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Influence of Nanoparticle Chemical Composition on *In Situ* Hydrogel Friction

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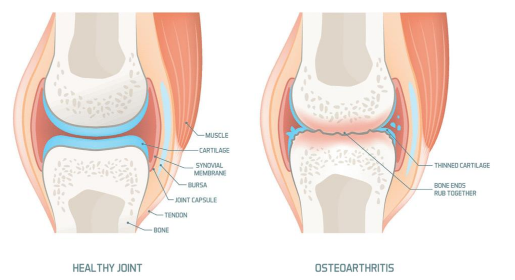
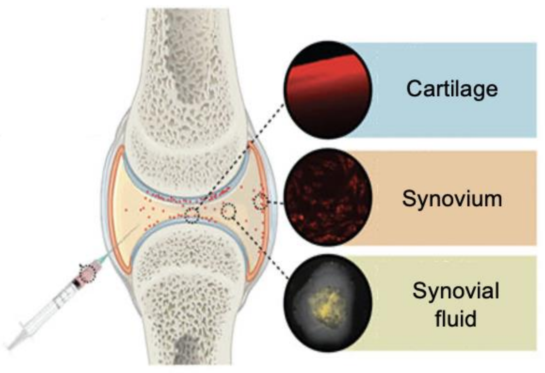
Introduction

Background: Osteoarthritis (OA) is characterized by the degradation of cartilage in the joints.



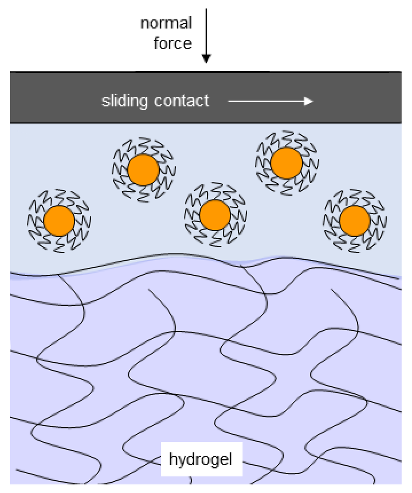
Current treatments control inflammation and pain, but there is no proven way to repair the degraded cartilage.

One developing route for drug delivery employs nanoparticles (NPs). With tunable size, composition, and surface chemistry, NPs can be used as carriers for drugs treating OA and injected directly into synovial joints.



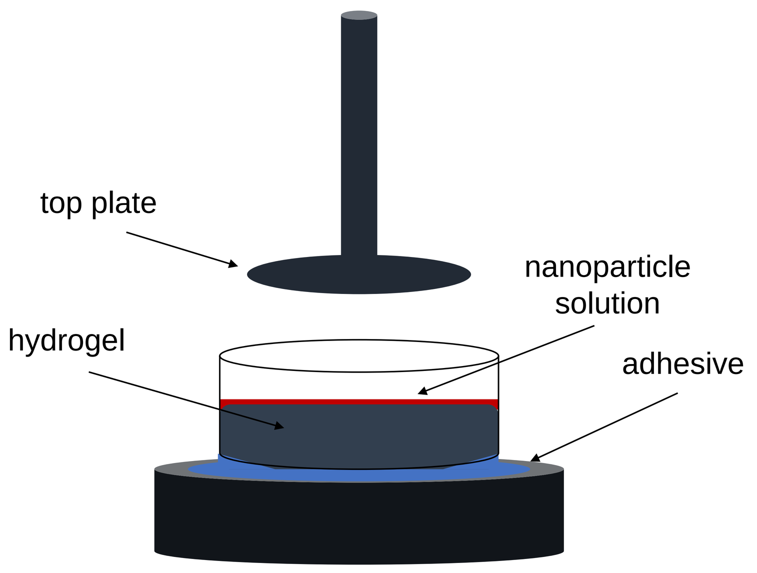
However, there are still open questions regarding how NPs impact sliding within the joint. Potential impacts range from NPs inducing abrasive sliding, or NPs integrating and strengthening the cartilage.

Project Overview:
Understand interfacial interactions between nanoparticles and cartilage-mimicking hydrogels during sliding.



Sliding Tests

A rheometer with a tribology adapter was used to perform macroscale *in situ* sliding tests.



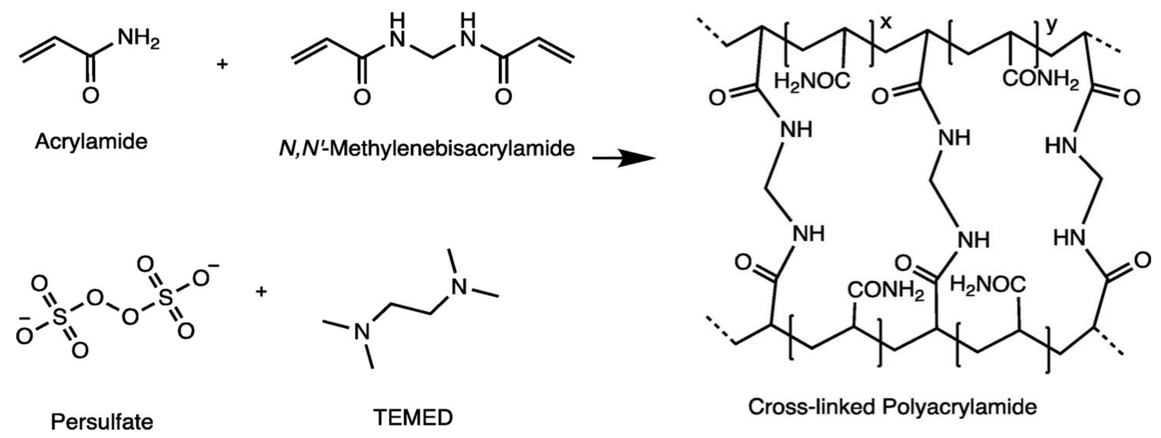
Sliding parameters:

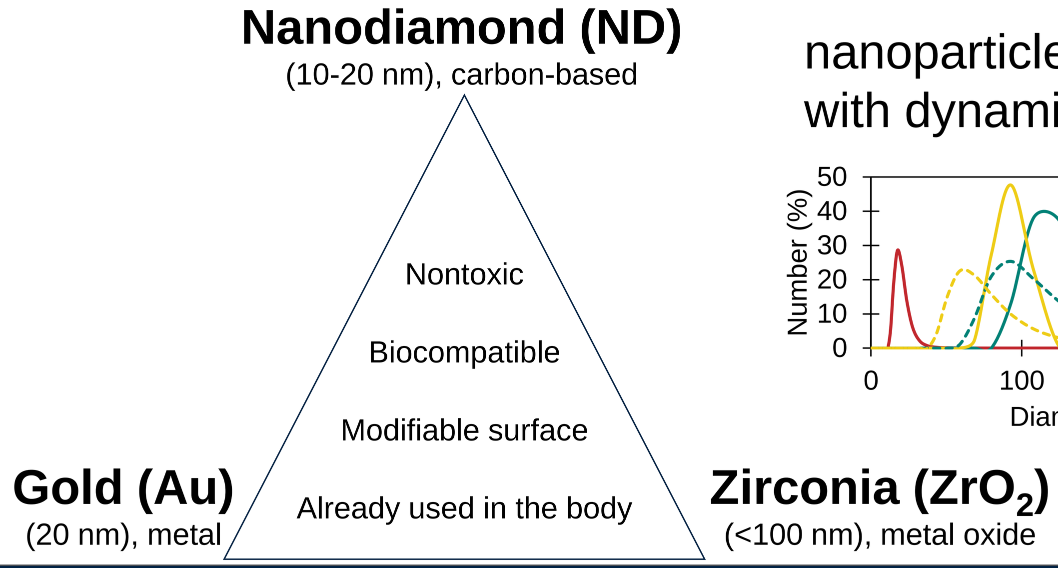
- Axial force: 10 N
- Velocity: 0.1 rad/s to 20 rad/s
- Duration: 300 s
- Temperature: 23 °C

Materials: Hydrogels and Nanoparticles

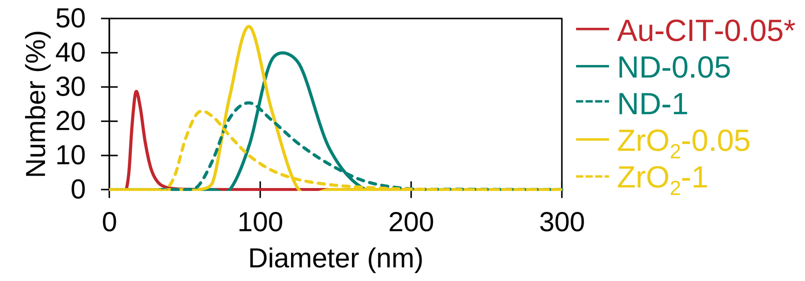
Polyacrylamide (PAM) hydrogels:

- Well known systems
- Biocompatible
- Tunable stiffness





nanoparticle diameters measured with dynamic light scattering



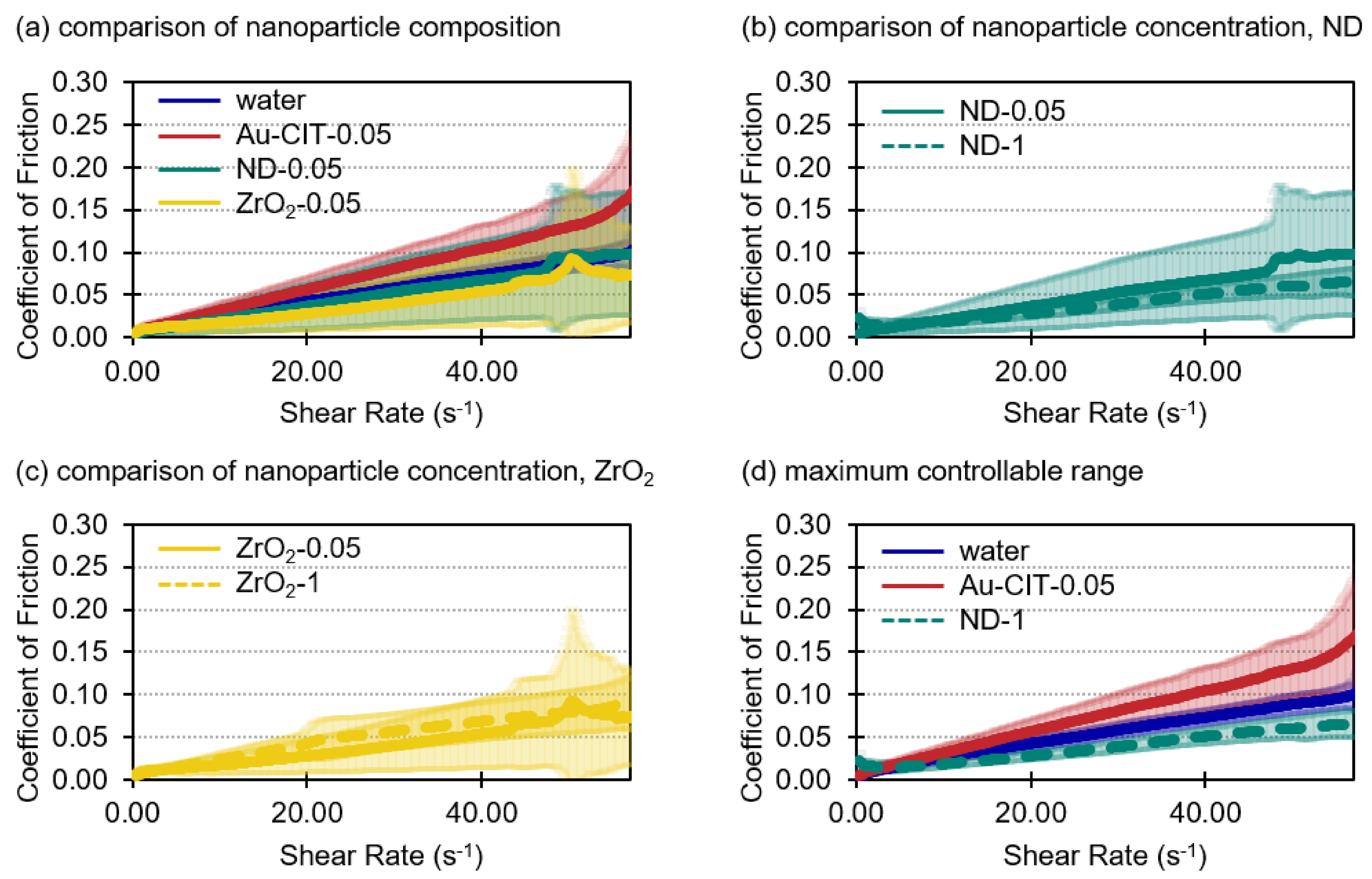
*CIT = citrate capping ligand

nanoparticle concentration: 0.05 mg/mL or 1 mg/mL

Nanoparticle-Hydrogel Interfacial Interactions

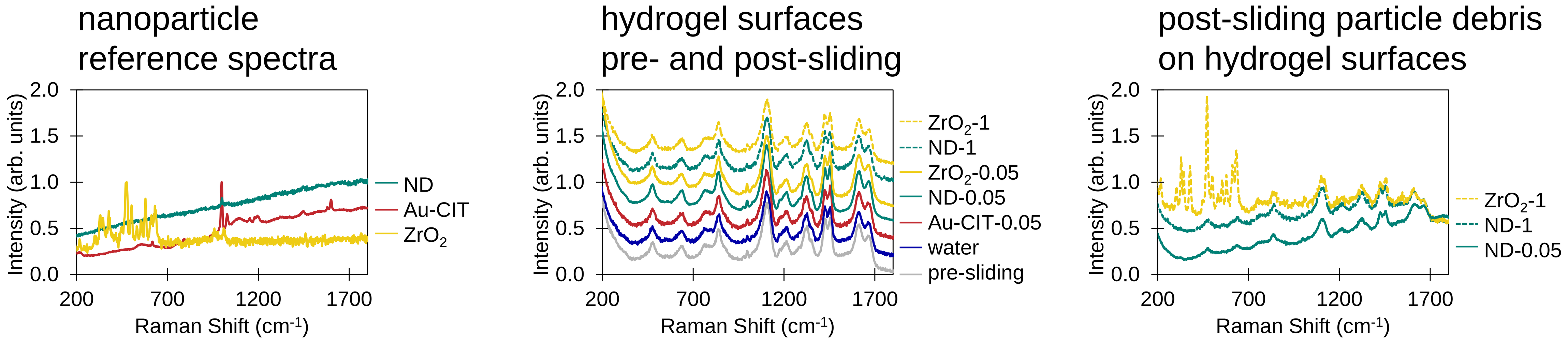
For all *in situ* sliding tests, friction increased as the shear rate increased. At constant concentration (a) Au-CIT exhibits the highest friction. No concentration dependence is observed (b, c). The highest and lowest friction values observed (d) represent the maximum controllable friction range based on NP presence.

Nanoparticle Immersion Sliding Data



Optical imaging and Raman spectroscopy surface analysis:

(a) pre-sliding (b) water (c) Au-CIT-0.05 (d) ND-0.05 (e) ZrO_2-0.05 (f) ND-1 (g) ZrO_2-1



- Focusing on the hydrogel, no change in PAM characteristic Raman peaks are observed for pre- vs post-sliding.
- Post-sliding, Raman spectra indicate visible debris particles are NP aggregates.

Summary

Summary:

- Chemical composition of nanoparticles modulates the friction of immersed hydrogel surfaces.
- A likely driving factor is the citrate capping ligand on the Au NPs increasing friction through hydrogen bonding interactions with the PAM.
- *In situ* friction is not as dependent on particle concentration.
- Raman spectra provides evidence that particles remain on the hydrogel surface post-sliding.

Future work:

- Use 3D Raman mapping to measure how deep the nanoparticles are embedded in the hydrogel.
- Test hydrogel nanocomposites for a wider array of disease treatment capabilities.
- Develop hydrogels through tribochemistry to aid in the regrowth and strengthening of cartilage.

Acknowledgements

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