COLLEGE OF ENGINEERING
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Honors Capstone Research (HCR) Summer Program 2020

Role of the adhesion torque on spiky particles deposition

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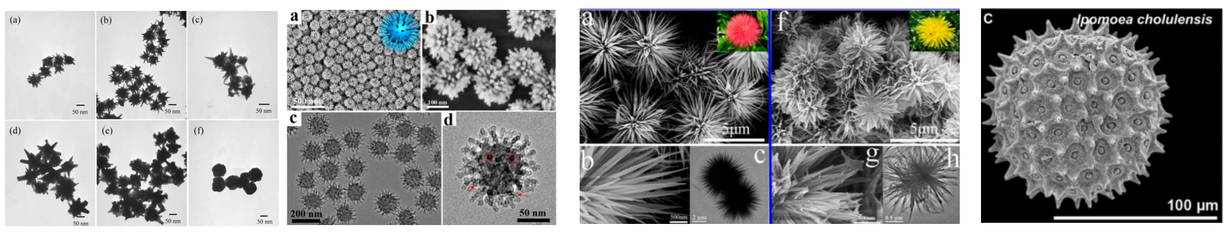
Introduction

Range in size from nanometers to micrometers



Urchin-like (1) Virus-like (2) Flower-like (3) Pollen (4)

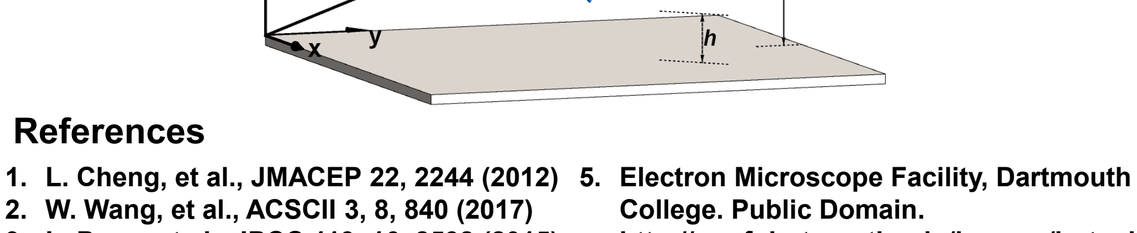
The study of the interactions of anisotropic colloids with substrates is of interest due to their widespread applications in medicine, energy, defense, etc. Spiky colloidal particles are commonly seen in nature; however, there is evidence that undermines its effectiveness. Because of anisotropy, the spikes affect the DLVO interactions as well as the adhesion torque. In this study of particle-surface interactions, the interactions are modeled as a function of particle position, orientation, and shape. Gold spiky particles are modeled after micron-sized pollen. We quantify the DVLO interactions using the surface element integration method. As the spike shape and length vary, the changes in energy confirm previous studies on the effect of Gaussian curvature on planar-substrate interactions, and the overall torque is observed.

The objectives are to

- Model the effect of spikes on colloidal particles on DLVO interactions and separation distance.
- Study the spike influence on particle adhesion.

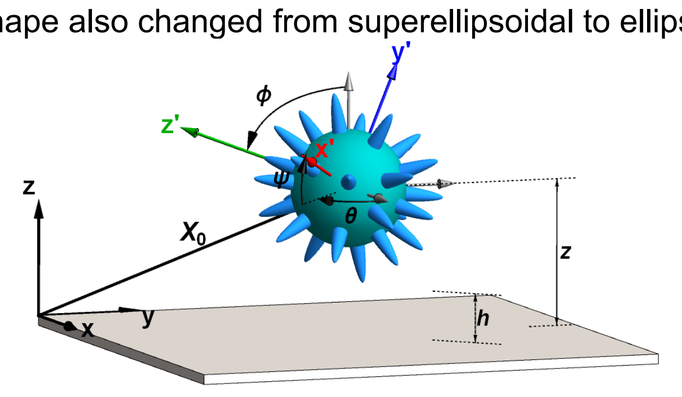
Methodology

1.) Initial image 2.) Reconstruction 3.) Mesh rendering



Helianthus annuus (common sunflower) pollen (5)

- The DLVO theory states that the overall interaction potential energy (electrostatic energy (U_E) and Van der Waals energy (U_V)) is a function of separation distance (h) and orientation.
- The gold spiky particle modeled is at the micron scale using image reconstruction.
- The spikes of the particles were arranged according to the 3 Euler Angles.
- The particle's overall orientation due to particle symmetry is plotted as a function of the polar angle φ and the rotor angle ψ.
- The spike length size of the particle was varied by changing the aspect ratio of the spikes with respect to the core.
- The spike shape also changed from superellipsoidal to ellipsoidal.

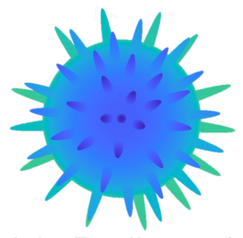


References

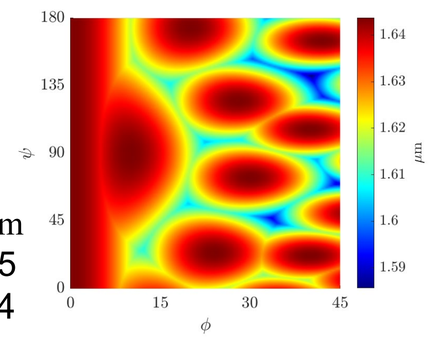
1. L. Cheng, et al., JMACEP 22, 2244 (2012)
2. W. Wang, et al., ACSCII 3, 8, 840 (2017)
3. L. Peng, et al., JPCC 119, 16, 8538 (2015)
4. J. Liu, et al., PNAS 117,18, 9704 (2020)
5. Electron Microscope Facility, Dartmouth College. Public Domain. http://remf.dartmouth.edu/images/botanicalPollenSEM

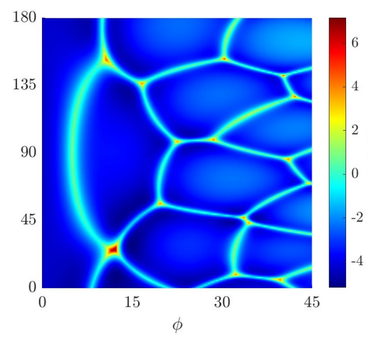
Results

Separation distance and DLVO interaction energy



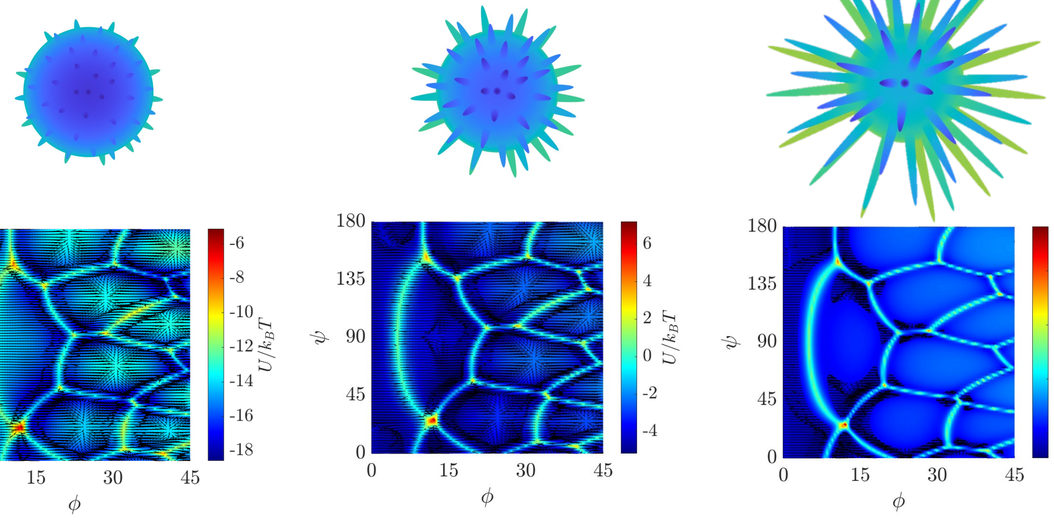
Particle Radius = 1 µm
Aspect Ratio r_z/r_x = 15
Core Size r_c/r_x = 10.4





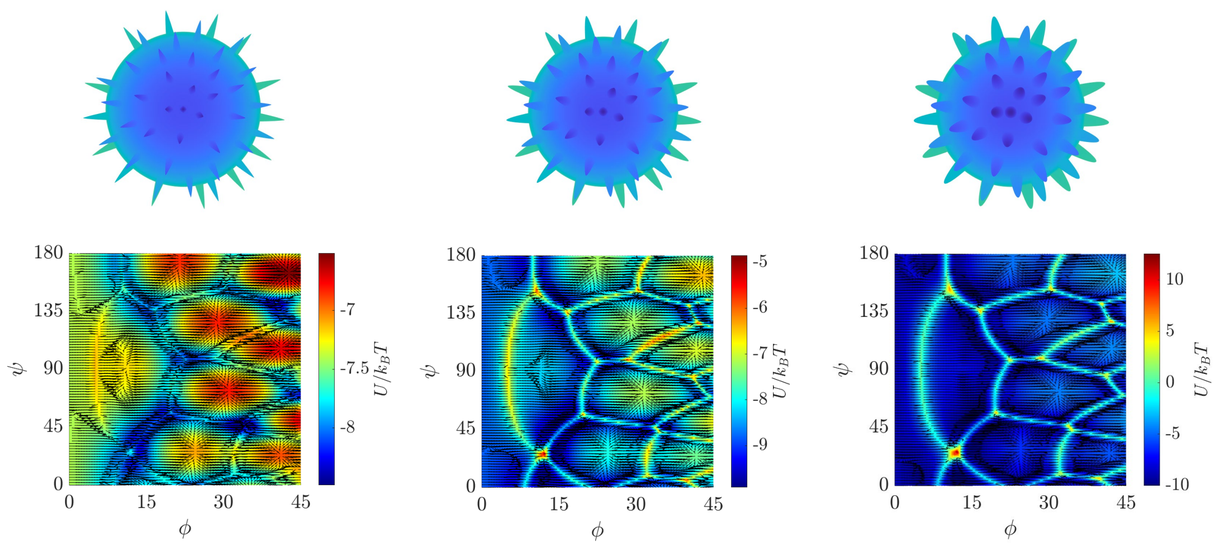
Influence of the spike length (Spike shape = 2, Core size r_c/r_x = 10.4)

Aspect Ratio r_z/r_x = 12 Aspect Ratio r_z/r_x = 15 Aspect Ratio r_z/r_x = 25



Influence of the spike shape (Aspect ratio r_z/r_x = 10, Core size r_c = 7.6)

Spike Shape n = 1.3 Spike Shape n = 1.6 Spike Shape n = 2



Conclusions

- We developed a methodology to study the particle-surface interactions of spiky particles.
- The preliminary results explain the prevalence of spiky particles in nature despite the decreased surface area of interaction.
- As many spikes contact the surface, they generate a resistive torque, which prevents particle rotation.
- Whereas spike length and spike shape have no effect on the energy surface profile as a function of orientation, particles with less roughness have more attraction.
- The roughness creates an energy barrier that stabilizes the particle at different orientations over the surface.
- As the Gaussian curvature increases, the adhesion energy decreases.
- In the future, this work can be extended to different geometries, particle shapes, and surfaces.

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