生命ナノシステム科学

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(4)

後期２００９年

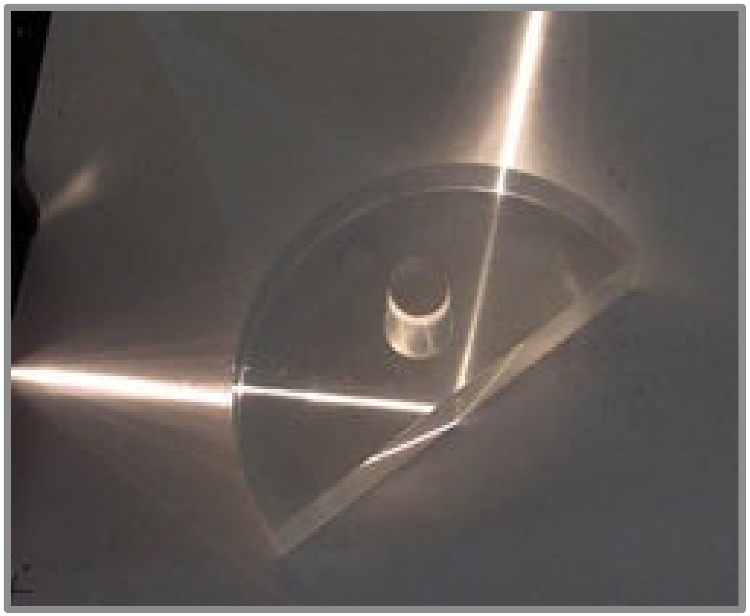
What do we need to make an Artificial Tongue ?

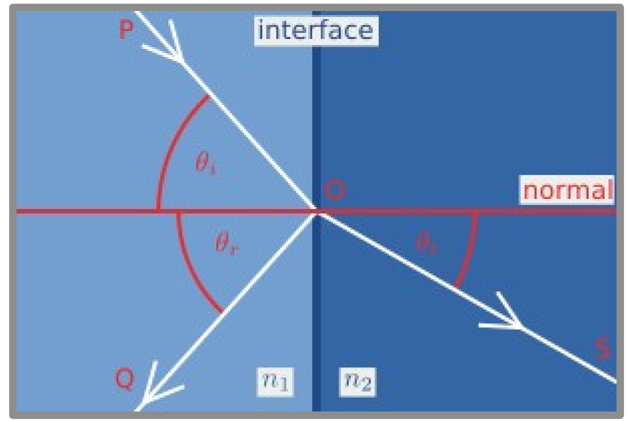
- food is something that must be **TOUCHED**

- sensing **CHEMICAL** properties at **CONTACT**

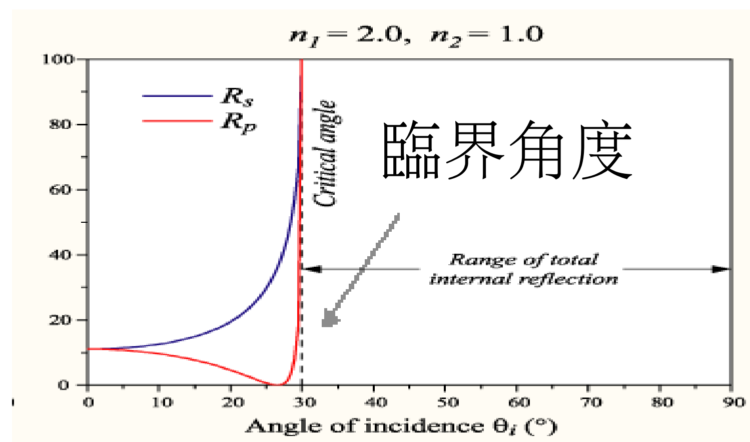
We need different chemical RECEPTORS for different TASTES (sweet, salty, bitter, sour...)

Fresnelの方式





Fresnel理論の結果：全反射
（Total Internal Reflection, TIR）



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表面プラズモン測定装置の原理

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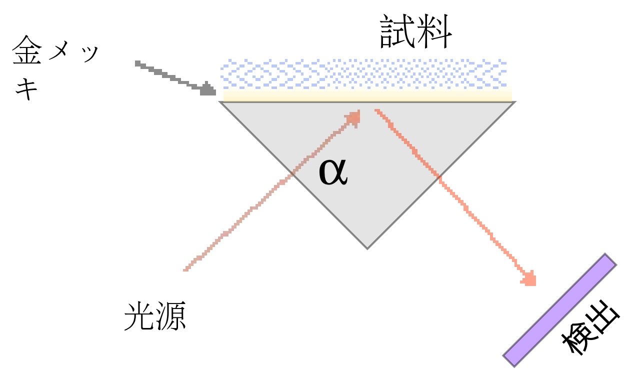
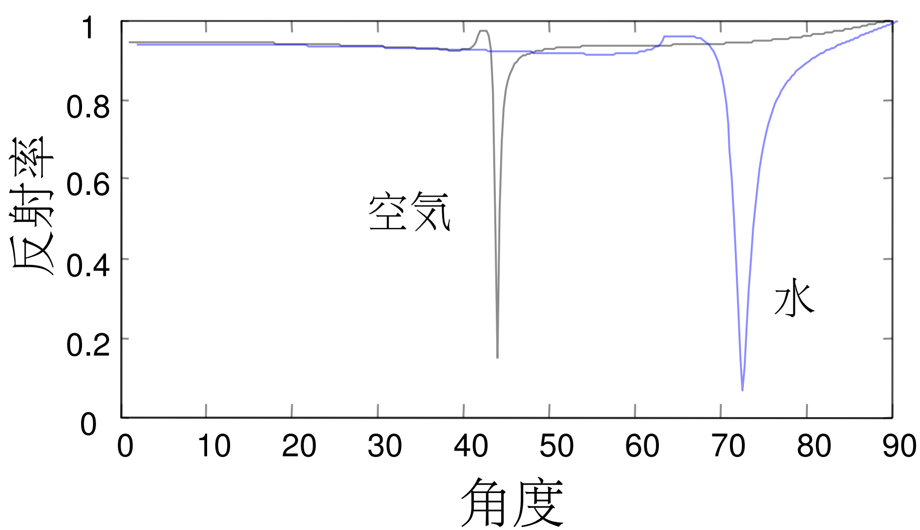
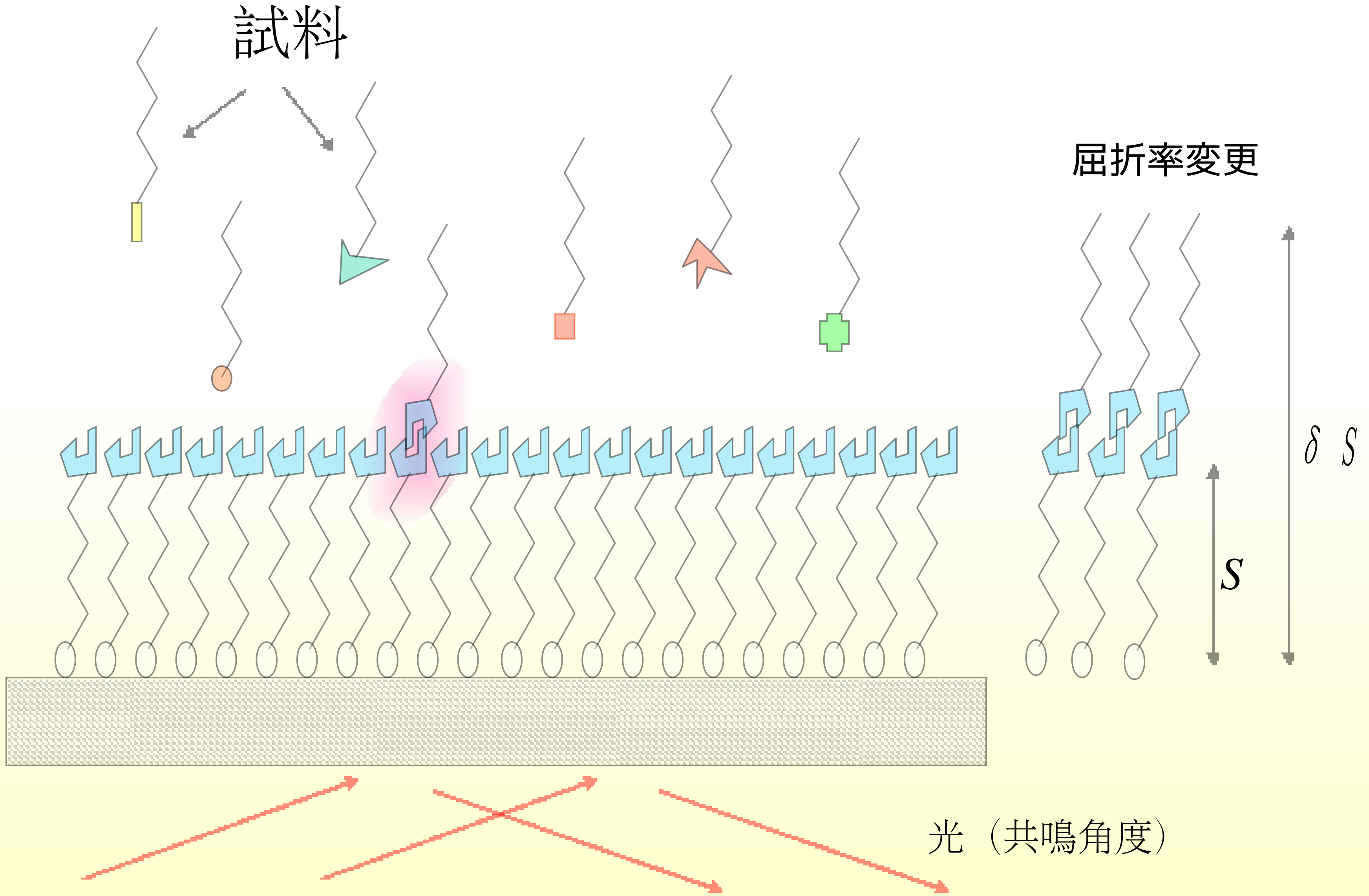


従来のバイオセンシング技術は、プリズムを用いた複雑な光学系と大がかりなシステムのため使いにくいという問題点があった



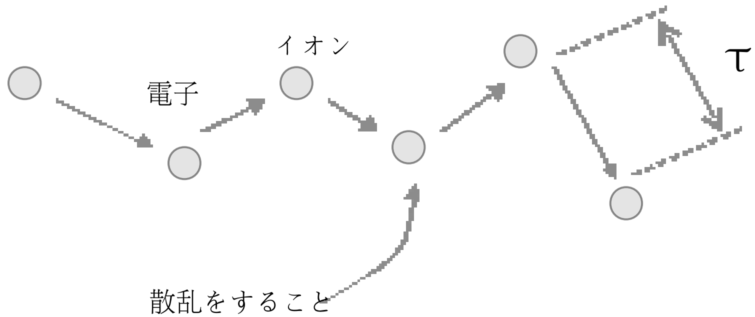
試料の屈折率によってプラ**ズモン共鳴角度は変わりま**すので、光学的物質サンプルのあらゆる□化に敏感であります。

表面プラズモン共鳴を用いたバイオセンシング技術の観念

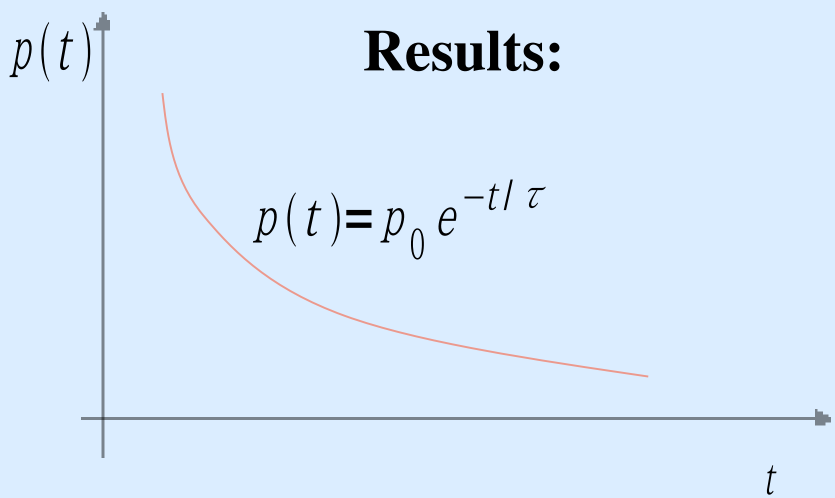


Drude モデル, 金属プラズマ共鳴

Drude Model (1897)



Results:



The momentum p(t) of the electron is dumped by the Ion scattering of a factor -t over mean free time

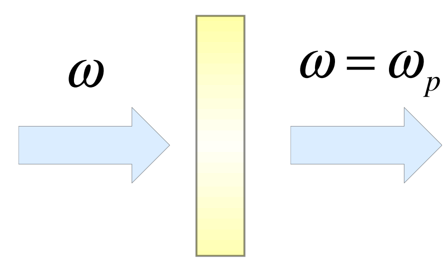
Conditions:

τ= mean free time

- Free Electrons（イオンは関係ありません)
- Independent Electrons (他の電子から影響はない)
- After impact, Random Directions（向はない）
- Scattering probability 1/tau   for an interval of duration dt

（散乱させる確率は**τ**分の一）

Results:



ω_p を超えると金属は透明になること（！）

Current Density 電流密度

$$\bar{J} = q\frac{N}{A*dt}$$

Definition

$$dV = A*dx$$

$$N = n*dV$$

$$\bar{J} = q\frac{n*dV}{A\,dt}$$

$$\bar{J} = q\frac{n*A*dx}{A\,dt}$$

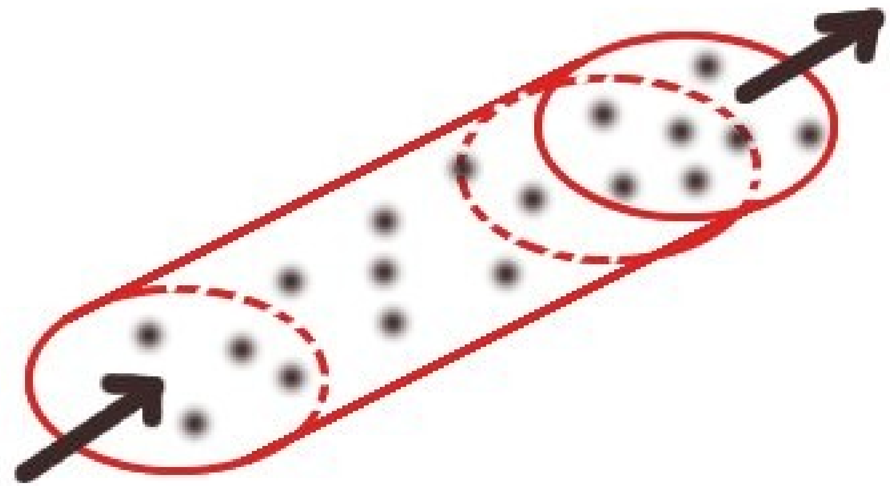
$$\bar{J} = q\,n*\bar{v}$$

$$\bar{J} = ne\;\bar{v}$$

$$\bar{p} = m\bar{v}$$

$$J = ne\;\bar{p}/m$$

Final



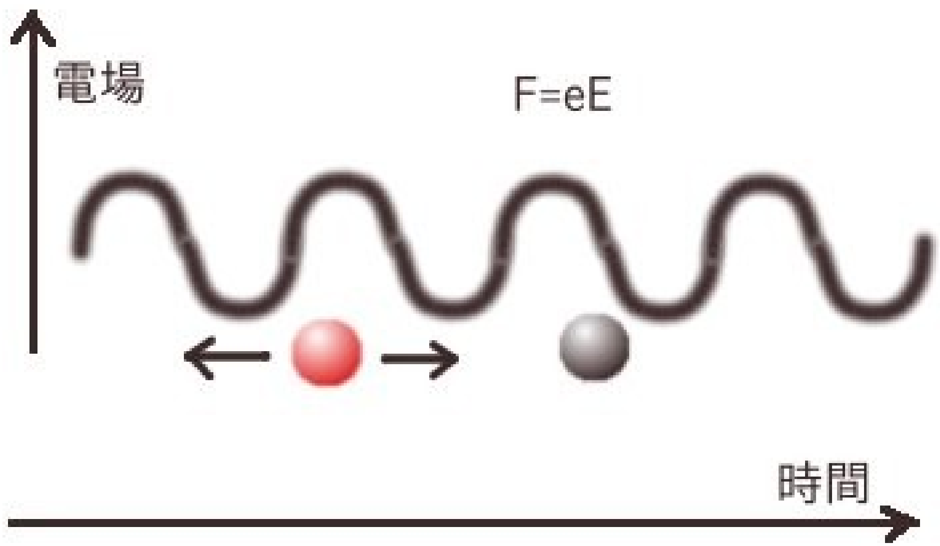
$$p(t+dt)=(1-dt/\tau)[p(t)+f(t)dt]$$

$$p(t+dt)=p(t)+f(t)dt-p(t)d(t)/\tau-O^2(dt)$$

$$\frac{p(t+dt)-p(t)}{dt}=f(t)-p(t)/\tau-O^2(dt)$$

$$\lim_{dt\to 0}\Rightarrow p'(t)=f(t)-p(t)/\tau$$

$$p'(t)=e\ \bar{E}-p(t)/\tau$$



In the case of Light
E is a wave:

$$\bar{E}=Ee^{i\omega t}$$

$$p(t)=\left[p(\omega)e^{-i\omega t}\right]$$

$$-i\omega p(\omega)=-eE(\omega)-p(\omega)/\tau$$

$$p(\omega)=-eE(\omega)\tau/(1-\omega\tau)$$

$$\bar{J} = ne\ \bar{p}/m$$

$$p(\omega) = \frac{-eE(\omega)\tau}{(1-\omega\tau)}$$

$$\bar{J} = \frac{ne^2\tau}{m(1-i\omega\tau)}\bar{E} = \sigma(\omega)\bar{E}$$

$$\omega\tau \gg 1$$

$$\bar{J} = i\frac{ne^2}{m\omega}\bar{E}$$

J is not real !!

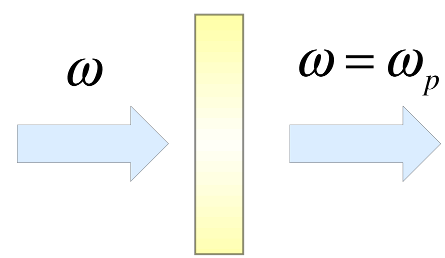
$$\nabla\cdot\bar{E} = 0, \nabla\cdot\bar{H} = 0$$

$$\nabla\times\bar{E} = -\frac{1}{c}\frac{\partial\bar{H}}{\partial t}$$

$$\nabla\times\bar{H} = 4\pi\frac{\bar{J}}{c} + \frac{1}{c}\frac{\partial\bar{E}}{\partial t}$$

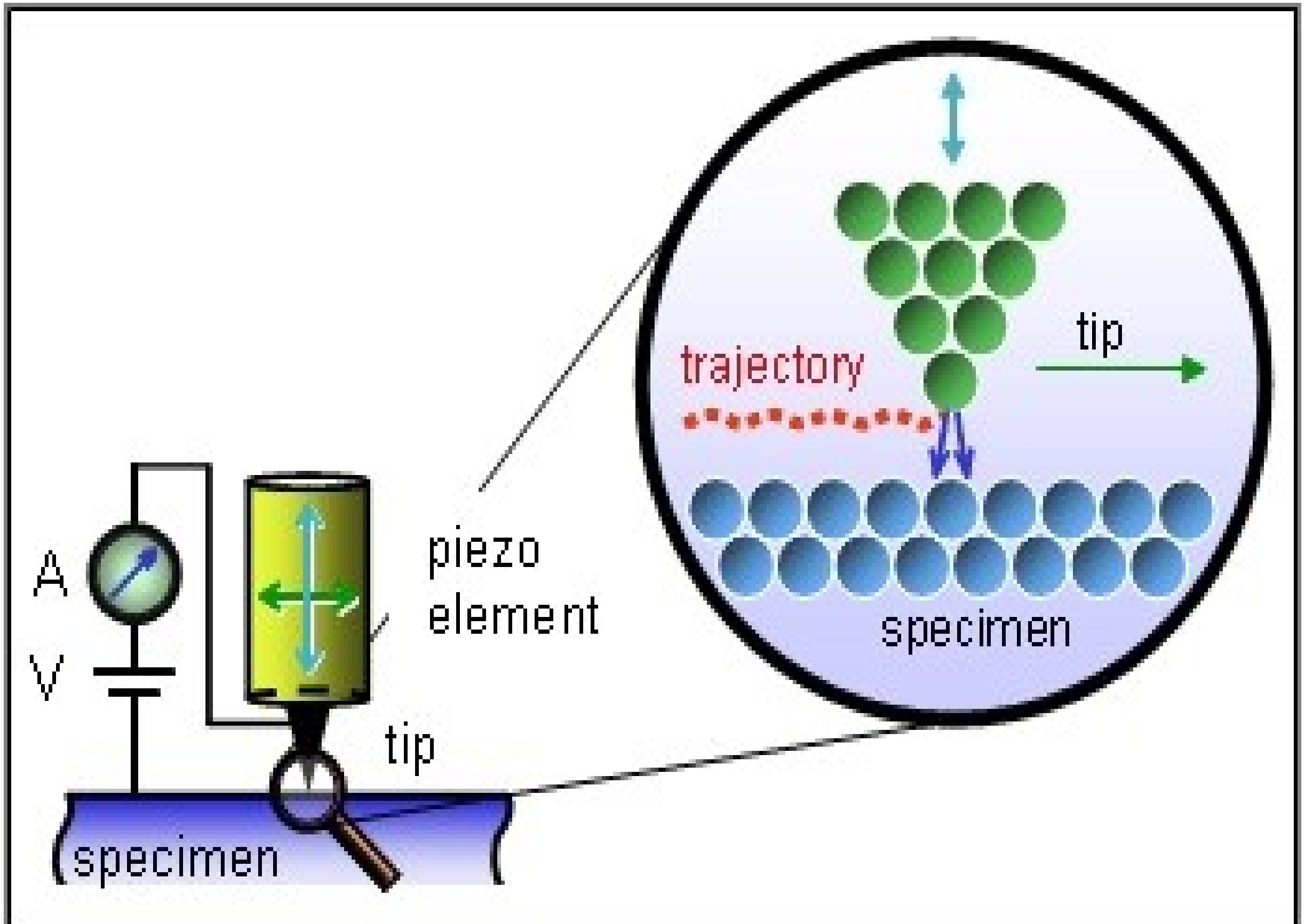
$$\nabla^2\bar{E} + \frac{\omega^2}{c^2}\left(1 - \frac{\omega_p^2}{\omega^2}\right)\bar{E} = 0$$

$$\omega_p = \frac{4\pi ne^2}{m}$$

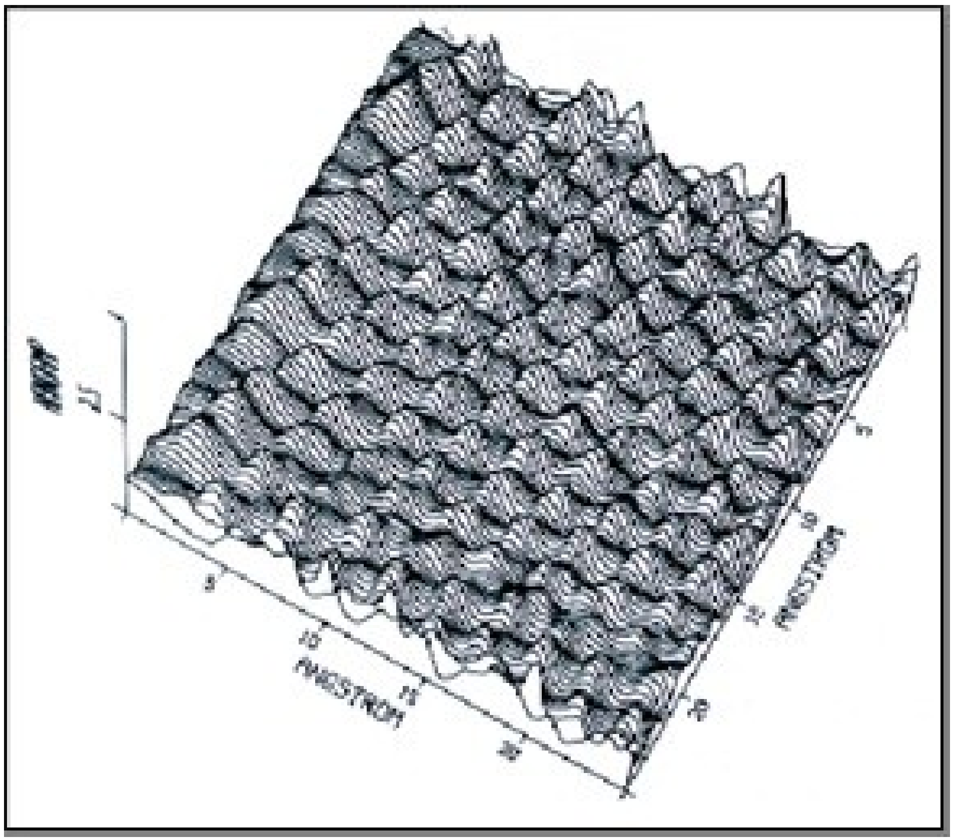


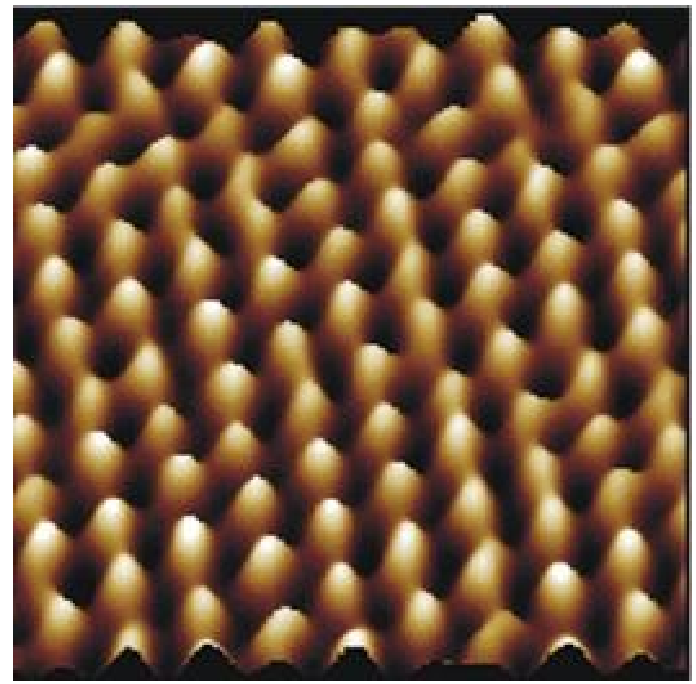
ω_p を超えると金属は透明になること（！）

Scanning Tunneling Microscope (STM)
電子トンネル顕微鏡

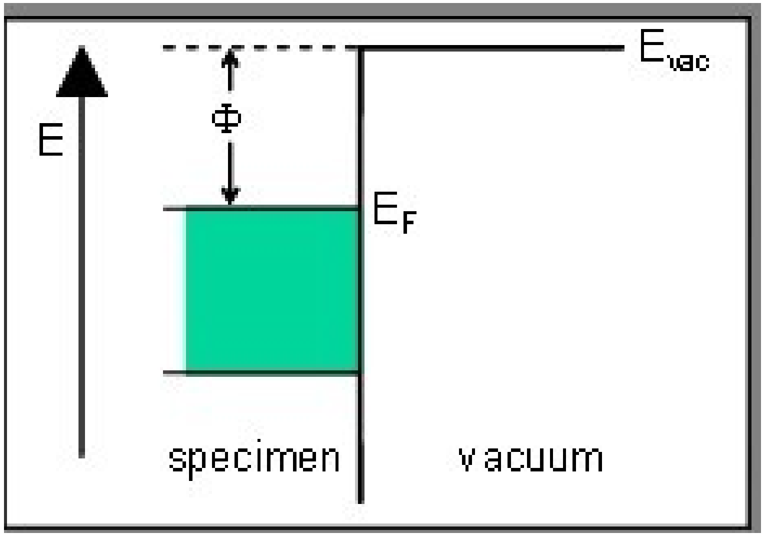


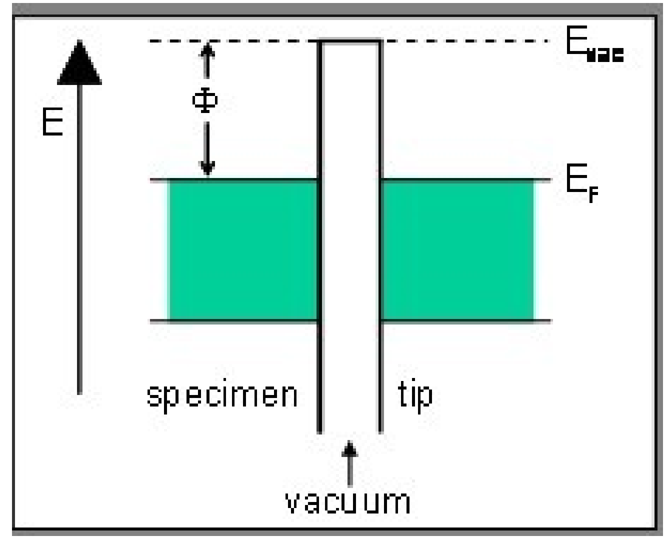
原子を見ました！





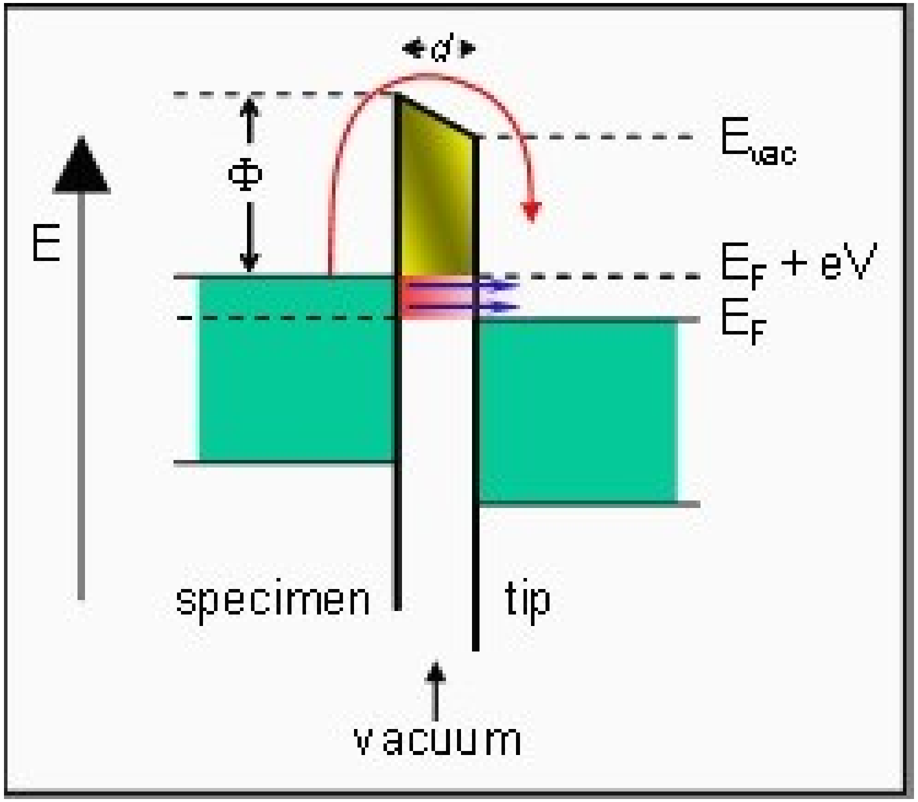
Graphite　HOPG

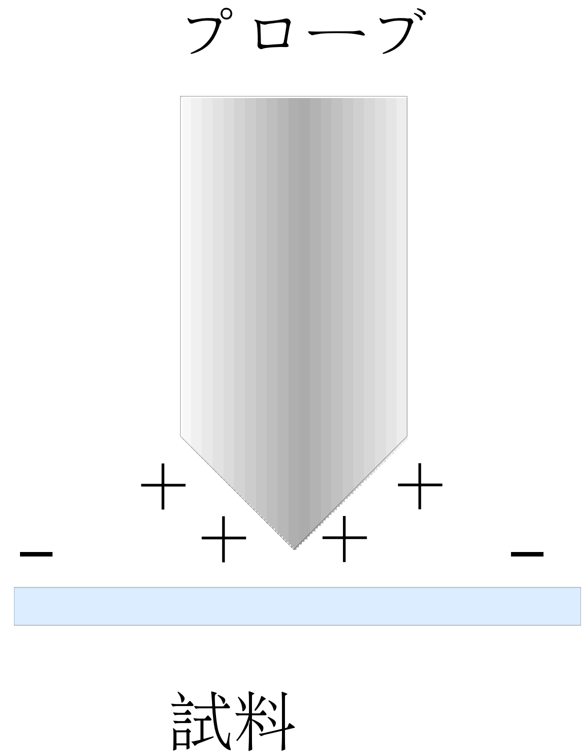




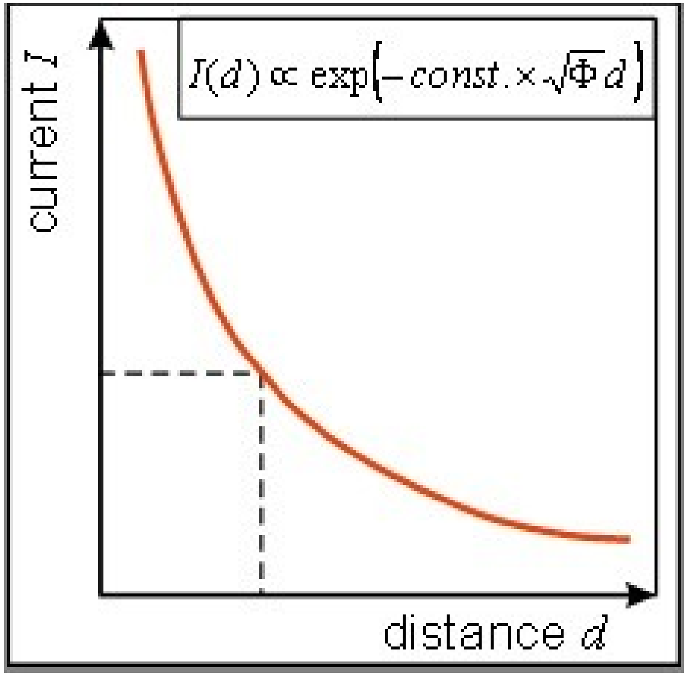
In a metal, the energy levels of the electrons are filled up to a particular energy, known as the 'Fermi energy' E_F. In order for an electron to leave the metal, it needs an additional amount of energy F, the so-called 'work function'.

When the specimen and the tip are brought close to each other, there is only a narrow region of empty space left between them. On either side, the electrons are present up to the Fermi energy. They need to overcome a barrier F to travel from tip to specimen or vice versa.





If the distance d between specimen and tip is small enough, electrons can ‘tunnel’ through the vacuum barrier. When a voltage V is applied between specimen and tip, the tunneling effect results in a net electron current. In this example from specimen to tip. This is the tunneling current.

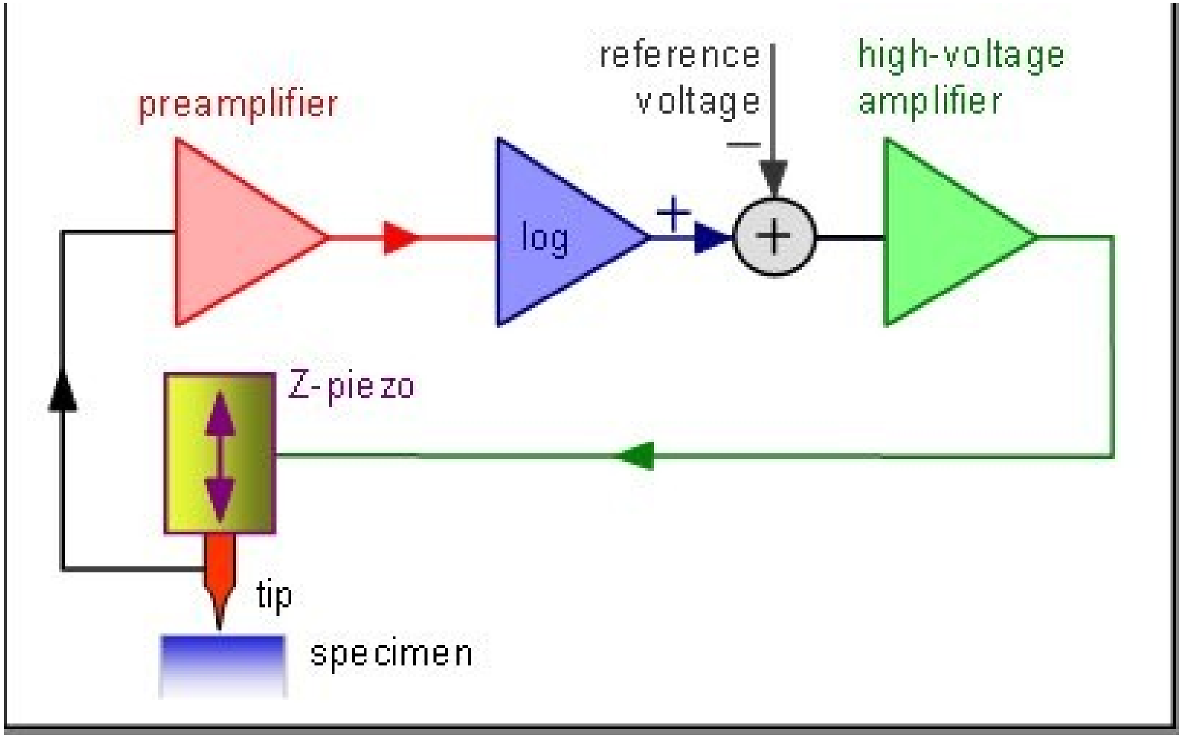


$$I(d) = constant \times eV \exp\left(-2\frac{\sqrt{2m\Phi}}{\hbar}d\right)$$

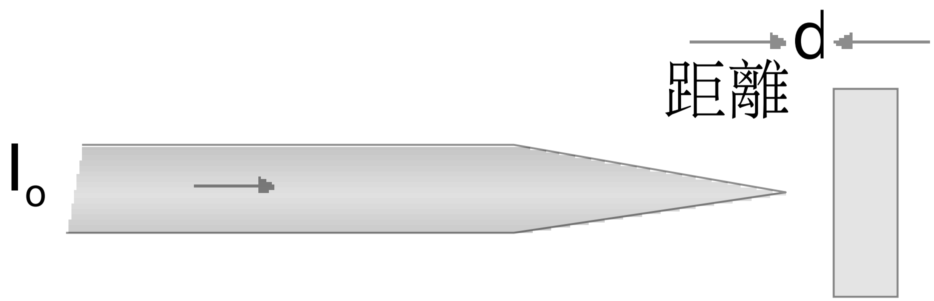
$$\phi = 4\,\mathrm{eV}$$

Typical Work Function

This (approximate) equation shows that the tunneling current obeys Ohm's law, i.e. the current I is proportional to the voltage V. It depends exponentially on the distance d. The other quantities in the equation are the work function F, the electron charge and mass e and m, and Planck's constant. For a typical value of the work function F of 4 electronVolt (eV), the tunneling current reduces by a factor 10 for every 0.1 nm increase in d. This means that over a typical atomic diameter of e.g. 0.3 nm, the tunneling current changes by a factor 1000! This is what makes the STM so sensitive. The tunneling current depends so strongly on the distance that it is dominated by the contribution flowing between the last atom of the tip and the nearest atom in the specimen.



- Pico ampere control



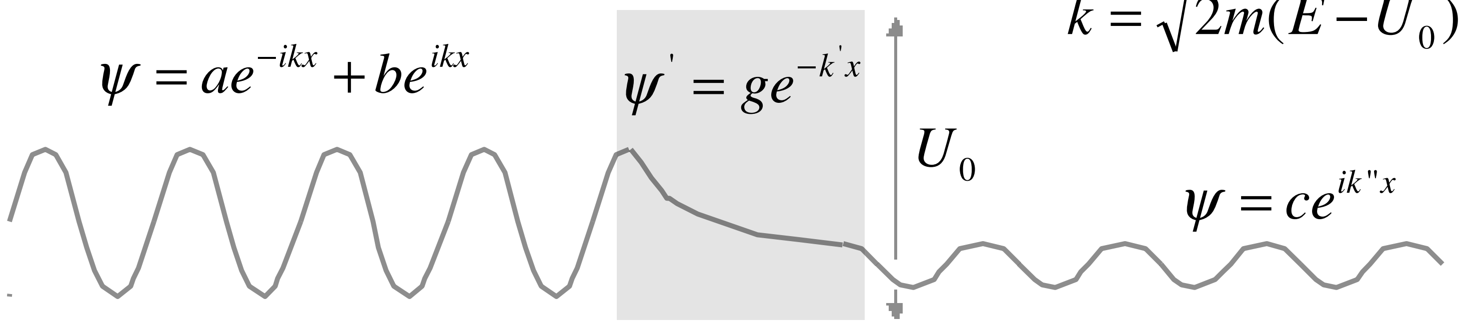
電流の値は距離に従って指数関数的に
減衰します

$$k = \sqrt{2m(E - U_0)/h^2}$$

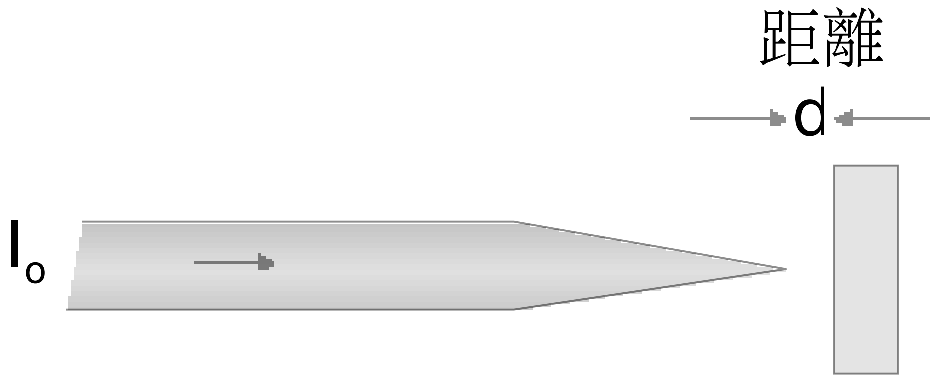
$$\psi = ae^{-ikx} + be^{ikx}$$

$$\psi' = ge^{-k'x}$$

$$\psi = ce^{ik''x}$$



One dimensional model



電流の値は距離に従って
指数関数的に
減衰します

The signal measured
is Exponentially
dependent to the
morphology in “Z”

The intensity is function
of the gap distance