BioMEMS Applications Activity: Nanomachines
Instructor Guide

Notes to Instructor

This Activity provides the opportunity for exploration into biomedical applications of MicroElectroMechnical Systems (MEMS). It is one of three activities in the bioMEMS Applications Overview Learning Module. These three activities can be completed in any order or combination. The participants can complete one of the activities prior to completing the primary knowledge unit. This would provide an opportunity for inquiry.

The BioMEMS Applications Overview Learning Module consists of the following units:

- BioMEMS Applications Knowledge Probe (KP or pretest)
- BioMEMS Applications Overview PK
- **BioMEMS Applications Overview Activity: Nanomachines**
- BioMEMS Applications Overview Activity: ELISA
- BioMEMS Applications Overview Activity: DNA Hybridization
- BioMEMS Applications Overview Assessment

Description and Estimated Time to Complete

This is one of three activities for the BioMEMS Applications Learning Module. You can complete this activity either before or after reviewing the BioMEMS Applications Overview PK.

Some biomolecules are nanomachines. For example, there are proteins and enzymes that perform the same functions of rotary and linear motors, or act as filters by identifying and separating molecules. Many bioMEMS applications could utilize nanomachines that already exist as biomolecules. This activity provides the instructions for accessing an on-line tutorial on nanomachines.

This activity has some post-activity questions that allow you to demonstrate your understanding of the information presented in the tutorial.

Estimated Time to Complete
Allow at least 30 minutes to complete.

Introduction

Imagine a device that restores sight when implanted in the retina of the eye, or a "skin patch" chip capable of detecting an invading microorganism before symptoms develop. These two applications of bioMEMS devices are already being tested for the commercial market.

Applications for bioMEMS devices exist in clinical medicine, environmental, biological and chemical analysis. Applications from one area often overlap with other areas. Applications can be broadly placed into the categories of clinical diagnostics and therapeutics, environmental applications including Homeland Security, food safety, and bioprocessing.

Many of these applications could utilize nanomachines that already exist as biomolecules. Such nanomachines include biomolecular rotary motors (e.g. ATP synthase enzyme in the cell membrane) and biomolecular linear motors (e.g. myosin proteins that assist with muscle contraction). Designing bioMEMS can be just a matter of knowing how these biomolecules work and exploiting their mechanical characteristics.

Activity Objectives and Outcomes

<u>Activity Objectives</u>

- Interact with nanomachines using Molecular Workbench
- Explain the forces that allow nanomachines to work
- Demonstrate your understanding of these forces by designing and building a nanomachine

<u>Activity Outcomes</u>
Upon completion of the Molecular Workbench activity "Nanomachines", you will have observed and interacted with nanomachines, including biological nanomachines. You will use the information gained from these interactions to design and build your own nanomachine.

This activity relates to the BioMEMS applications described in the *BioMEMS Applications Overview* Primary Knowledge unit.

Resources

Computer with high-speed Internet access.

Documentation

Your documentation should include all of the questions asked during each stage of this activity and your answer to each of these questions.

Documentation should also include the <u>Post-Activity Questions</u> and your answers.

Activity: Playing with Nanomachines

This activity will help you better understand how nano-sized devices are used to move and manipulate molecules and atoms. You will utilize the tutorial at The Molecular Workbench.

1. Go to The Molecular Workbench at http://workbench.concord.org/database
2. In the upper right hand corner, "Jump to Activity" #276. Select "Student". This should take you to an interactive called Nanomachines. (*NOTE: If you have a problem with the link, do a search within Molecular Workbench for Nanomachines.)*
3. "Go to Activity" (It may take a few minutes to download.)
4. Complete the activity by selecting all links on all pages.
   Some links are games. Some links are demonstrations.
5. During this activity, record all questions and your answers to these questions.
6. Answer the Post-Activity questions.

Post-Activity Questions

a. What is a monolayer?

b. How can Coulomb forces be used in the self-assembly of a monolayer?

c. What are Van der Waals forces?

d. Nanomachine –
   - What did you make?
   - What did it do?
   - What might be a possible application for your nanomachine?

Post-Activity Questions / Answers

a. What is a monolayer?
   Answer: A layer consisting of a single layer of molecules

b. How can Coulomb forces be used in the self-assembly of a monolayer?
   Answer: Coulomb's Law states "The magnitude of the force is proportional to the product of the two charges, divided by the square of the distance between them".[3] In other words, "the Coulomb force increases as two charges get closer, so at atomic dimensions it is much stronger than in our macroscopic world. We are occasionally aware of electrostatic forces at the macroscopic scale, as when hair clings to a comb, but it certainly does not

dominate our lives the way gravity does." (Molecular Workbench, Nanomachines, p 2 of 5)

c. What are Van der Waals forces?

Answer: "Van der Waals attractions are tremendously important at the molecular level; they make the molecular world very sticky. At the macroscopic level, electrostatics never causes two neutral objects to attract, but it can have that effect at the atomic level. Random fluctuations in the electrons around one atom can induce a fluctuation of charge in any nearby atom. The resulting attraction between the two atoms is called the van der Waals attractions. While this is a relatively weak force, it causes any two atoms to attract when they are sufficiently close. Without this force, there would be no liquids and few solids." (Molecular Workbench, Nanomachines, p 3 of 5)

Variation: Van der Waals force is a" weak attractive force between atoms or nonpolar molecules caused by a temporary change in dipole moment arising from a brief shift of orbital electrons to one side of one atom or molecule, creating a similar shift in adjacent atoms or molecules."[4] While this is a relatively weak force, it causes any two atoms to attract when they are sufficiently close. It is the force "responsible for nonideal behaviour of gases and for the lattice energy of molecular crystals."[4]

d. Nanomachine –

- What did you make?
- What did it do?
- What might be a possible application for your nanomachine?

Summary

BioMEMS exploit the characteristics of biological molecules to perform tasks that improve diagnostics and therapeutic applications within the medical field. As engineers and designers of bioMEMS understand more about the workings of nanodevices and nanomachines, everyone will benefit through improved and more efficient healthcare.

References

[1] The Molecular Workbench at http://mw.concord.org/ (Program funded by the National Science Foundation)

[2] SCME's *BioMEMS Applications Overview* Primary Knowledge unit

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