3D Trajectories, Diffusion, and Interaction Energies of Ceria Particles on Glass Surfaces

by

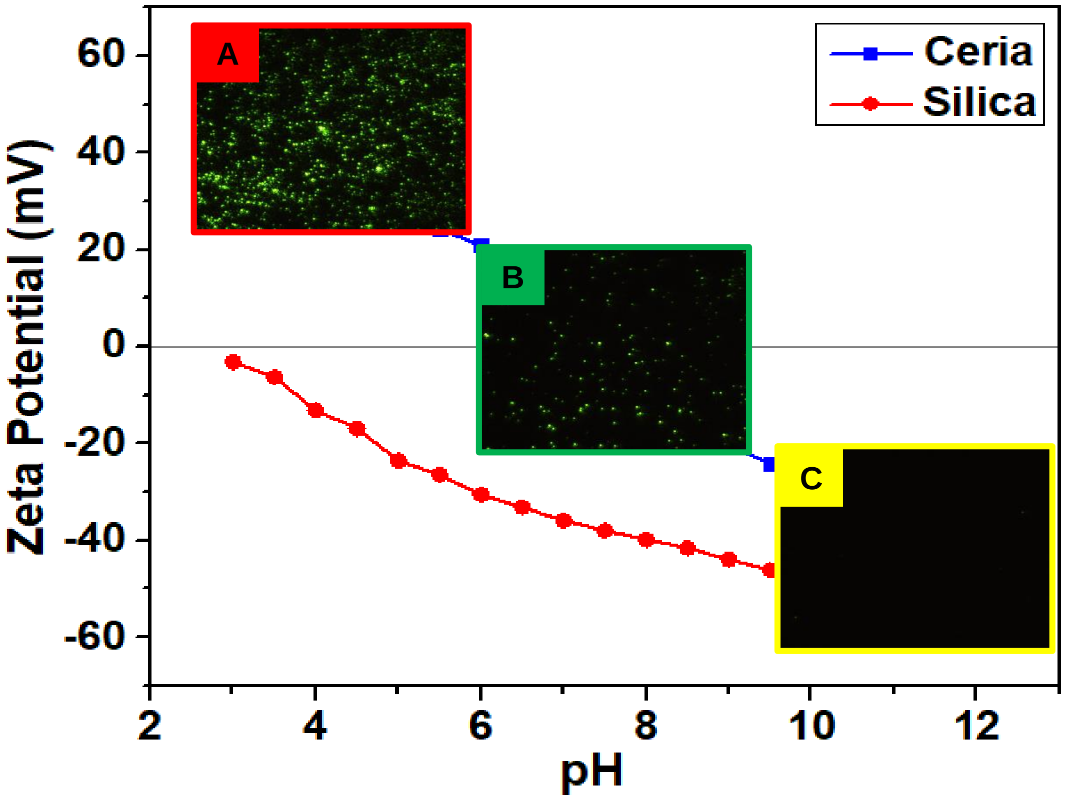
Akshay Gowda,[1] Jihoon Seo,[1] Panart Khajornrungruang,[2] Satomi Hamada,[3] S.V. Babu[1,*]

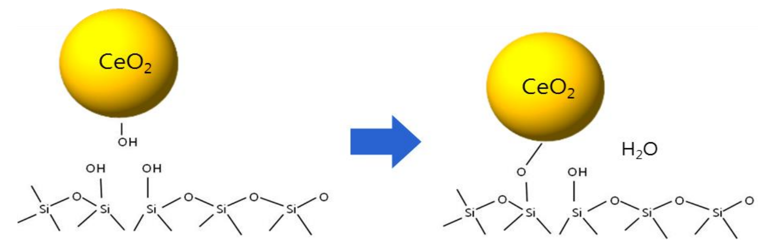
[1]Center for Advanced Materials Processing, Clarkson University, Potsdam, USA.
[2]Department of Mechanical Information Science and Technology, Kyushu Institute of Technology, Iizuka-shi, Fukuoka, Japan
[3]Technologies, R&D Division, EBARA Corporation, Fujisawa-shi, Kanagawa, Japan

Outline

- **Introduction**
- **Principle of evanescent wave microscopy**
- **Results**
  - ❖**2D and 3D trajectories, Diffusion coefficients and Interaction potentials**
  - ❖**Cleaning of ceria particles adsorbed at pH 3, pH 5 and pH 7**
- **Conclusions**
- **Acknowledgements**

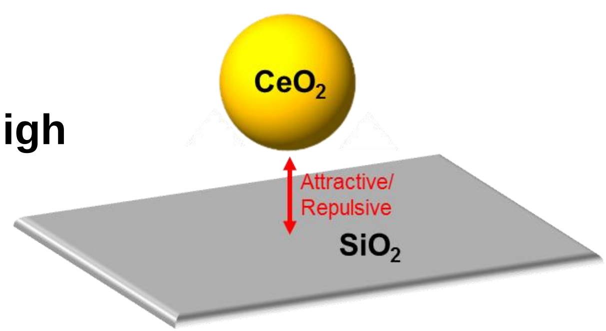
Why ceria-silica interaction ? - Motivation of this research





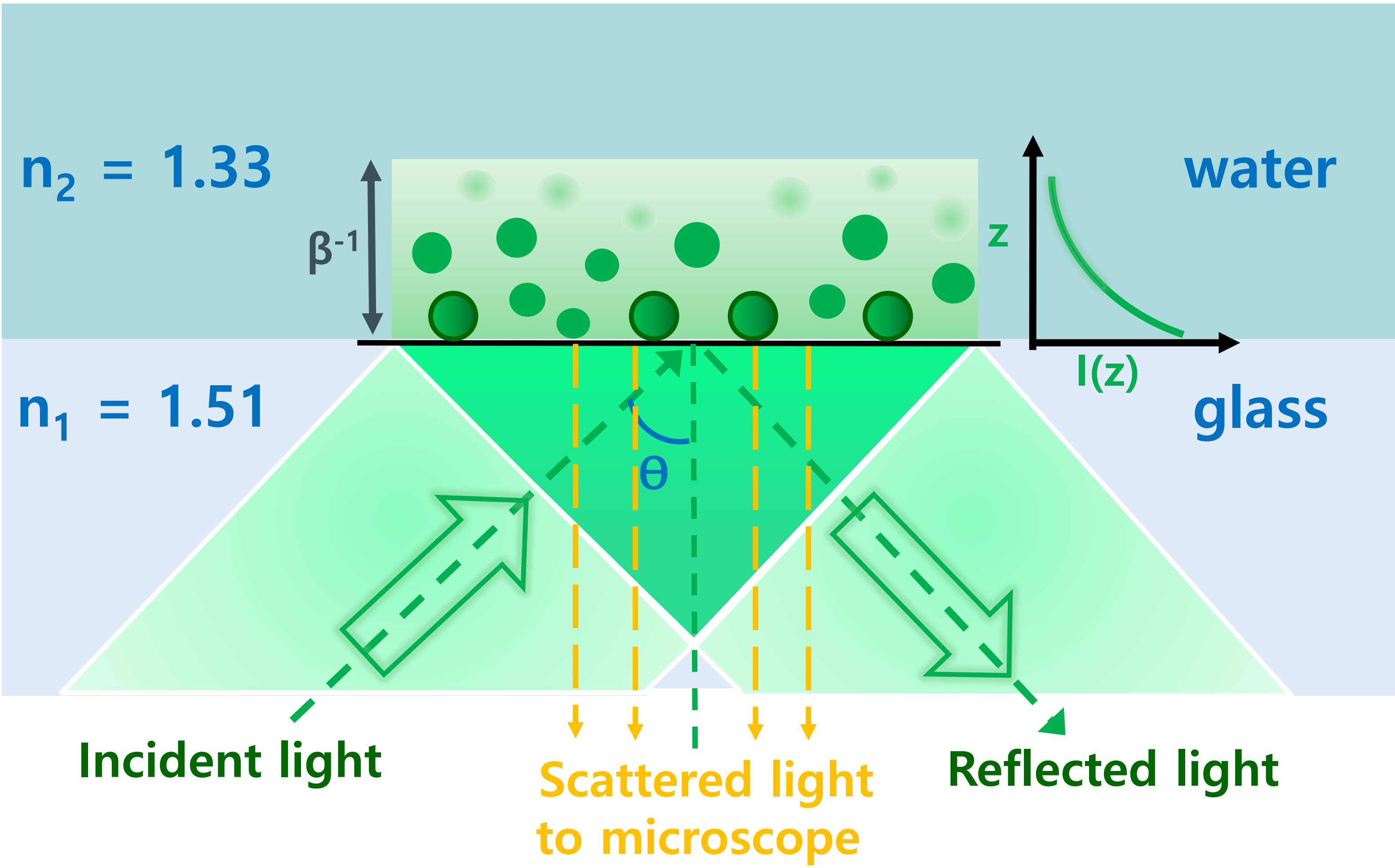
$$-Ce\text{-}OH + -Si\text{-}OH \leftrightarrow -Ce\text{-}O\text{-}Si\text{-} + H_2O$$

- ❖ **Ceria based slurries in STICMP – high oxide polish rate**
- ❖ **Cleaning of ceria particles is challenging due to their high chemical affinity**



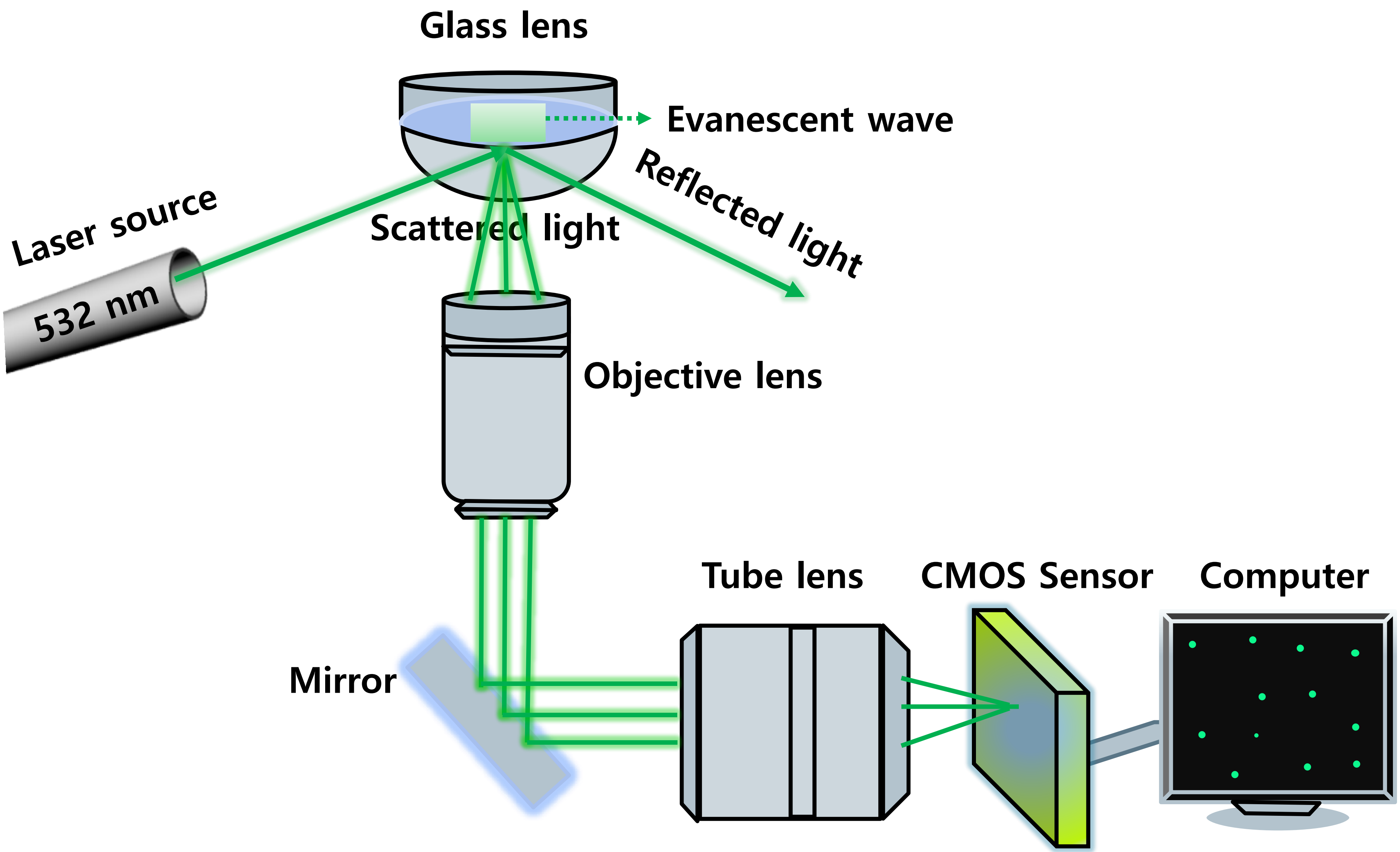
J. Seo, J. W. Lee, J. Moon, W. Sigmund, and U. Paik, ACS Appl. Mater. Interfaces, 6, 7388 (2014)
L. M. Cook, J. Non-Cryst. Solids, 120, 152 (1990)

Principle of evanescent wave (EW) microscopy

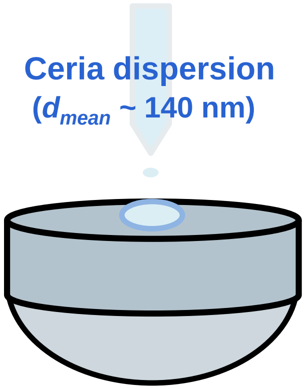


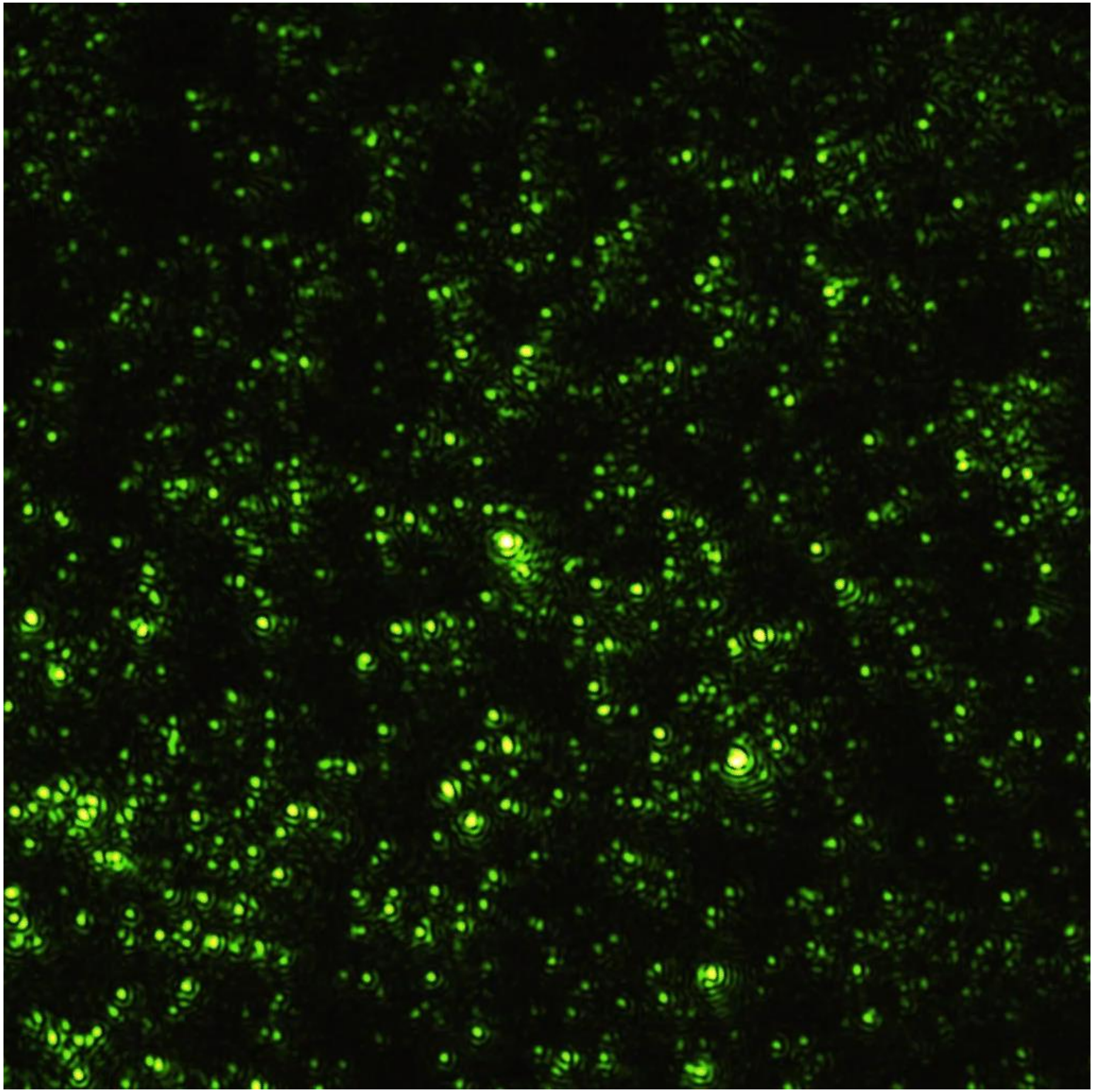
$$\beta = \frac{4\pi}{\lambda}\sqrt{(n_1 \sin\theta_i)^2 - n_2^2}$$

Experimental setup

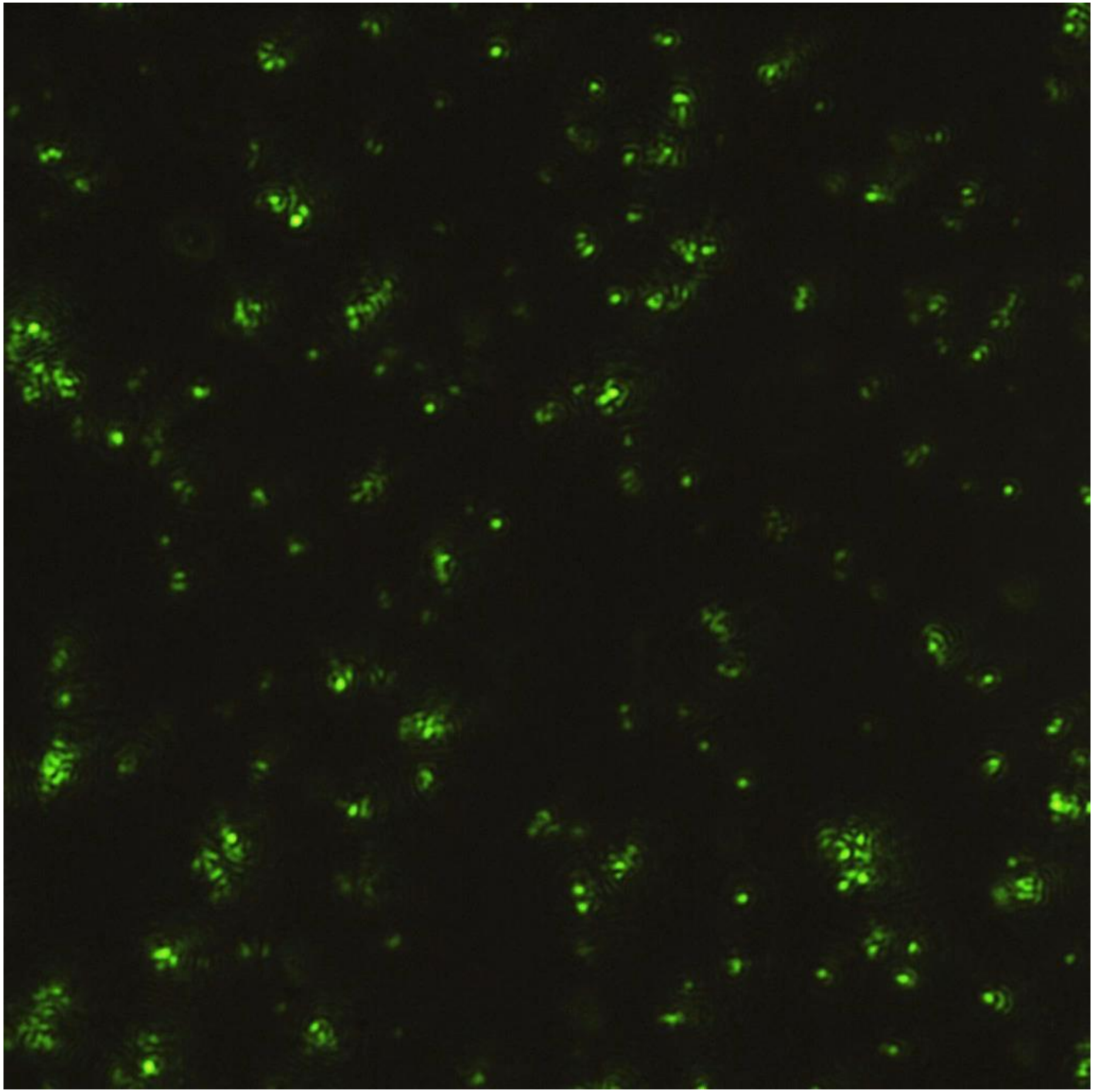


Real time imaging of ceria particles on glass film

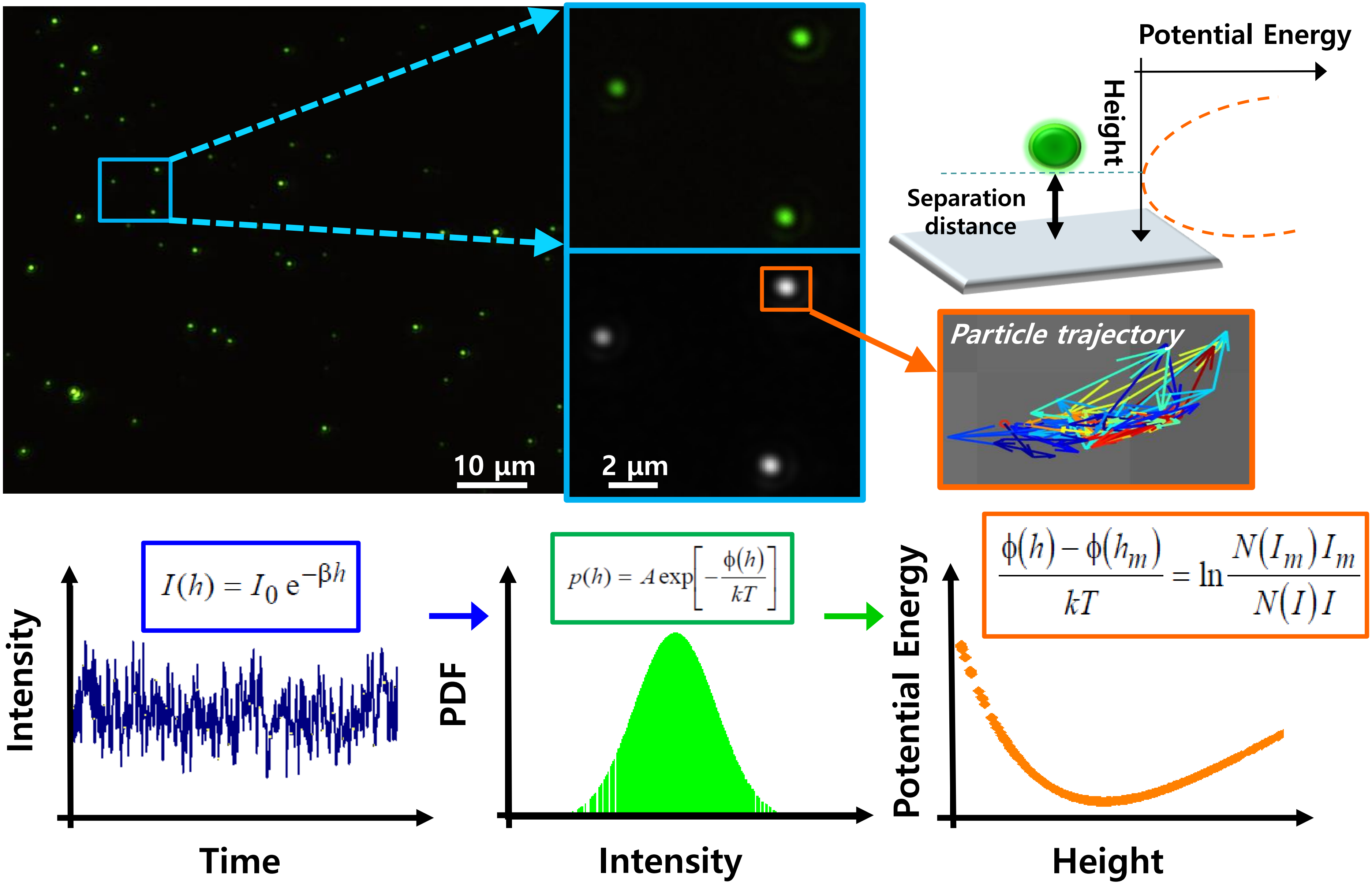




Agglomeration of ceria at pH 7

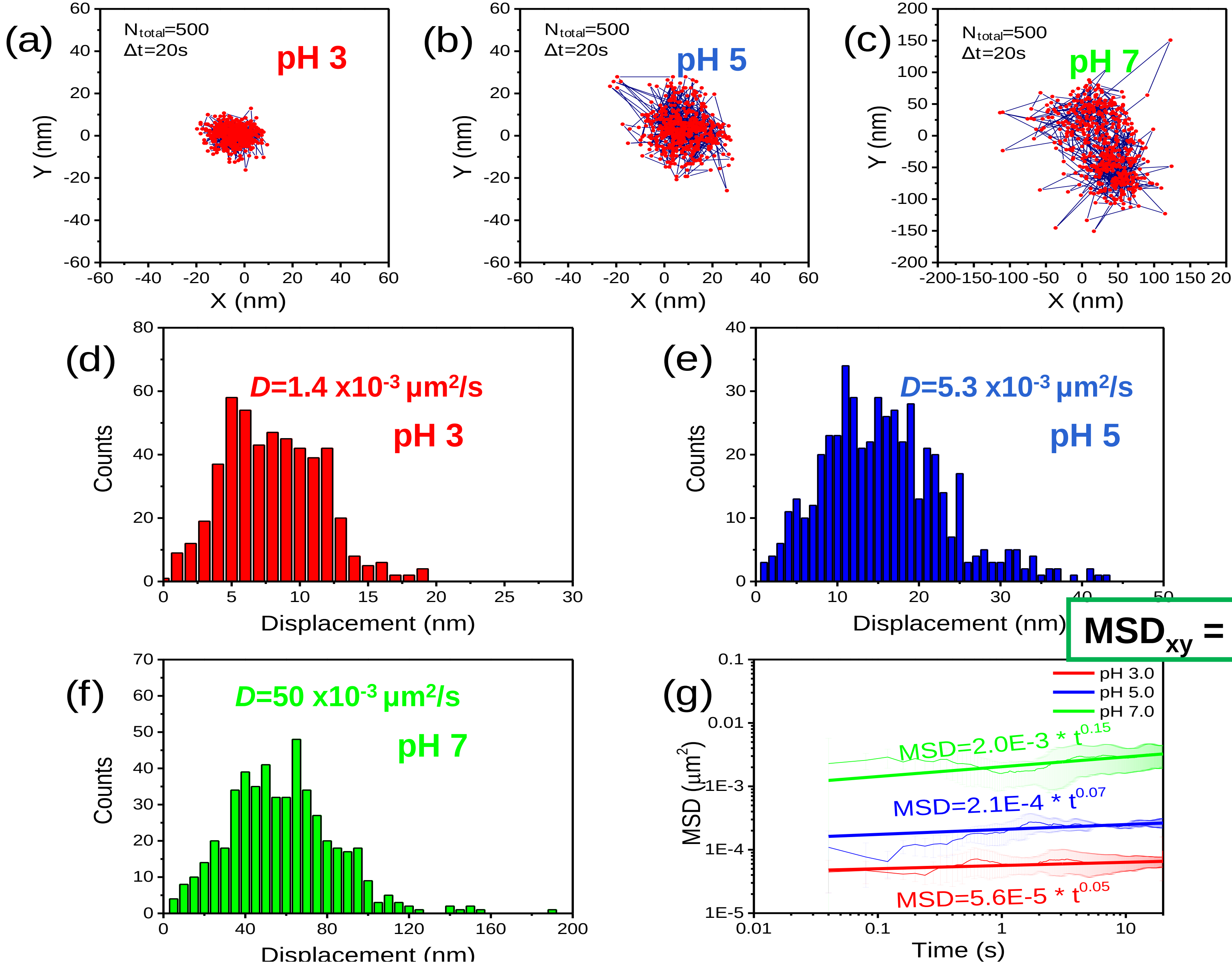


Schematic of the procedure to calculate interaction potentials



D. C. Prieve, Adv. Colloid Interface Sci., 82, 93 (1999)

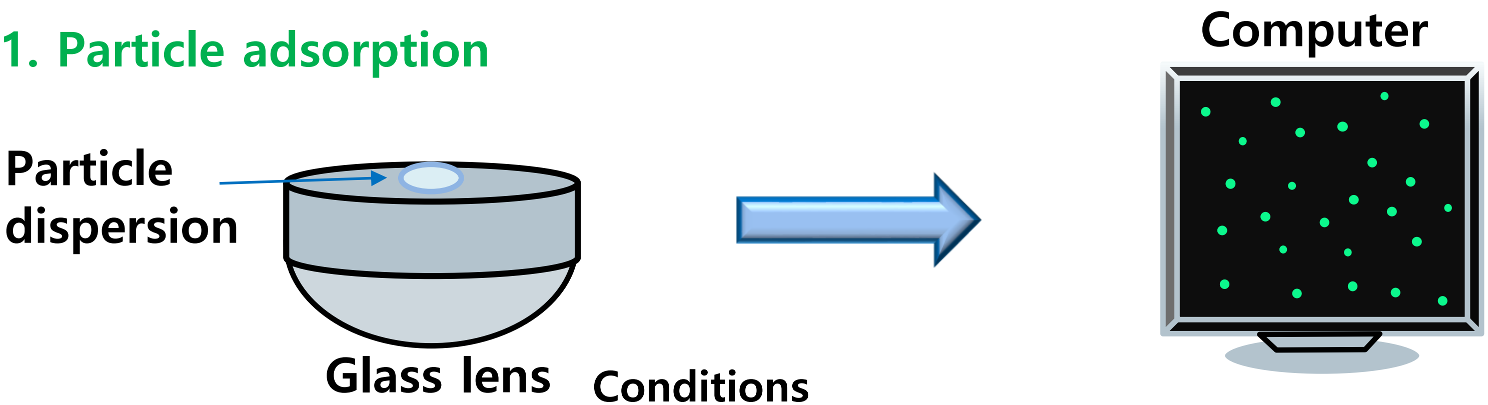
2D trajectories, histograms of particle displacements and MSD vs time



$$MSD_{xy} = 4D\Delta t^{a}$$

Ceria particle cleaning procedure

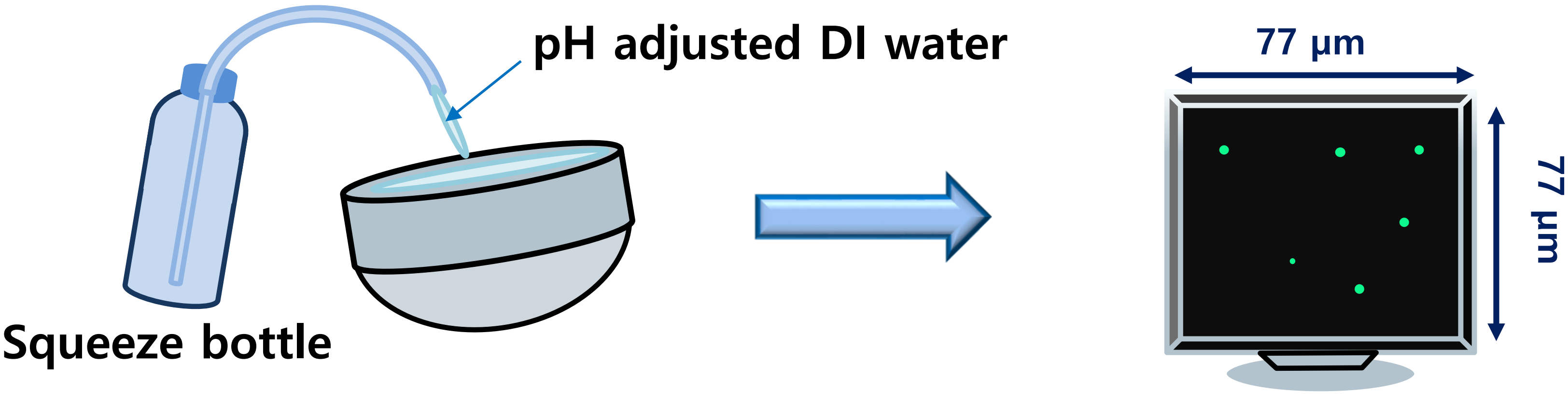
1. Particle adsorption



Conditions

-0.005 wt% Ferro ceria dispersion (d_{mean} ~ 140 nm)
-Particles adsorbed for 20 minutes

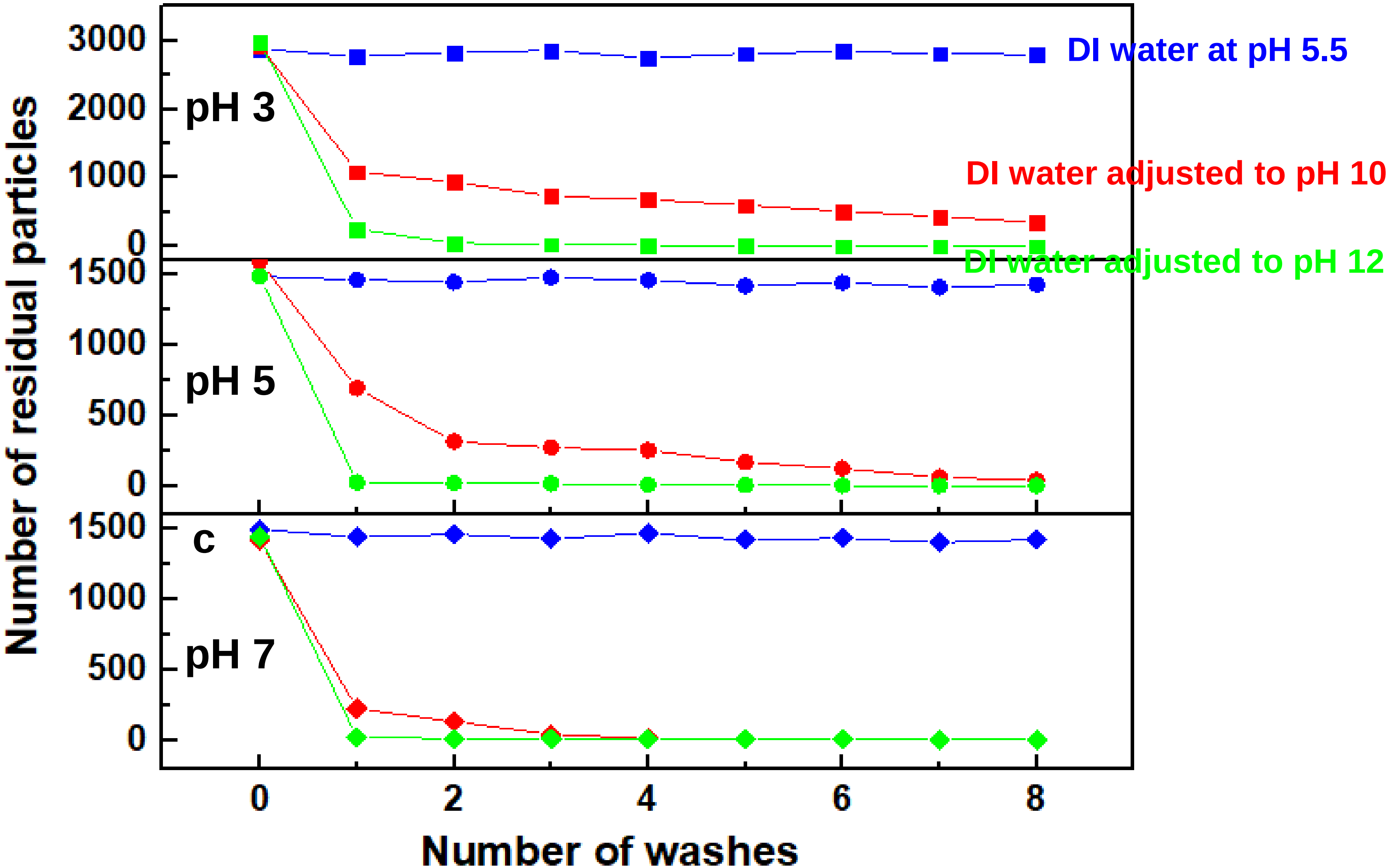
2. Particle cleaning



Procedure

-Lens covered with ceria particles was washed multiple times.
-Each time with 40 mL of pH adjusted DI water for 20s

Number of residual particles vs number of washes



Conclusions

1. **Evanescent wave microscopy is a powerful tool to study particle-surface interactions.**

2. **Ceria particles at pH 5.0 (D_{3D} = 3.8×10^{-3} μm^2/s) and pH 7.0 (D_{3D} = 45×10^{-3} μm^2/s) exhi bited faster diffusion near glass surface than at pH 3.0 (D_{3D} = 1.2×10^{-3} μm^2/s)**

3. **As pH increased from 3.0 to 7.0, the most probable separation distance h_{min} of ceria particle from glass surface increased from 11 to 60 nm.**

4. **Ceria particles adsorbed at higher pH can be more easily cleaned.**

5. **Charge repulsion is shown to be a key driver towards cleaning performance.**

6. **While charge repulsion is enough to clean larger ceria particles, it is not efficient in removing smaller particles**

THANK YOU!