Nanoelectronics Undergraduate Research Fellowship (NURF) 
2010 Project Summary

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Project title: Guiding Bacteria Attachment with Magnetic Nanoparticles

Our group undertook the challenge of attaching a bacteria, p. Chloraphis with Fe3O4 (magnetite) nanoparticles, with the intent of controlling these newly formed objects with magnets. Complications in the experiment were to confirm that the magnetite was not toxic to the bacteria and secondly, that binding did happen between the two.

To overcome these obstacles we approached this experiment in several ways, which included but not limited to, Spectroscopy, XPS, SEM, AFM and Confocal microscope work. We determined size and shapes of nanoparticles plus attachment. APTES was used to enhance binding of the two. The addition of an external magnet was then used to control the area of bacterial growth in a flow cell.

(Results below)

We have presented a poster of our work to date. We are also doing continual work to bring forth to a paper. (See following page)
Guiding Bacterial Attachment with Magnetite Nanoparticles

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Background

The ability to control the orientation and formation of bacterial biofilms could have a significant impact on our understanding of the steps in biofilm formation and on the activities of bacteria on human health and the environment. We have designed a method to localize the attachment of selected bacteria to a substrate using nanoparticles. Using a combination of magnetic force microscopy and transmission electron microscopy, the attachment of bacteria to a substrate was further delineated with an orientation, amnogamosynthetase, and magnetite nanoparticles (SNMPs), which can be manipulated by a magnetic field. Attachment of bacteria to the magnetic nanoparticles was observed with a magnetic field, suggesting that the SNMPs are associated with the bacterial cell wall.

Synthesis and characterization of magnetite nanoparticles (SNMPs)

Nanoparticles of magnetite (Fe₃O₄) were synthesized from FeCl₃ and FeCl₂ in a reducing environment. The nanoparticles were synthesized in a reducing environment. The resulting particles were characterized by transmission electron microscopy (TEM) and dynamic light scattering (DLS). The nanoparticles were used to study the attachment of bacteria to a substrate.

Modification of Pseudomonas bacteria

In order to follow bacterial attachment and the formation of biofilms, the bacteria were grown in a defined medium and treated with a magnetic field. The magnetic field was oriented to induce a magnetic moment in the bacteria. A combination of magnetic force microscopy and transmission electron microscopy (TEM) was used to visualize the attachment and detachment of the bacteria. In the presence of a magnetic field, the bacteria were oriented along the magnetic field lines, suggesting the interaction of the bacteria with the magnetic nanoparticles. The nanoparticles were also used to manipulate the bacteria, allowing for the study of bacterial behavior in the presence of a magnetic field.

Effect of SNMPs on the growth of P. chloro.

Growth of P. chloro in the presence of SNMPs

Growth of P. chloro was monitored in the presence and absence of magnetic nanoparticles. The growth rate of the bacteria was significantly lower in the presence of the magnetic nanoparticles, indicating a reduction in the growth rate. The nanoparticles were found to inhibit the growth of the bacteria, suggesting a potential for the use of magnetic nanoparticles in the control of bacterial growth.

Guided attachment of P. chloro-SNMPs

A microfluidic device was used to guide the attachment of P. chloro bacteria to a magnetic field. The device consisted of a magnetic field that was used to orient the bacteria in a specific direction. The guided attachment of the bacteria was monitored using magnetic force microscopy. The guided attachment was found to be highly dependent on the direction of the magnetic field, suggesting the potential for the use of magnetic nanoparticles in the control of bacterial behavior.

Conclusions

1. Our method of attaching magnetite nanoparticles (SNMPs) to bacteria provided a viable means of controlling bacterial attachment.
2. SNMPs were not toxic to P. chloro bacteria.
3. An external fixed magnet successfully localized the attachment of bacteria to the substrate, allowing for the selective attachment of bacteria to specific areas.
4. We have yet to gain evidence that the SNPMS are binding to the bacteria. An analysis of the time course of attachment suggests that SNMPs are temporarily bound to the bacteria and then selectively released to the substrate.

Future Work

Determination of the stoichiometry of binding of SNMPs to bacteria. We have yet to develop a way to quantitate the number of nanoparticles in solution. Scanning electron microscopy should provide us direct evidence of the number of SNMPs binding to each bacterium.

In order to more precisely localize the attachment of bacteria, we are developing arrays of microfluidic devices with a magnetic field in the substrate. The device consists of a magnetic field that is used to orient the bacteria in a specific direction. The guided attachment was found to be highly dependent on the direction of the magnetic field, suggesting the potential for the use of magnetic nanoparticles in the control of bacterial behavior.

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References


[Image of diagram related to the text]