Release Kinetics – Concepts and Applications. International Journal of Pharmacy Research & Technology, 8(1). https://doi.org/10.31838/ijprt/08.01.02
4. Yan, X., Marini, J., Mulligan, R., Deleault, A., Sharma, U., Brenner, M. P., Rutledge, G. C., Freyman, T., & Pham, Q. P. (2015). Slit-surface electrospinning: A novel process developed for high-throughput fabrication of core-sheath fibers. PLOS ONE, 10(5). https://doi.org/10.1371/journal.pone.0125407
5. Inovenso. (n.d.). STREAMSPINNER1000 industrial electrospinning/spraying. StreamSpinner1000 Open Surface Industrial Electrospinning/Spraying Line. Retrieved April 18, 2022, from https://www.inovenso.com/portfolio-view/streamspinner-1000/