Static-Tribo-Electricity of Powder

2014/12/20

Anatomy of Toner Adhesion with SPM Measurement and Electrostatic Simulation

Imaging Society of Japan

Technical Committee on Simulation Technology
Technical Committee on Toner Technology

Masami KADONAGA (Ricoh co.)
Jun HIRABAYASHI (Canon Inc.)

-Colaborators-

Experiment and Discussion

T.Tanaka（Canon）

SPM Measurement and Discussion

ISJ：Technical Committee on Toner Technology

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Estimation of Charge, Simulation and Discussion

ISJ：Technical Committee on Simulation Technology

J. HIRABAYASHI（Canon）、H. KAWAMOTO（Waseda Univ.）、N. NAKAYAMA（Fuji Xerox）、M. NAKANO（Canon）、T. KAGAWA（KONICA MINOLTA）、T. ITOH（Fuji Xerox）、M. MAEDA（brother）、S. HASEBE（Fuji Xerox）、J. MURAKOSO（FUJITSU）

Agenda

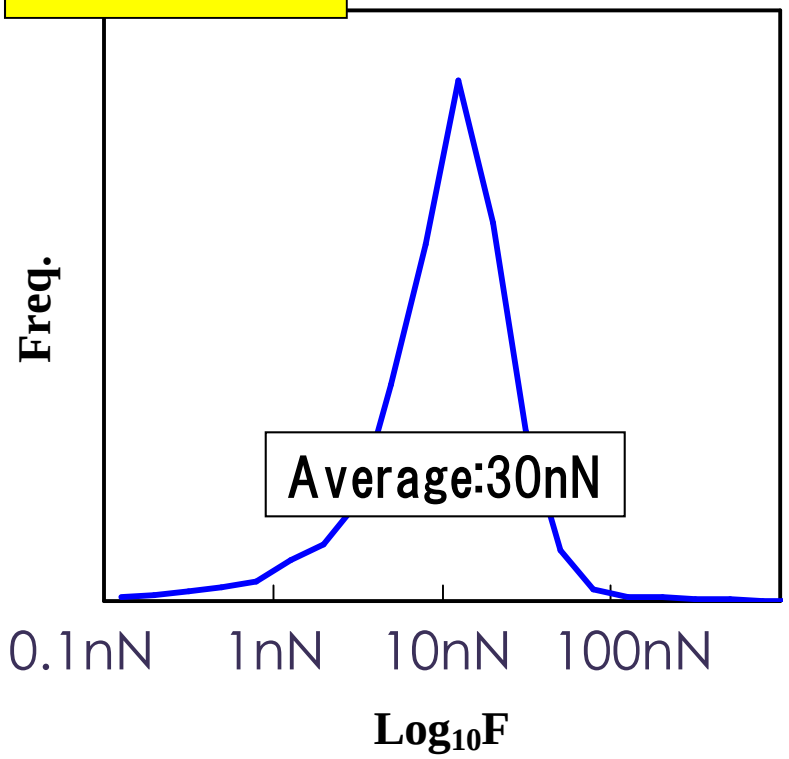
1. Introduction
2. Objective
3. Estimation of Charge Distribution with SPM Measurement
4. Estimation of Adhesion with Charge Distribution obtained from SPM Measurement
5. Analysis of Toner Adhesion with Simulation
6. Conclusion

Electrostatic Adhesion

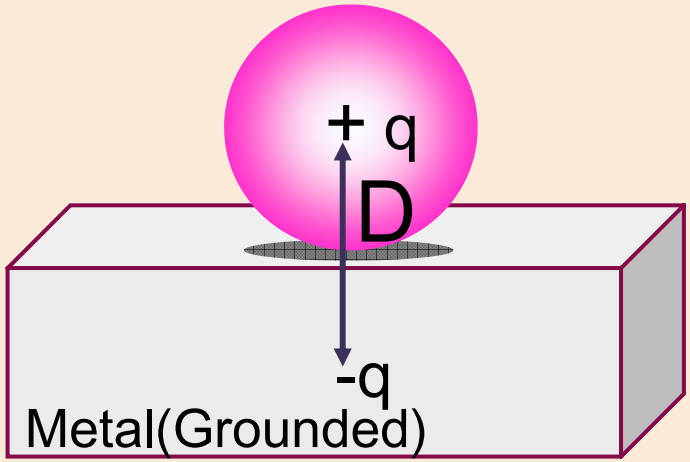
Measurement　1 nN ～ **50nN** ～100nN

Theory(Mirror Force)　～ **2nN** ～

Measurement



Theory(Mirror Force)

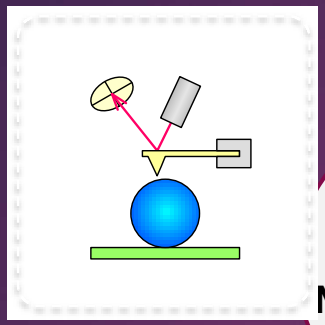


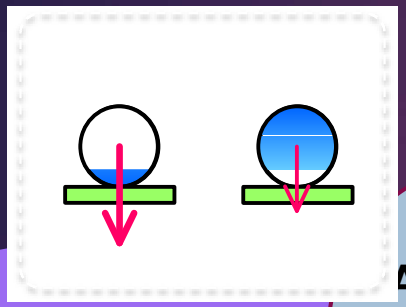
$$F_e = \frac{q^2}{4\pi\varepsilon_0 D^2}$$

(ex) Q=2.51fC　D=6 μ m⇒1.55nN

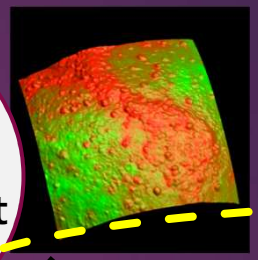
Measurements indicate forces on the order of 10x larger than what would be predicted from the mirror force theory.

Big Picture of Adhesion Analysis





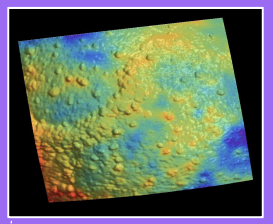
SPM Potential Measurement



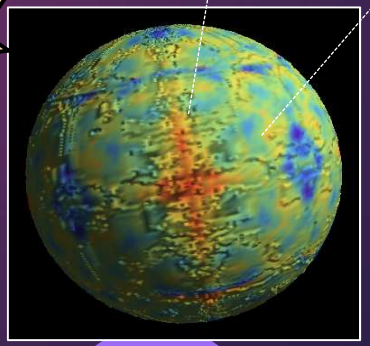
Our Study

Estimation of Charge

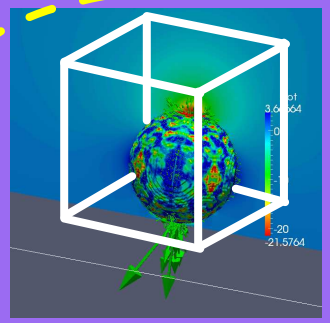
J. Hirabayashi (2014)



Charge Distribution on a Toner



Estimation of Adhesion (Simulation)



M. Kadonaga (2014)

Adhesion Measurement

Objective

To investigate adhesion mechanism with SPM and simulation

Step1 ：Estimation of charge distribution with SPM measurement

Step 2 ： Estimation of adhesion with the charge distribution

Step 3 ： Analysis of adhesion with simulation

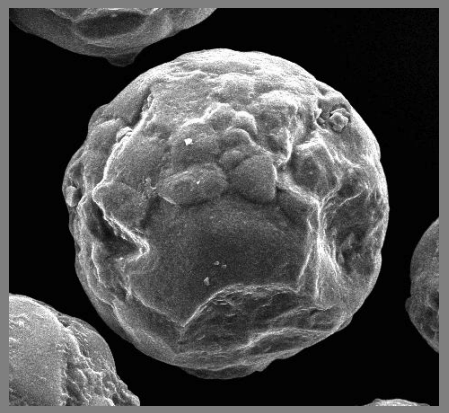
Step1 : Estimation of charge distribution with SPM measurement

Jun HIRABAYASHI(Canon Inc.)

Toner Charging

Sample

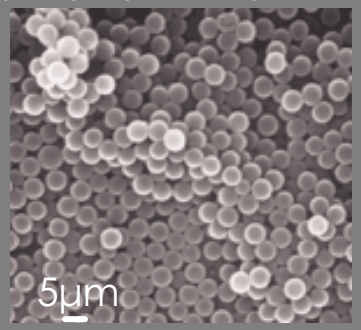
ISJ standard carrier



+

Model Toner

polystyrene particle

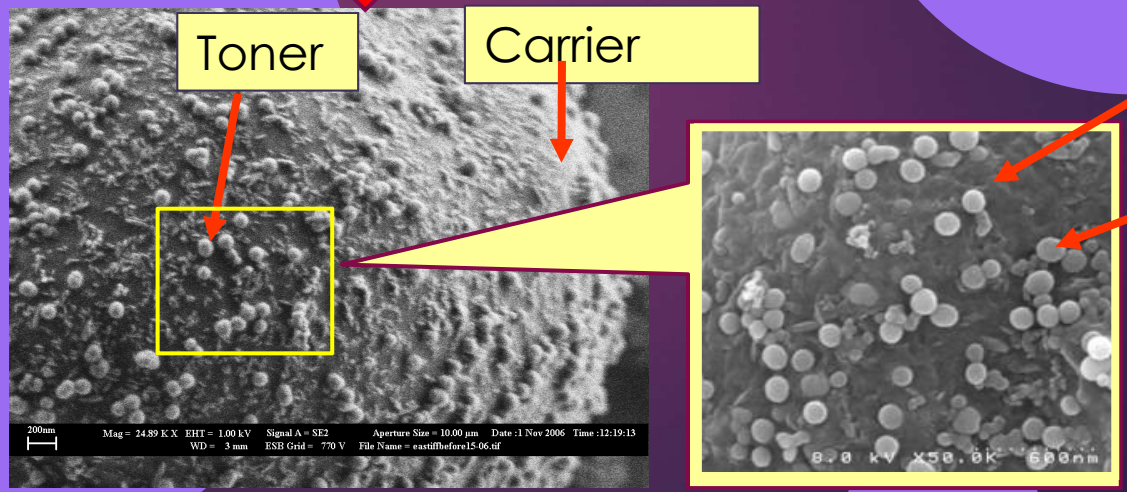


+

Additive

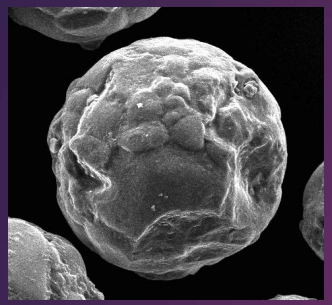
Fumed Silica
(Negative)

Mixing and Charging



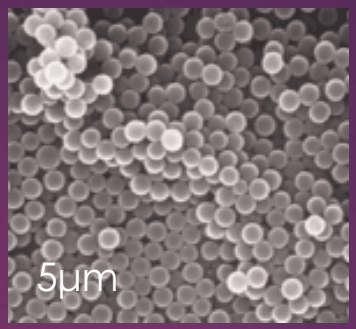
Toner Charging

Sample



ISJ standard carrier
N-02 (T/D:5%)

+

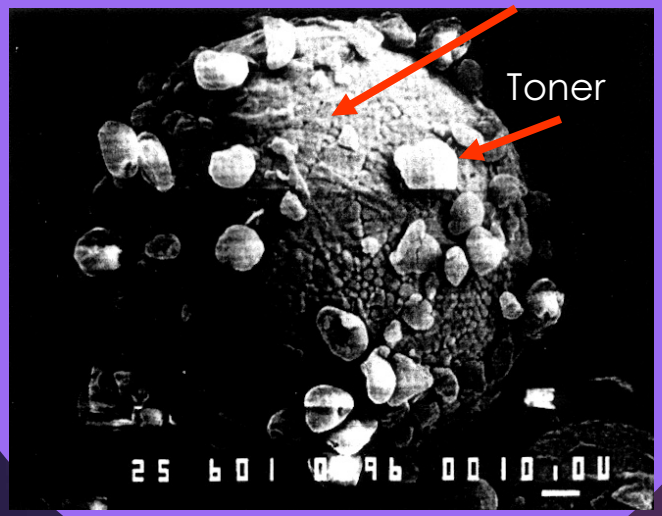


+

AEROSIL
Fumed Silica (Nega)
RY 200 (0.5部)

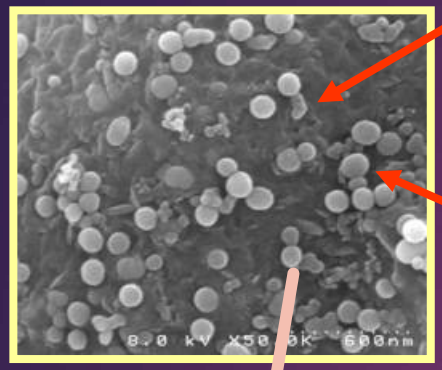
Soken chemical &
Engineering SX500H
(polystyrene particle)

Carrier



Measurement with SPM

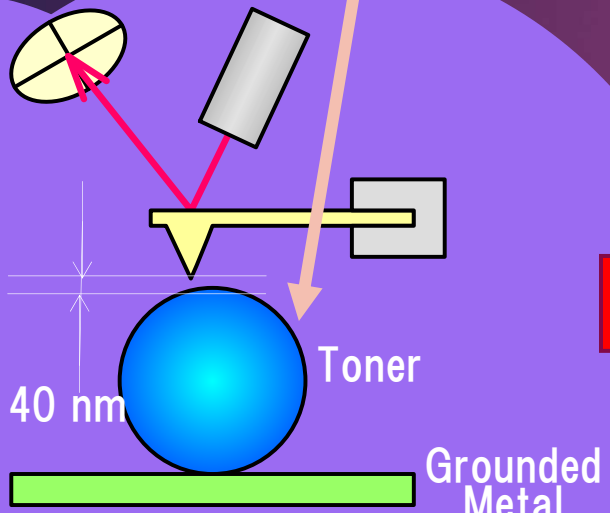
Sample



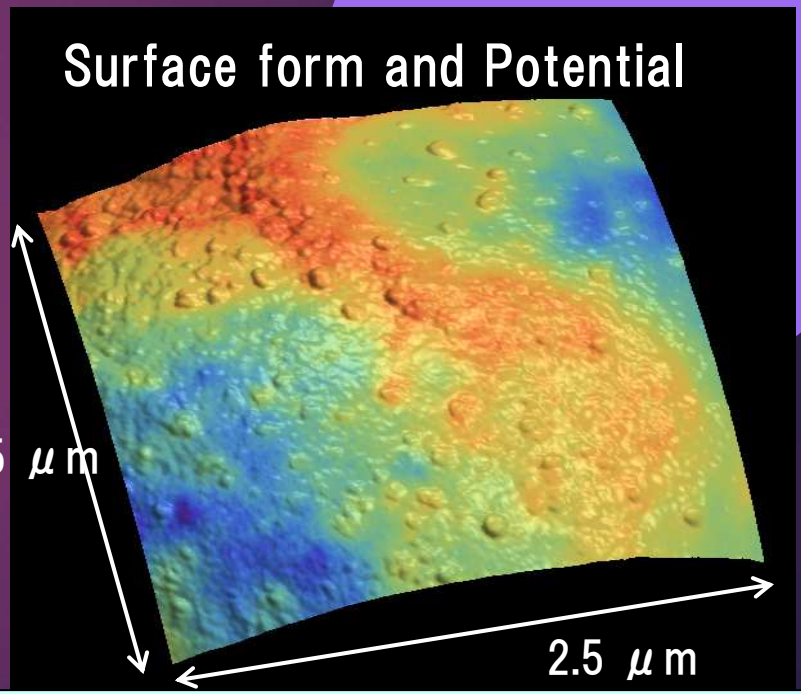
ISJ Standard Carrier

Mixed and toner is charged.

Toner Q=2～3 fC D=6μm
Polystyrene + Additive(Silica)



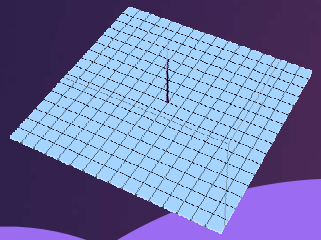
SPM(2013:Canon Tada)



We should estimate a charge distribution from the potential distribution.

Charge Estimation using de-Convolution with System Response

Point Charge



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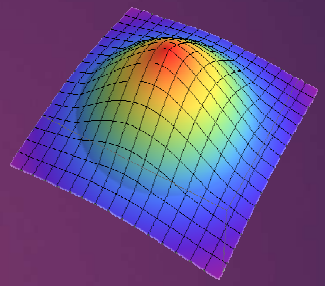
System Response

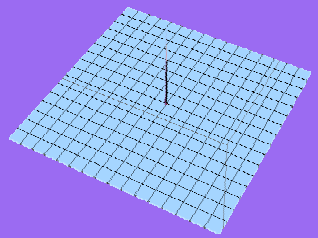
=

Potential



System response: Relation between charge and potential

Estimated Charge



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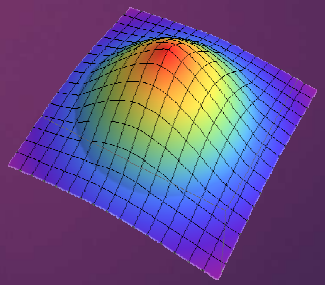
Measured Potential



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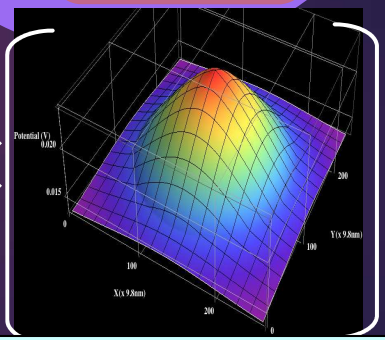
Inverse of System Response

-1

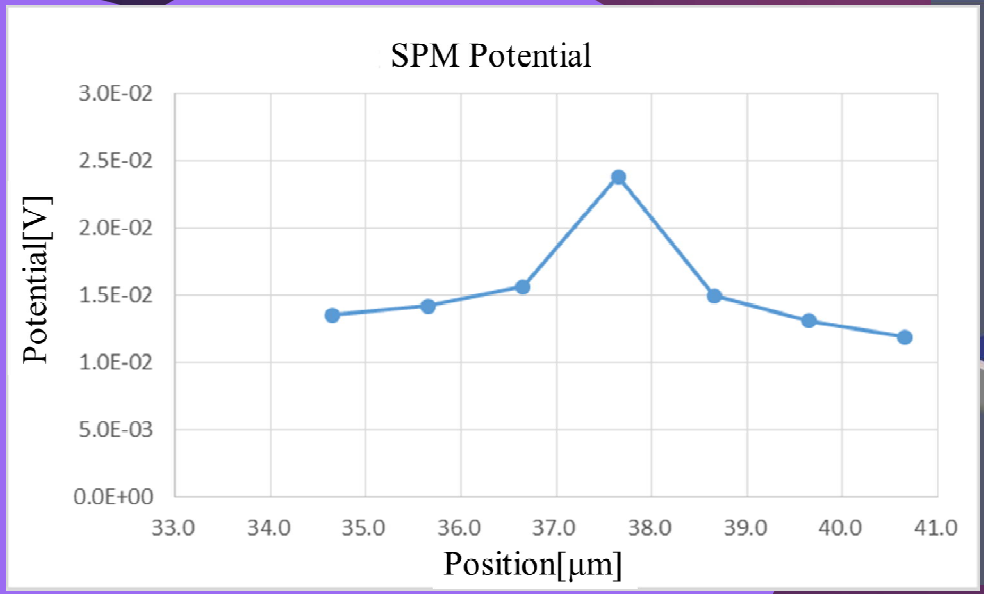


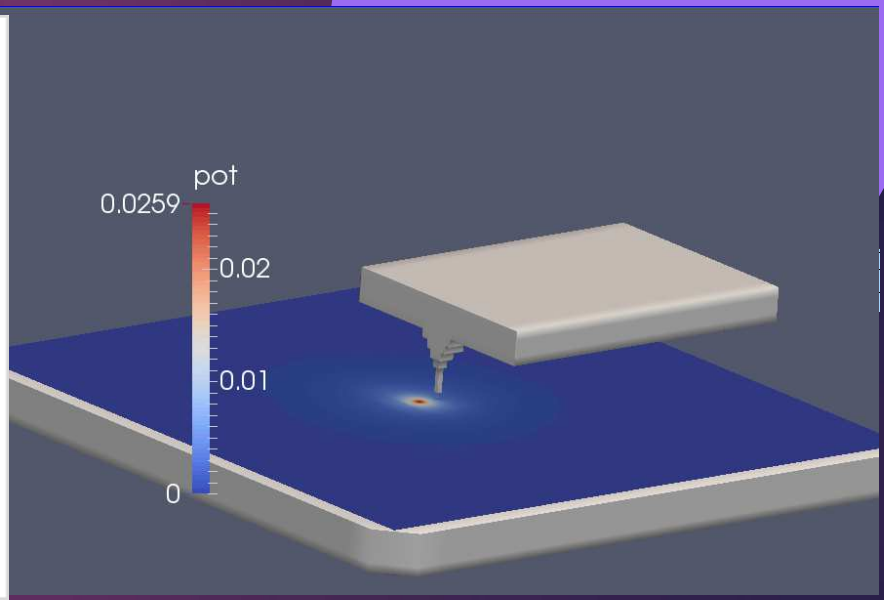
Theoretically speaking, we can estimate charge distribution with a system response.

Estimation of System Response

Electrostatic simulation of SPM is carried out.

Relation between the position of a charge and induced potential of the probe is obtained.

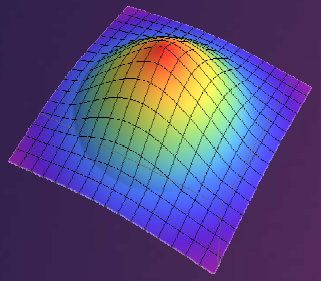




System response is estimated from a 3D-electrostatic simulation of SPM.

Estimation of Charge Distribution

Potential



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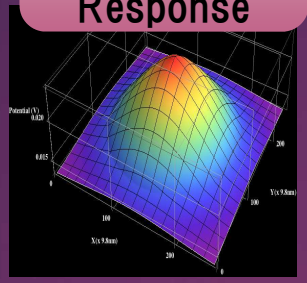
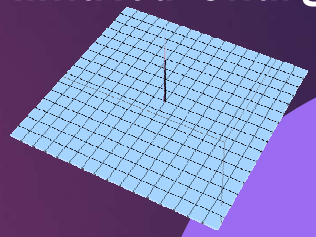
Inverse of System Response



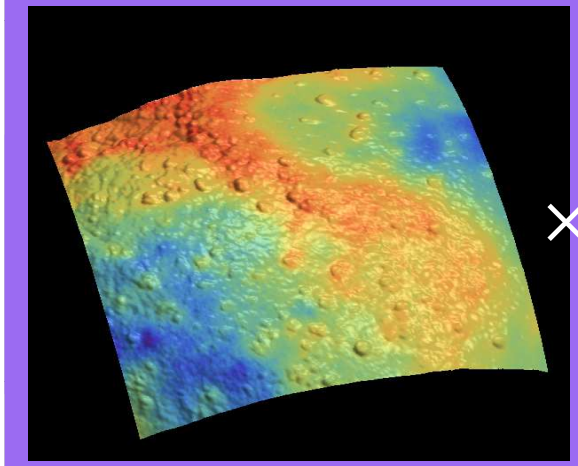
-1

=

Estimated Charge



Potential from SPM



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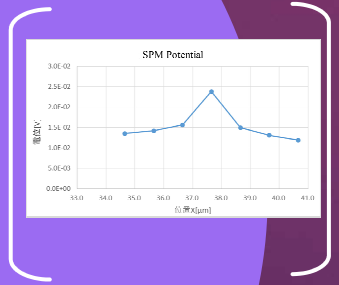
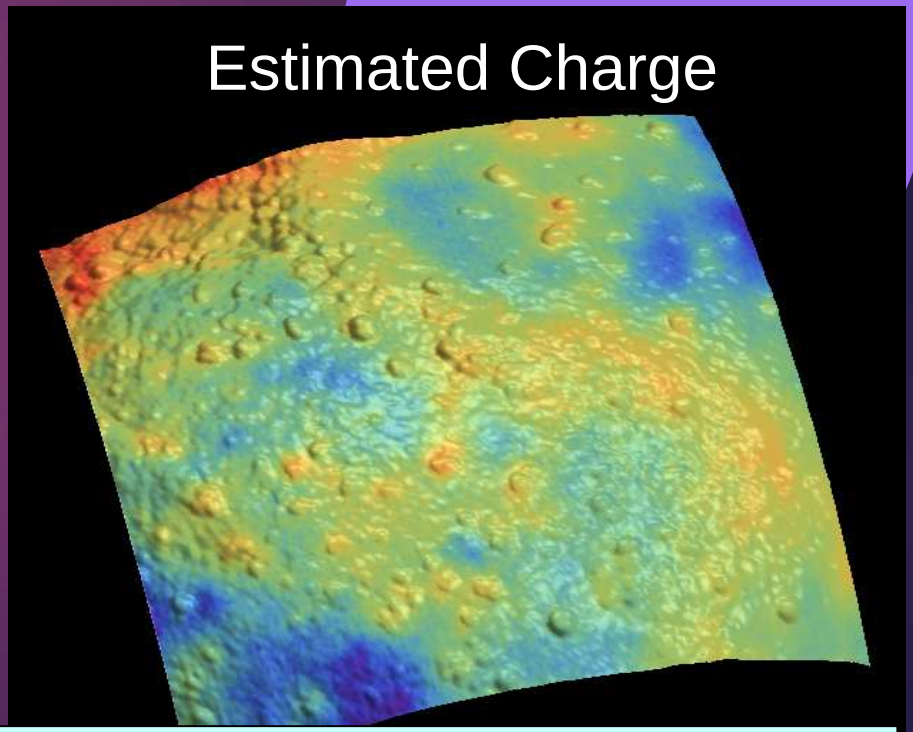


-1

=

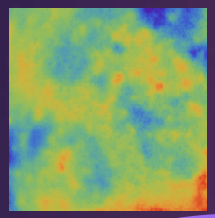
Estimated Charge



Charge distribution on a small area is obtained.

Estimation of Charge on the Whole Surface of a Toner

Charge on a small area



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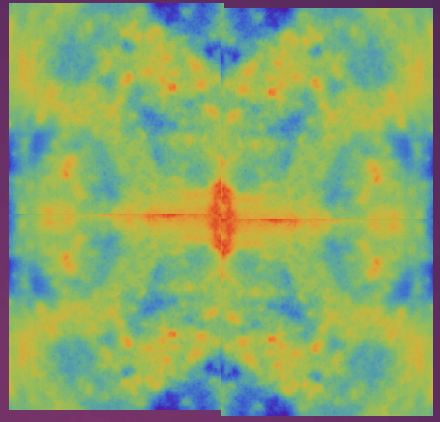
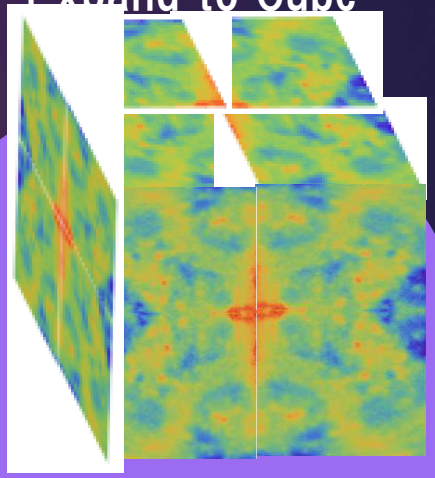
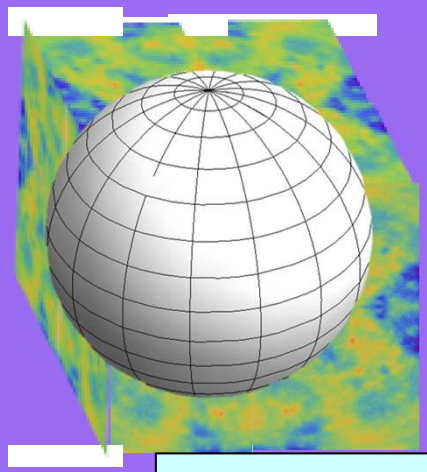


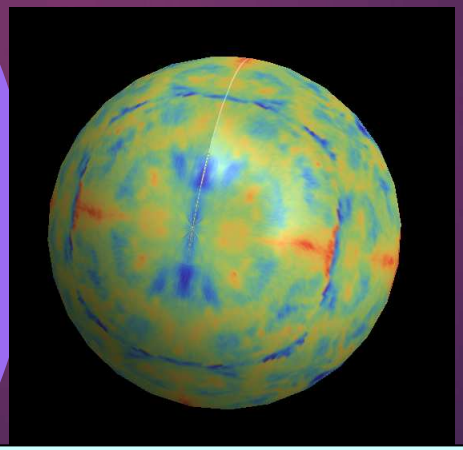
Expand to Cube



Projection to Sphere

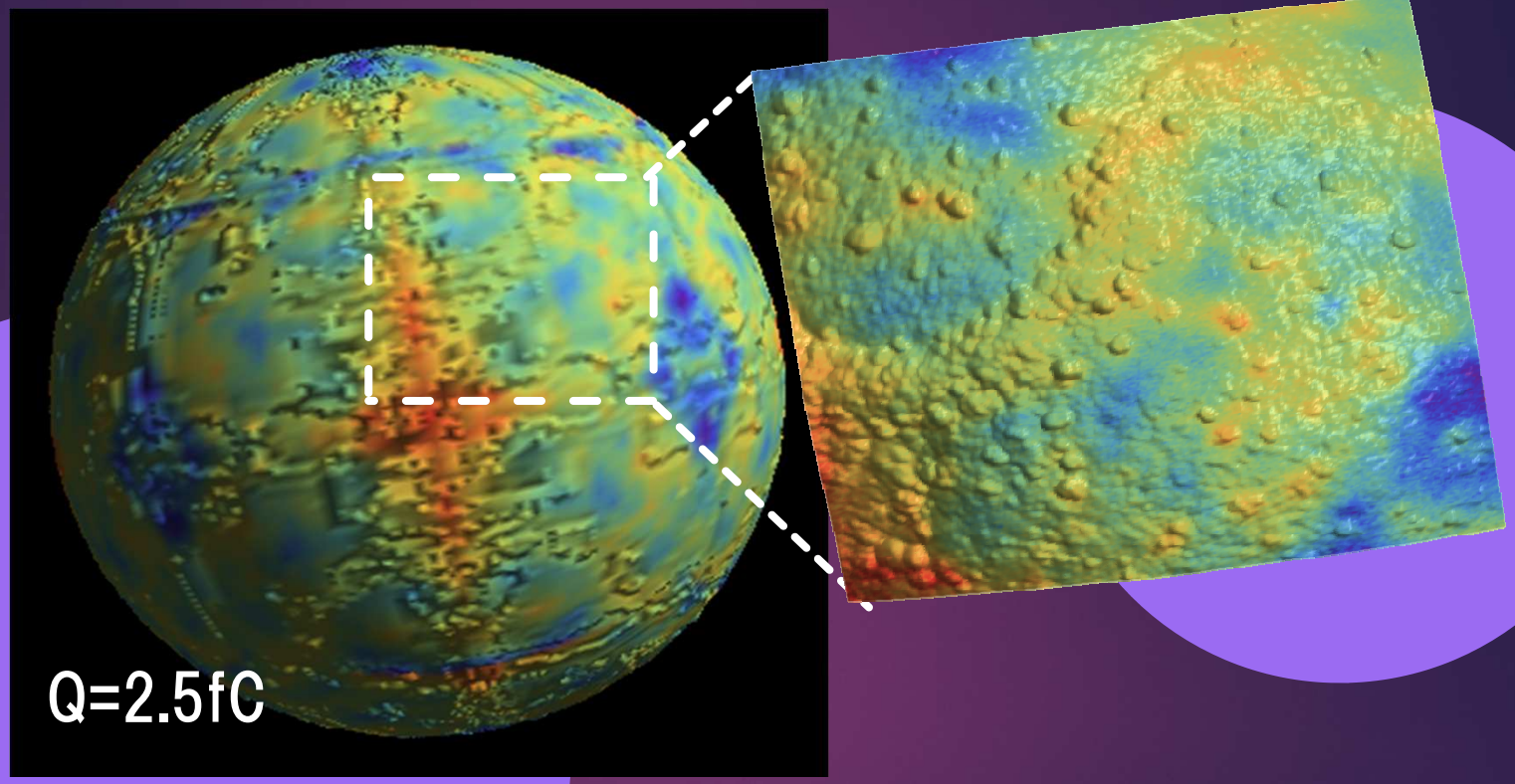


Sphere Mapping



Charge distribution on the whole surface of a toner is obtained.

Estimation of Charge on the whole surface of a Toner



Step1 : Estimation of charge distribution with SPM measurement

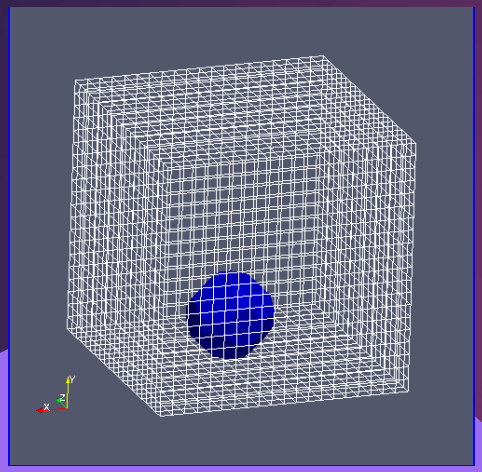
shows non-uniform charging!

Step 2 : Estimation of adhesion with the charge distribution

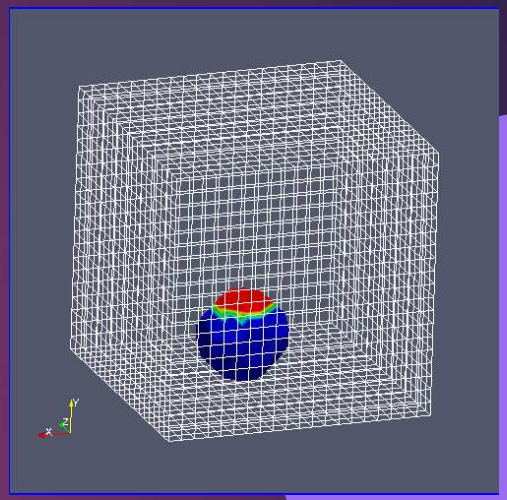
Masami KADONAGA（Ricoh）

Simulation Model (FDM)

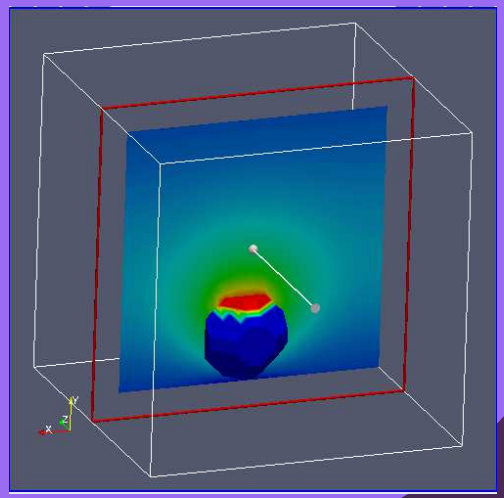
①Mesh Making/Setting Toner



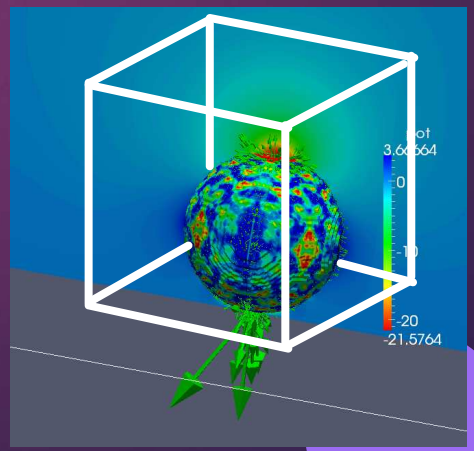
②Setting Charge



③Electrostatic Calculation

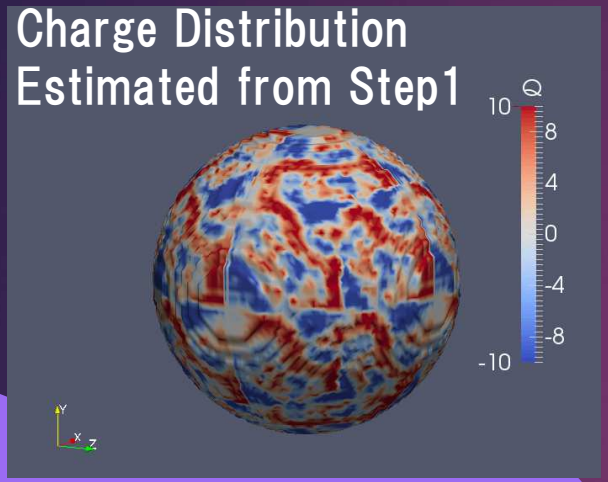


④Estimation of Adhesion to a Grounded Plane with Maxwell Stress Tensor

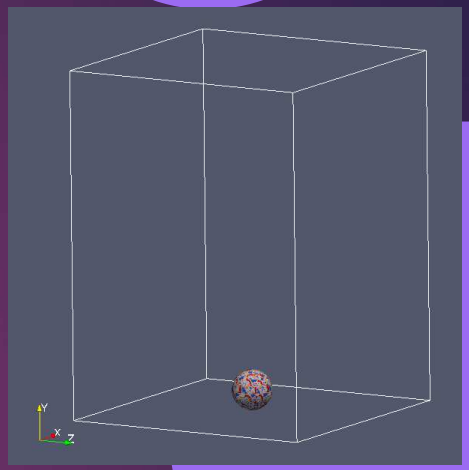


Adhesion with Charge Distribution Estimated from SPM Measurement

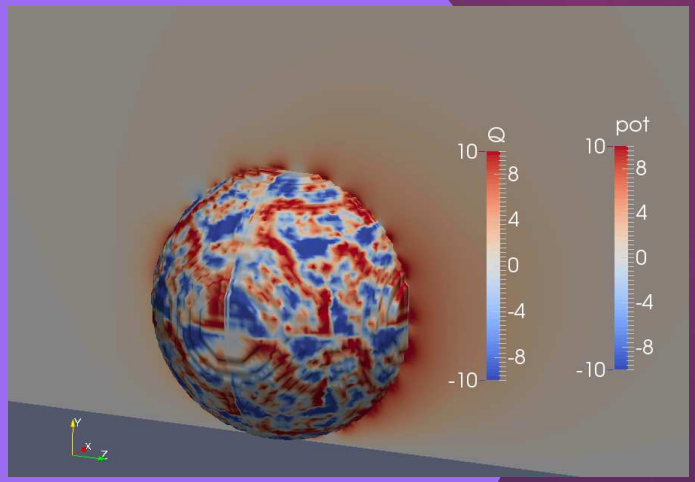
Charge Distribution Estimated from Step1



Deposit on the grounded plane



Electrostatic Simulation



Estimation of Adhesion

Result

Q=2.5fC

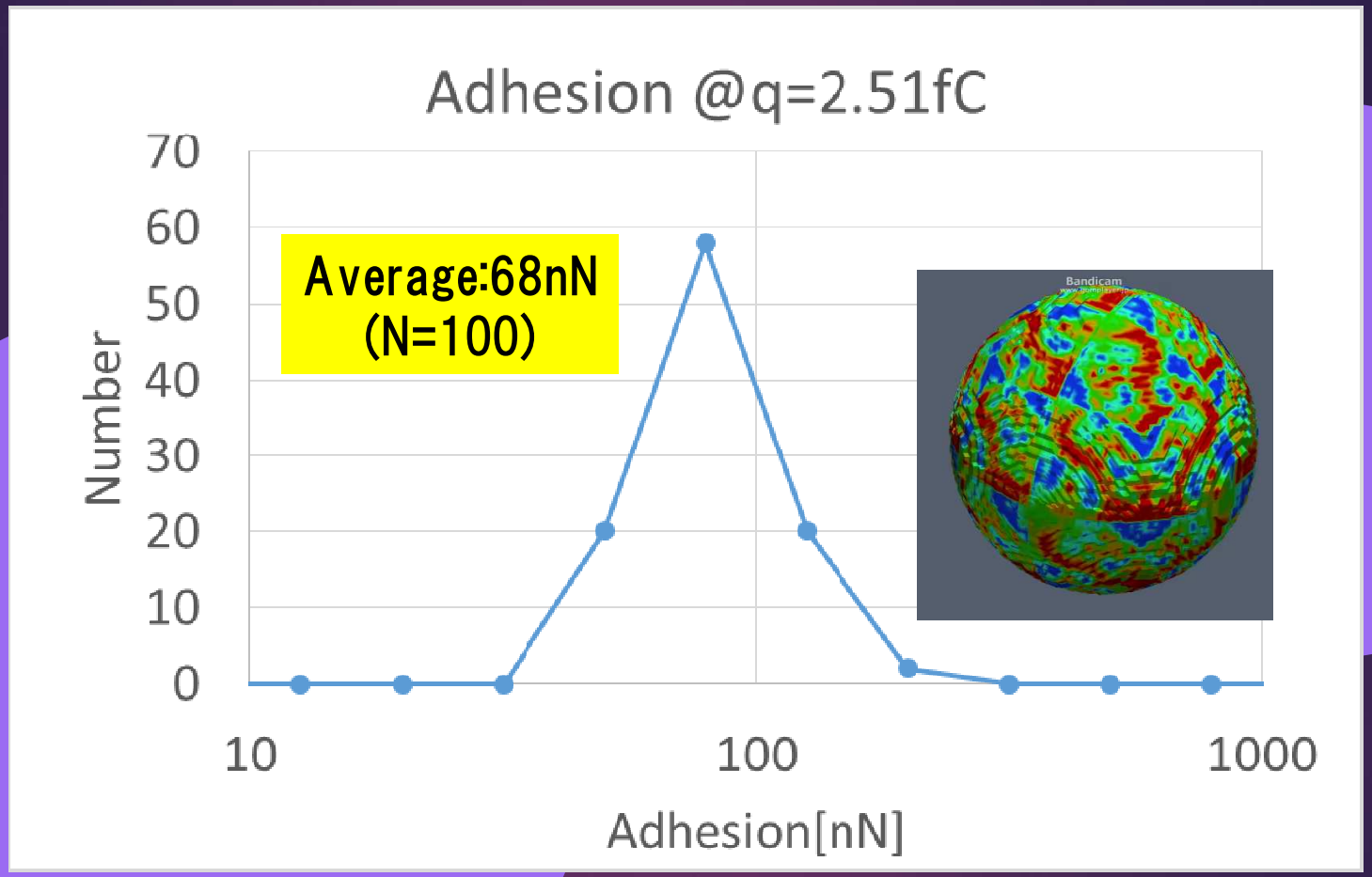
Adhesion:135nN

(Mirror Force:1.6nN)

Appropriate adhesion is obtained with the charge distribution obtained from Step1.

Adhesion with Rotated Charge Distribution

Rotated Toner(N=100)



Appropriate distribution of adhesion is obtained.

Step 2 : Estimation of adhesion with charge distribution

offers an appropriate adhesion value!

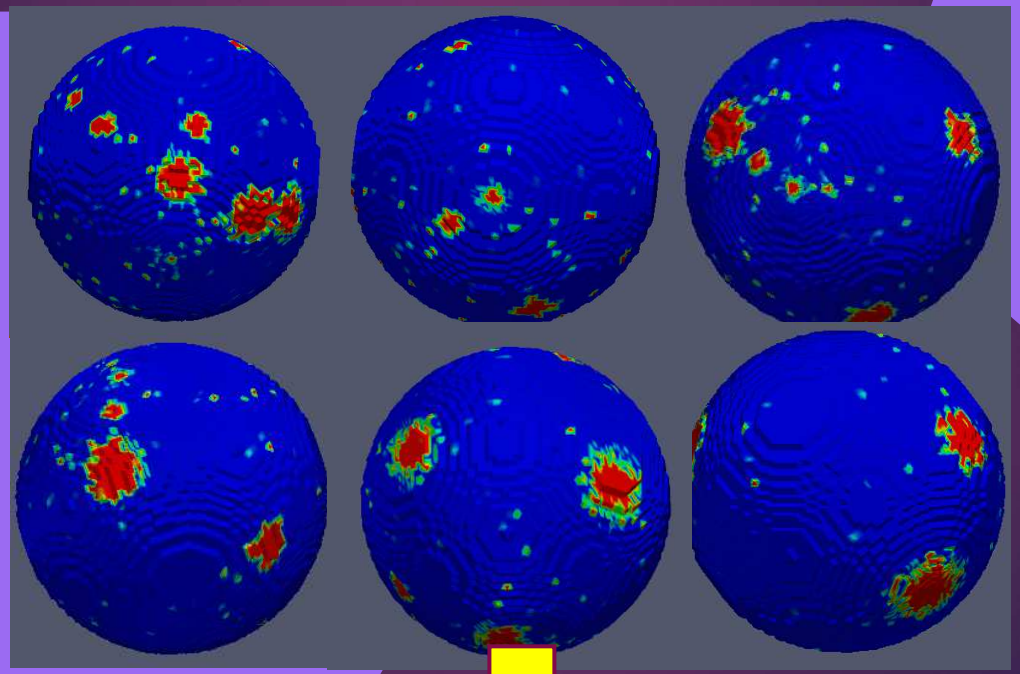
Step 3 : Analysis of adhesion with simulation

Masami KADONAGA（Ricoh）

Anatomy of Adhesion

SPM measurements and estimations of charge are laborious work・・・・

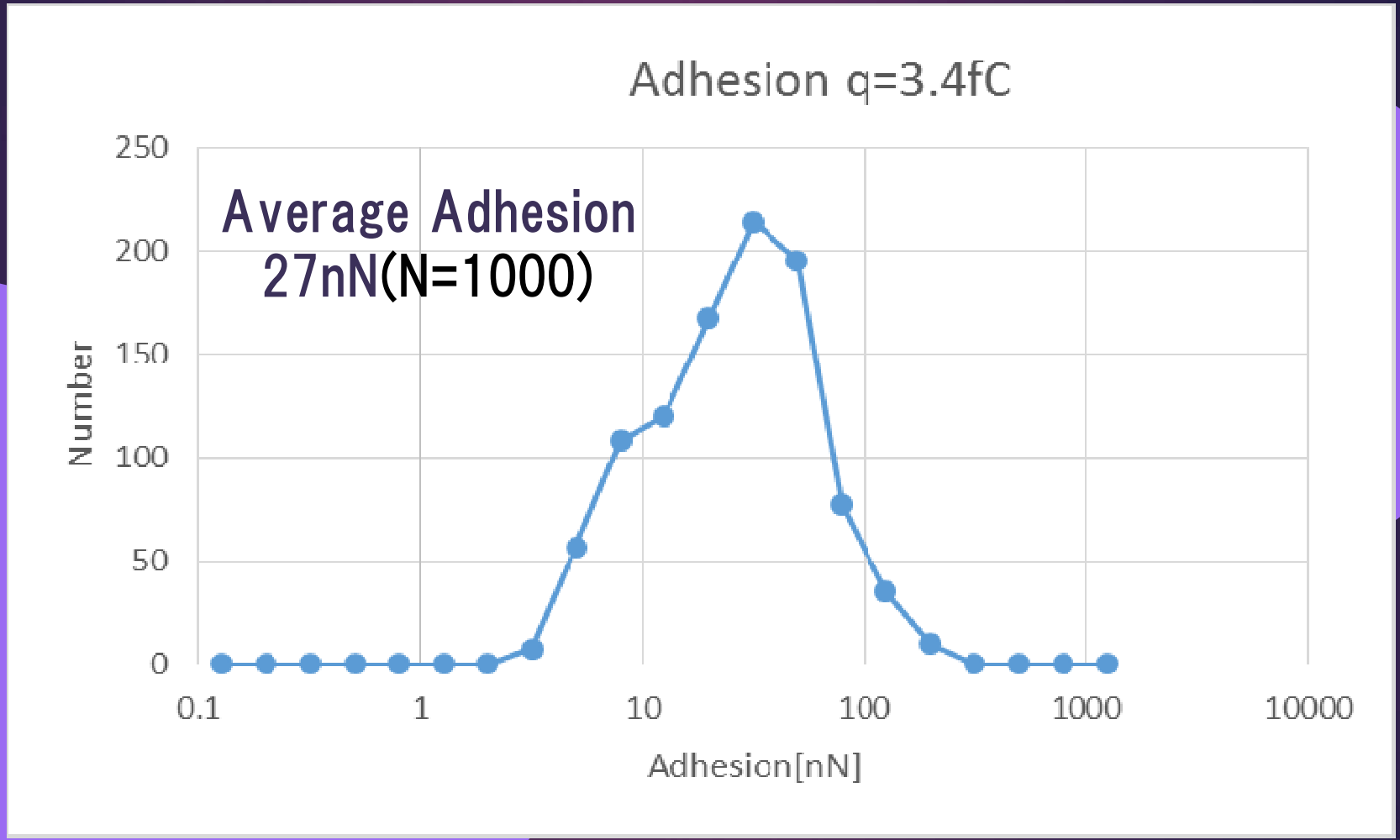
Artificial charge-distributions are made by random number.



Calculate adhesion

Estimated Adhesion of Artificial Toner

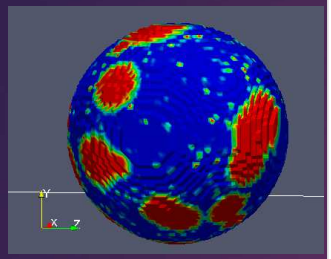
N=1000 q=3.4fC With Charge Patch on the South Pole

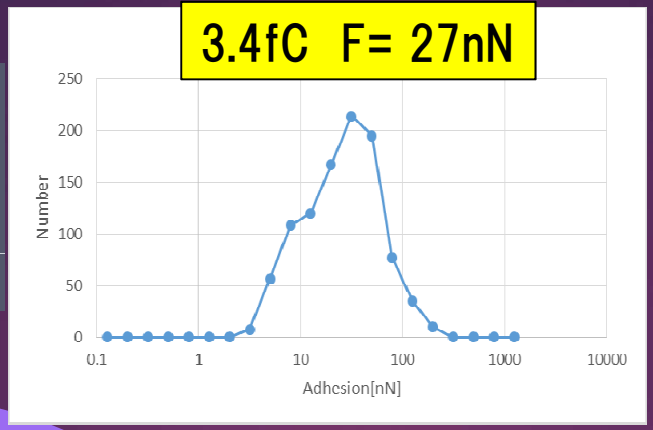


Appropriate adhesion is obtained with artificial toners.

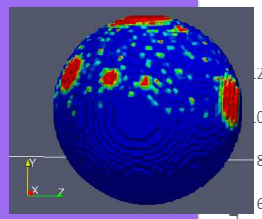
Effect of Location of Charge Patch

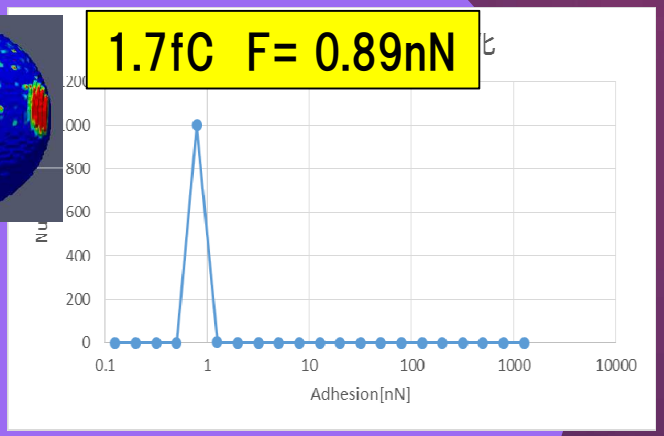
F_E(Whole Toner)



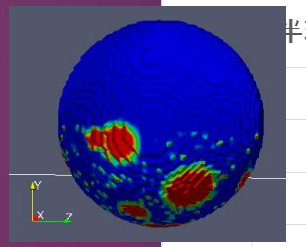


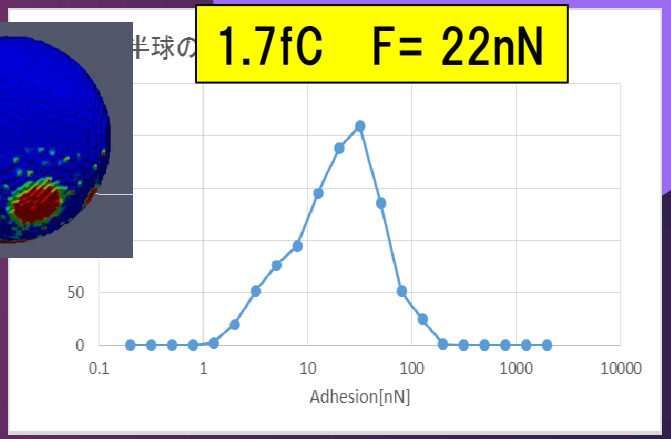
F_{EN}(Northern Hemisphere)





F_{ES}(Southern Hemisphere)



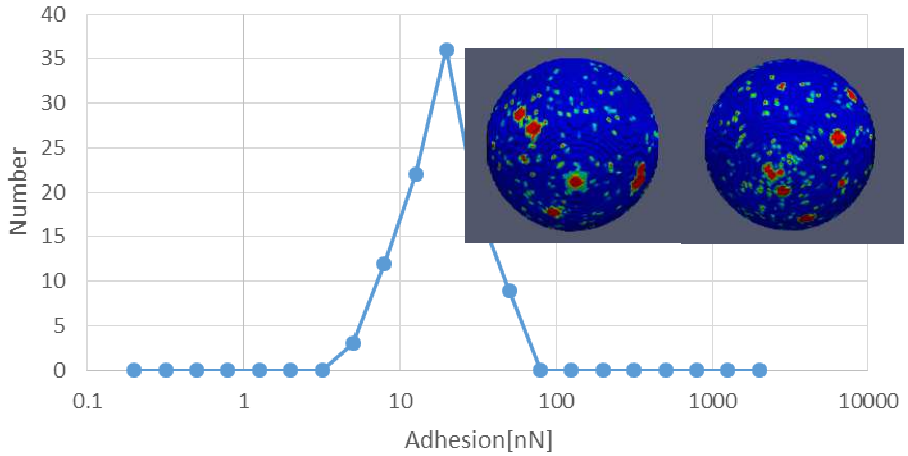


F_{EN}(Northern Hemisphere) << F_{ES}(Southern Hemisphere)

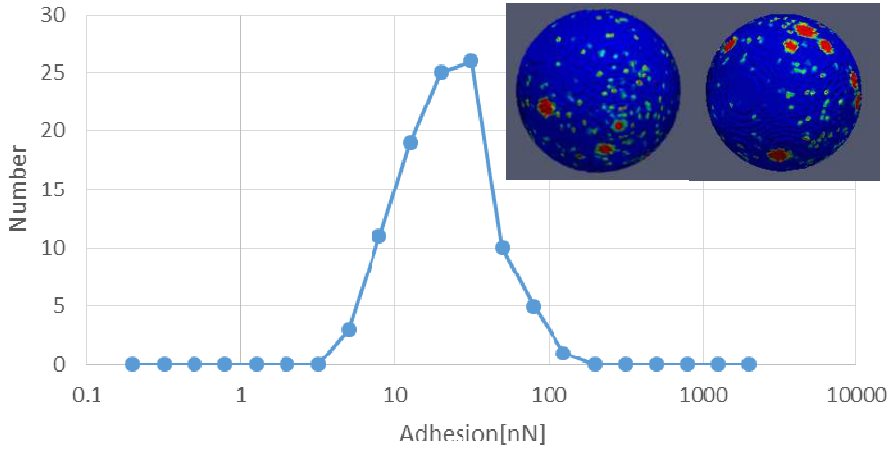
Charge of Southern Hemisphere is dominant.

Num.of Charge Patch/Size v.s. Adhesion

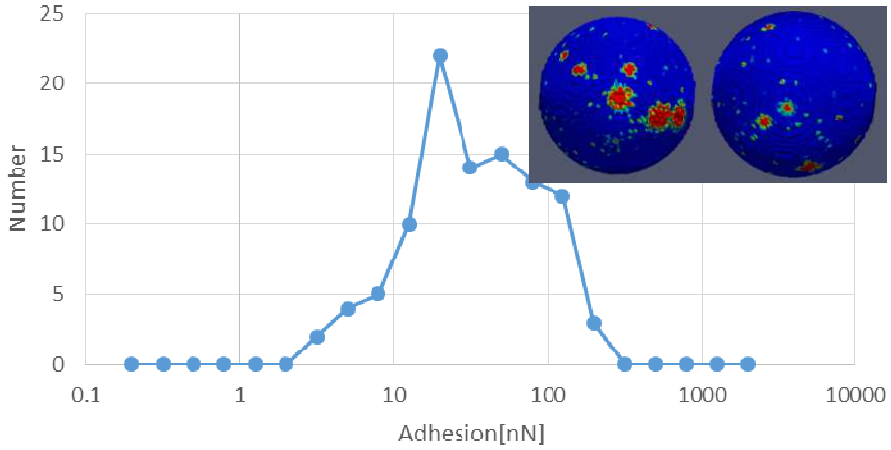
Patch Radius:0.4 μm Q=3.4fC



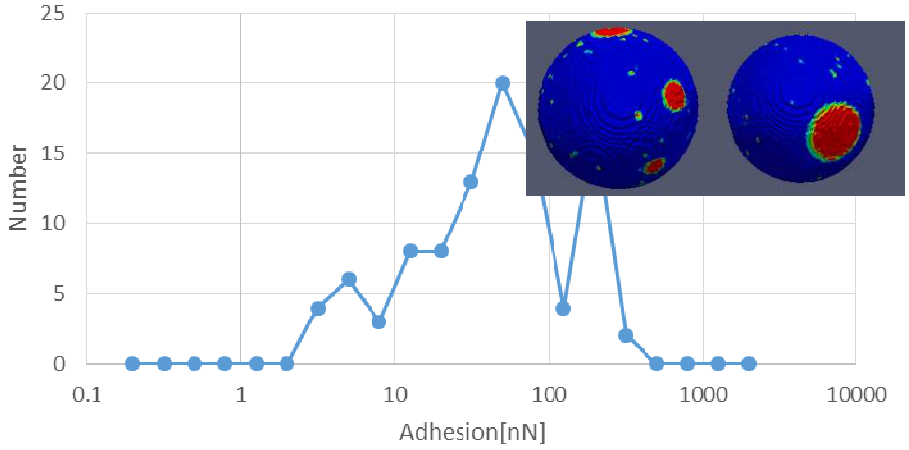
Patch Radius:0.5 μm Q=3.4fC



Patch Radius:1 μm Q=3.4fC

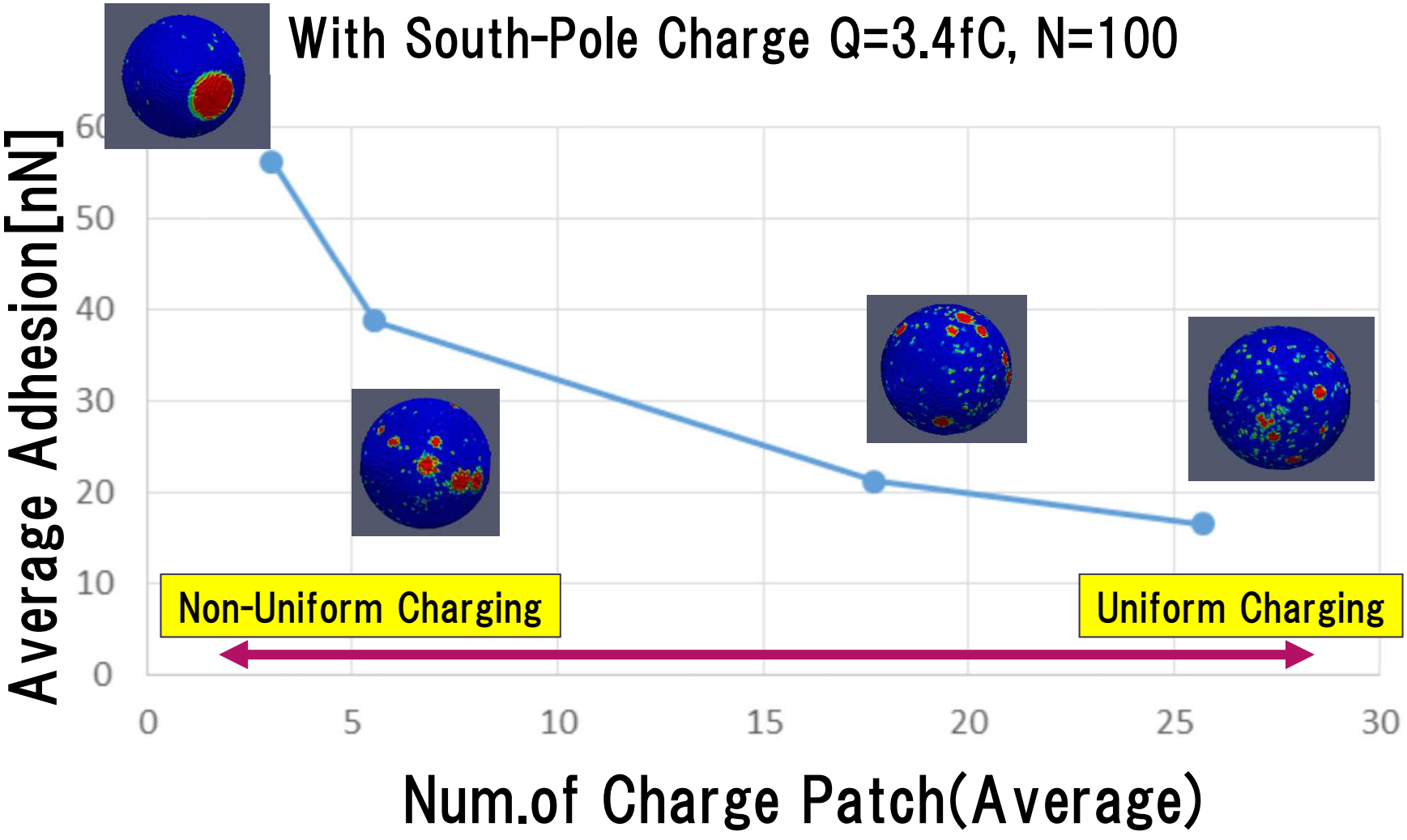


Patch Radius:1.5 μm Q=3.4fC



Q=3.4fC, N=100

Num.of Charge Patch/Size v.s. Adhesion



Non-uniform charging enhances adhesion.

Conclusion

Step1 : Estimation of charge distribution with SPM measurement

shows non-uniform charging!

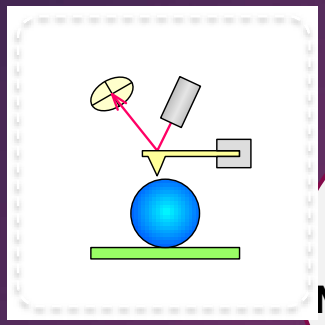
Step 2 : Estimation of adhesion with the charge distribution

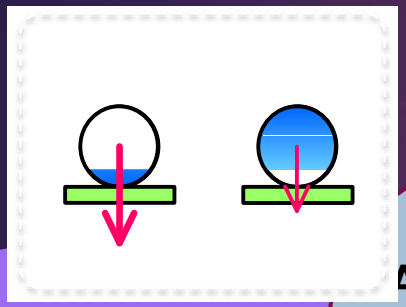
offers an appropriate adhesion value!

Step 3 : Anatomy of adhesion with simulation

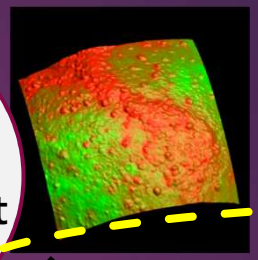
Charge of Southern Hemisphere is dominant.

Big Picture of Adhesion Analysis





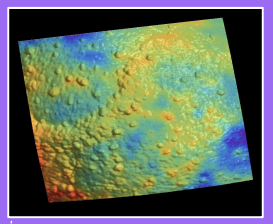
SPM Potential Measurement



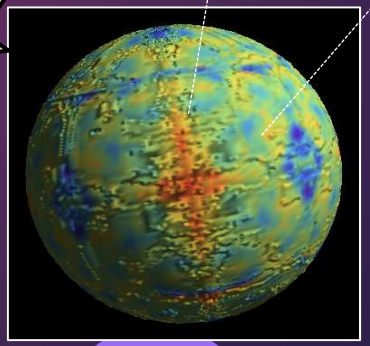
Our Study

Estimation of Charge

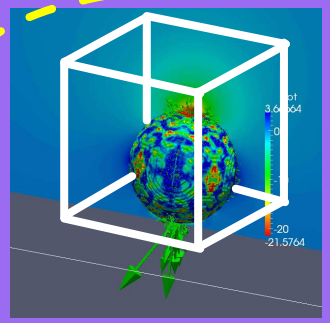
J. Hirabayashi (2014)



Charge Distribution on a Toner



Estimation of Adhesion (Simulation)



M. Kadonaga (2014)

Adhesion Measurement