ナノテクノロジーの楽しさ

ナノテクノロジーの楽しさ

1　身近なナノテクノロジー

2　ナノとは？

3　100年に一度の大革命：STM・AFMの発明

4　ナノ材料を作る

5　光とナノ

6　ナノテクノロジーの夢

ナノテクノロジーの楽しさ

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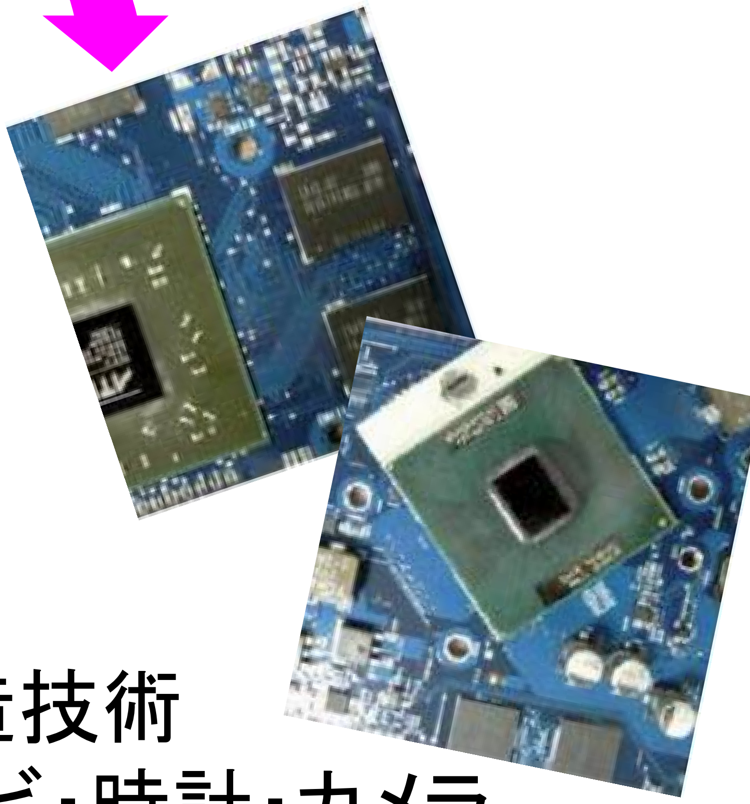
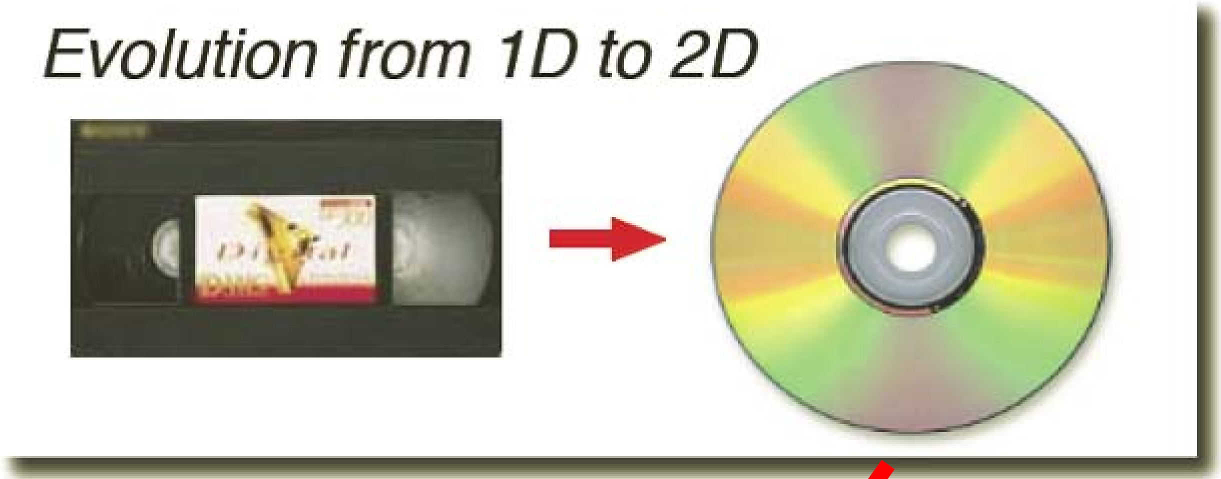
■LSIはナノ

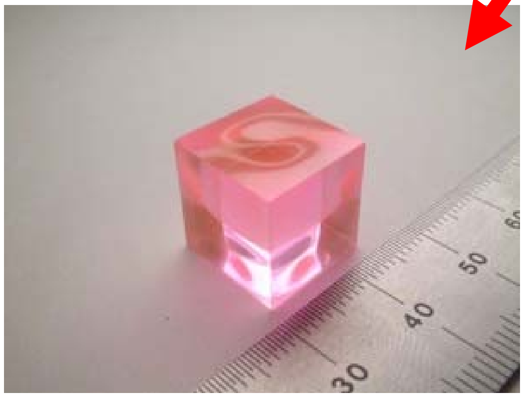


半導体・液晶製造技術
トランジスターラジオ・テレビ・時計・カメラ
ウオークマン・CD・DVD・携帯電話

ミニ→マイクロ→ナノ!!

メモリはナノ

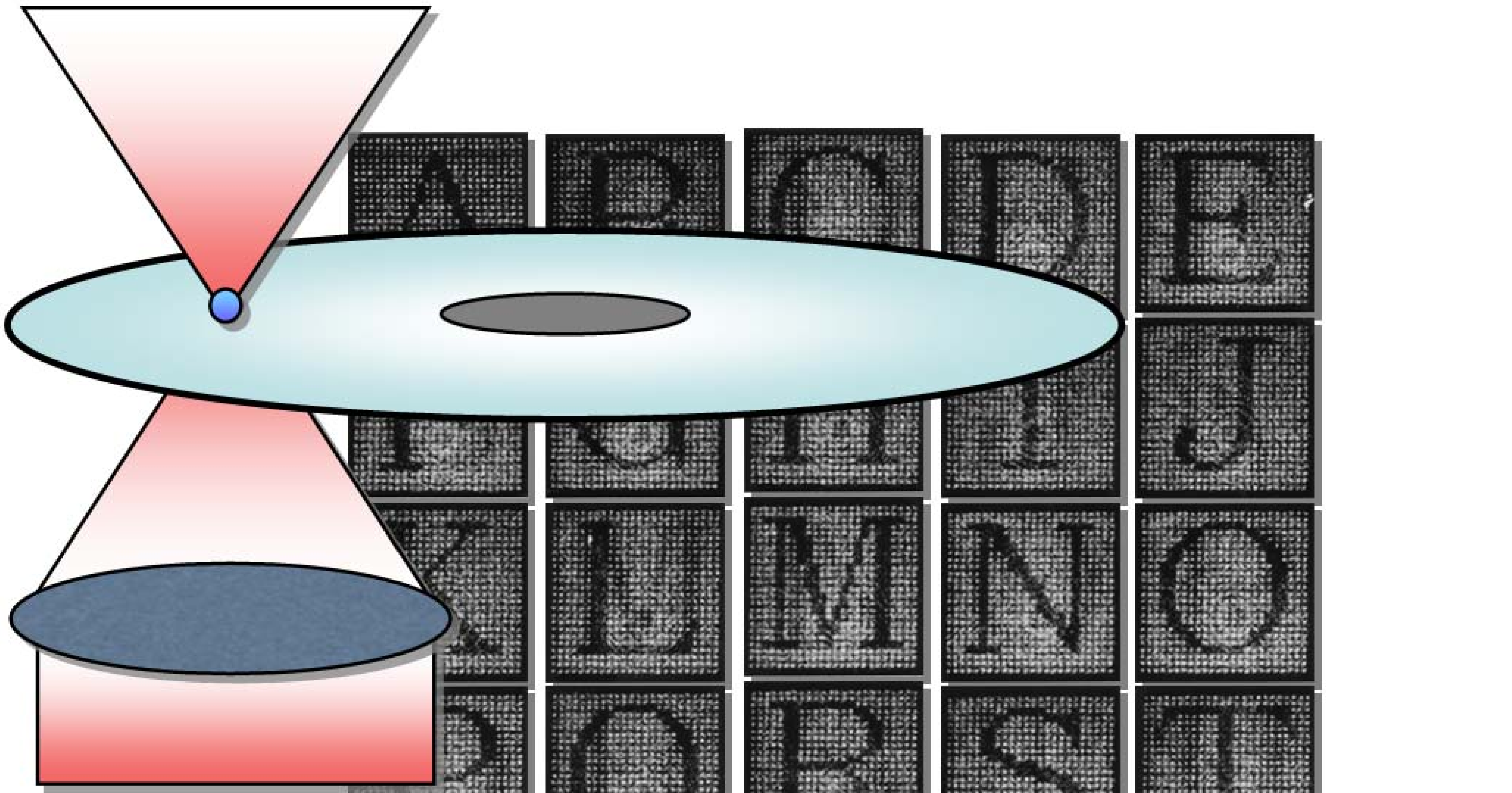


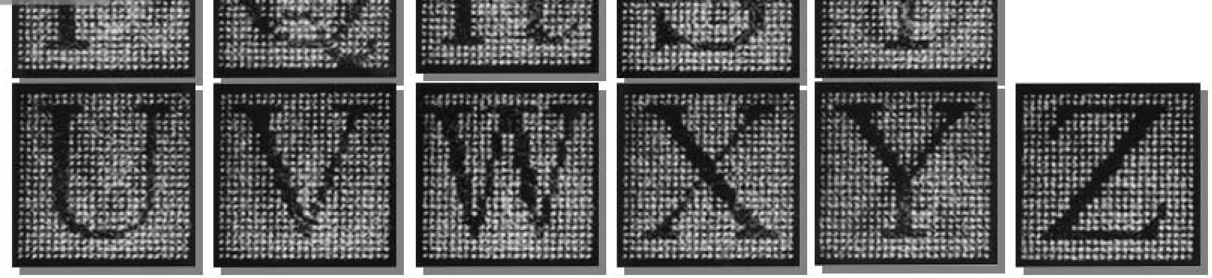


3D!!

A. Toriumi, S. Kawata, Opt. Lett 97,98
S. Kawata, Proc.IEEE Dec. 1999
S. Kawata, Y. Kawata, Chem Rev. 2000

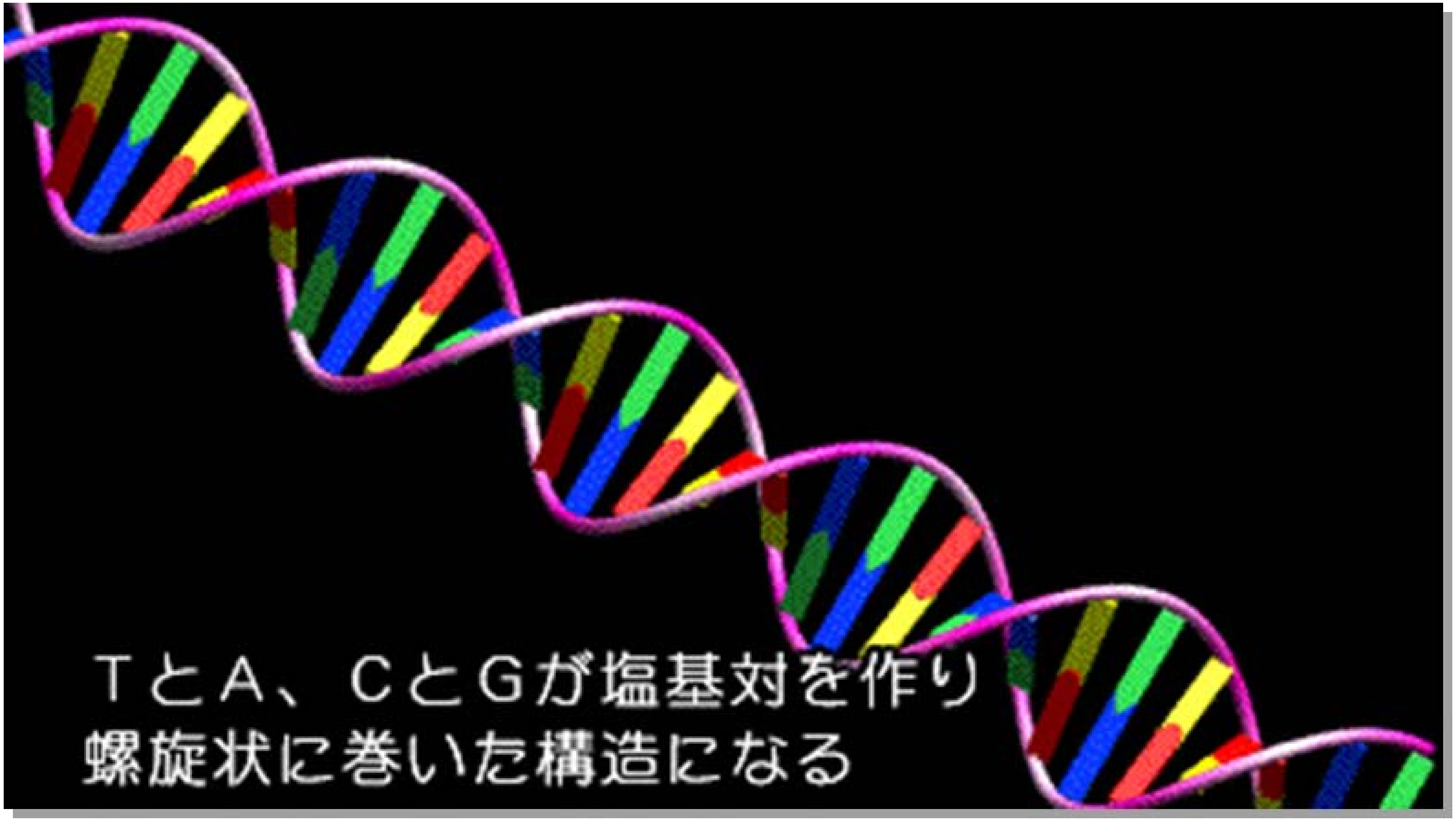
26層3次元光メモリ





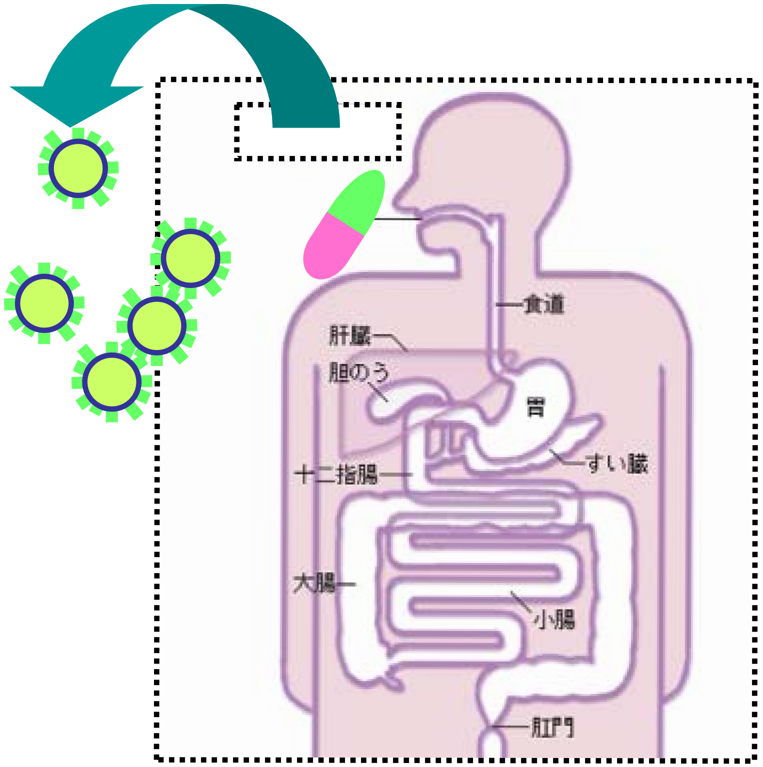
■ナノ粒子配合化粧品

■遺伝子はナノ



■小型化する医療器機

マイクロマシン→ナノマシン



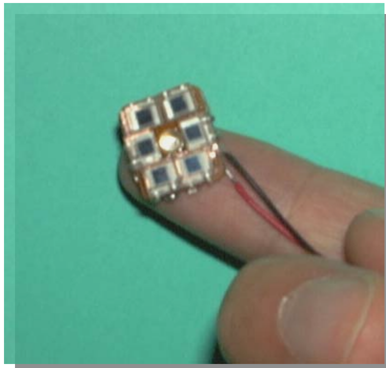
ドラッグデリバリーシステム

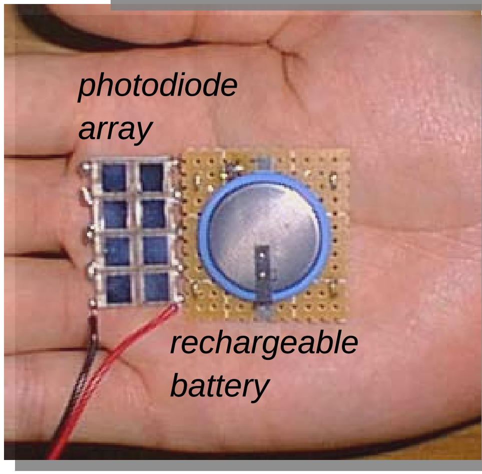
内視鏡

レーザーメス

センサー

ペースメーカー





Goto. et.al. Rev. Sci. Instrum., 72, 3079-3085 (2001)

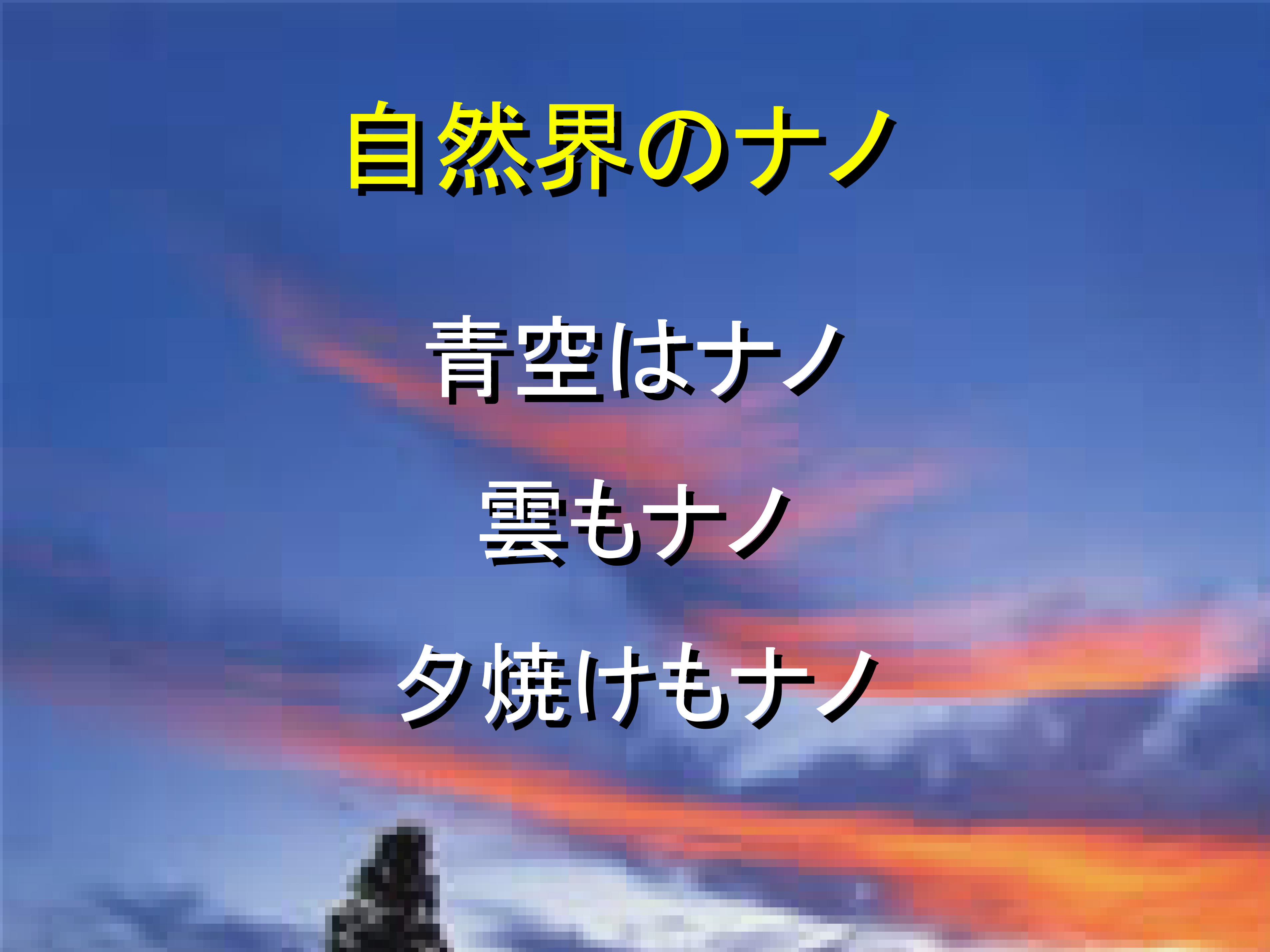
Murakawa, et.al. IEEE Eng.Med. Biol.,(Nov/Dec,1999).
Goto. et.al. IEEE Trans. Biomed. Eng. (2001).

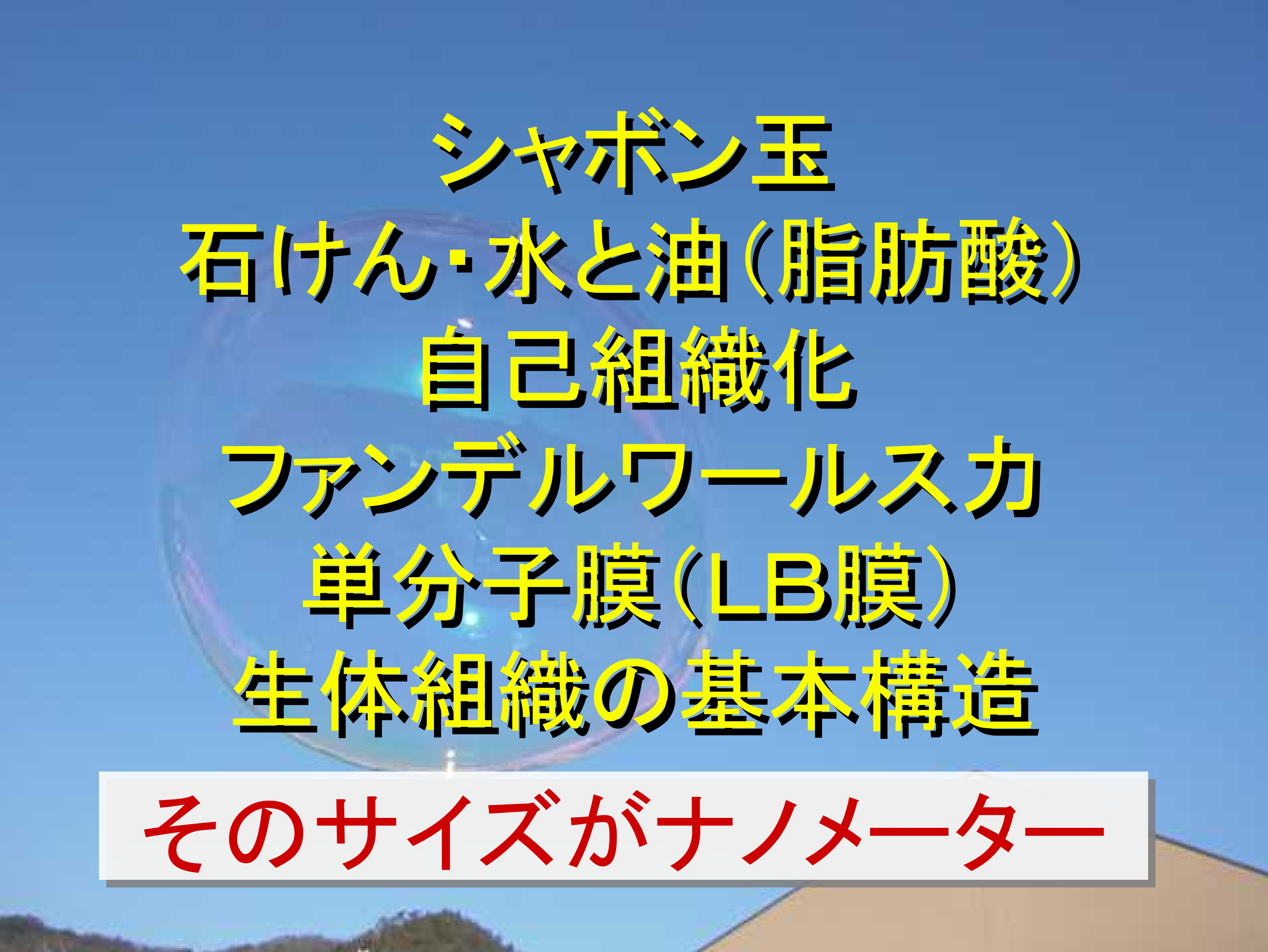
自然界のナノ

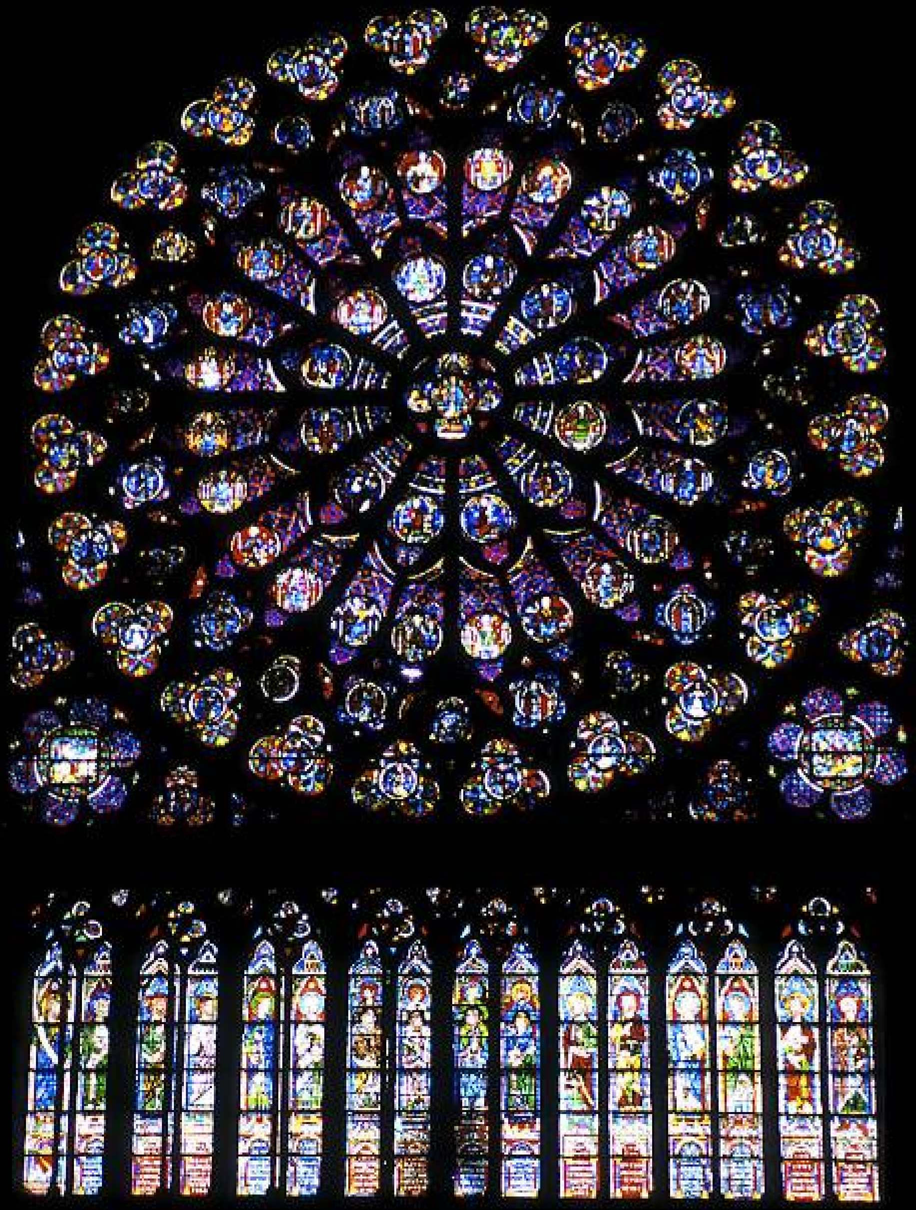
青空はナノ

雲もナノ

夕焼けもナノ




シャボン玉
石けん・水と油（脂肪酸）
自己組織化
ファンデルワールス力
単分子膜（LB膜）
生体組織の基本構造
そのサイズがナノメーター



ステンドグラスもナノ

ナノテクノロジーの楽しさ

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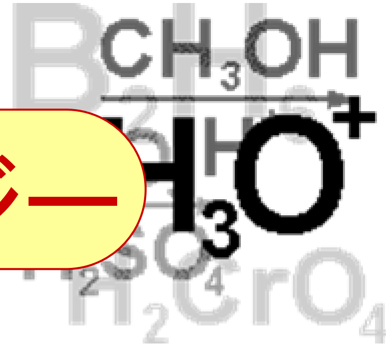
ナノという単位

nano

1nm, 1ng, 1ns, 1nl, 1nN

	ペタ	
	テラ	
1000,000,000	ギガ	十億
1000,000	メガ	百万
1000	キロ	千
1		一
ミリ		0.001
マイクロ		0.000,001
十億分の1 ナノ		0.000,000,001
ピコ		
フェムト		
アット		

1km = 1000m = 10^{3}m	町
1m = 1m	人
1mm = 千分の1m = 10^{-3}m	文字の太さ
1μm = 百万分の1m = 10^{-6}m	細胞、IC
1nm = 十億分の1m = 10^{-9}m	ナノ＝分子
1Å = 百億分の1m = 10^{-10}m	原子 (atom)



ナノテクノロジー＝分子テクノロジー

分子？とナノの違い

分子？

酸素O_2・水素H_2・窒素N_2

炭素C

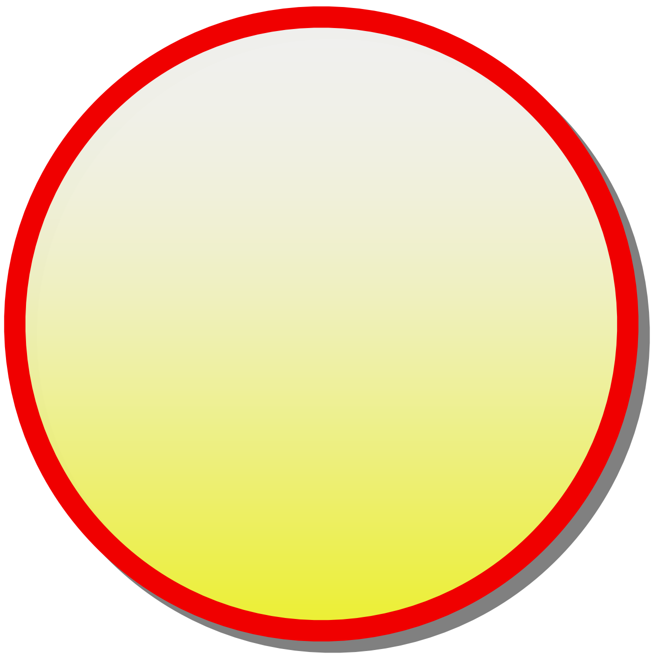
H_2O・CO_2

珪素（Si シリコン）

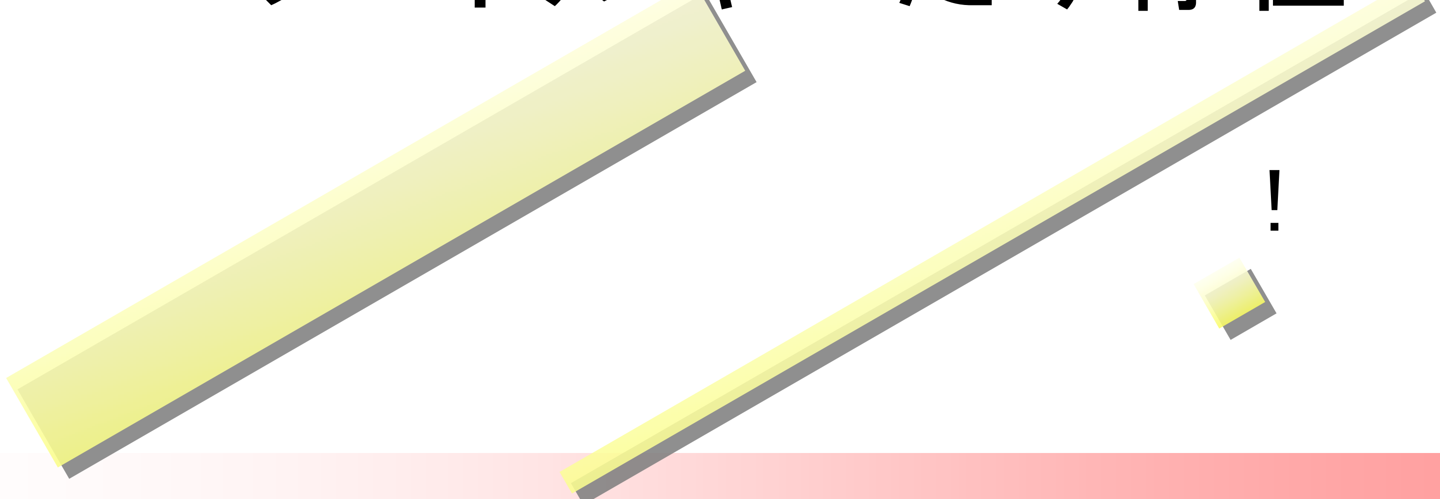
鉄Fe・金Au・水銀Hg

物質・水・空気

メゾスコピック効果：
表面と内部



量子効果：
一つのエネルギーだけ存在



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６　ナノテクノロジーの夢

1801-1900年　１９世紀　ワットの蒸気機関

1901-2000年　２０世紀　エジソンの電気の時代

ノーベル賞の時代

2001-2100年　２１世紀　ナノテクノロジーの時代

ノーベル賞。

1901 X線　Roentgen

1902 磁気と放射現象　Lorentz, Zeeman

1903 放射性元素　Curie

1904 希ガスの発見Ramsay, Rayleigh

1905 陰極線　Lenard

1907 干渉計　Michelson

1910 気体の状態方程式van der Waals

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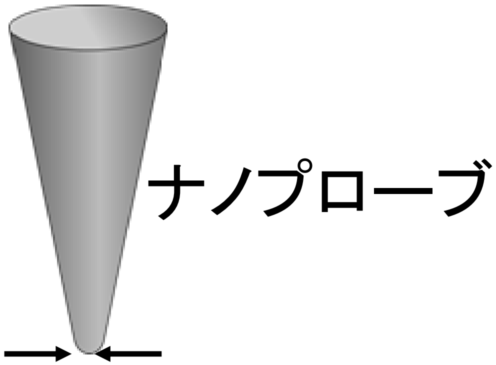
1986年　STM,AFMの発明　Binnig,　Rohrer
1996年　C_{60}の発見 Curl, Kroto, Smalley

・走査トンネル顕微鏡 (STM)

・原子間力顕微鏡 (AFM)　など

→ ナノプローブ顕微鏡

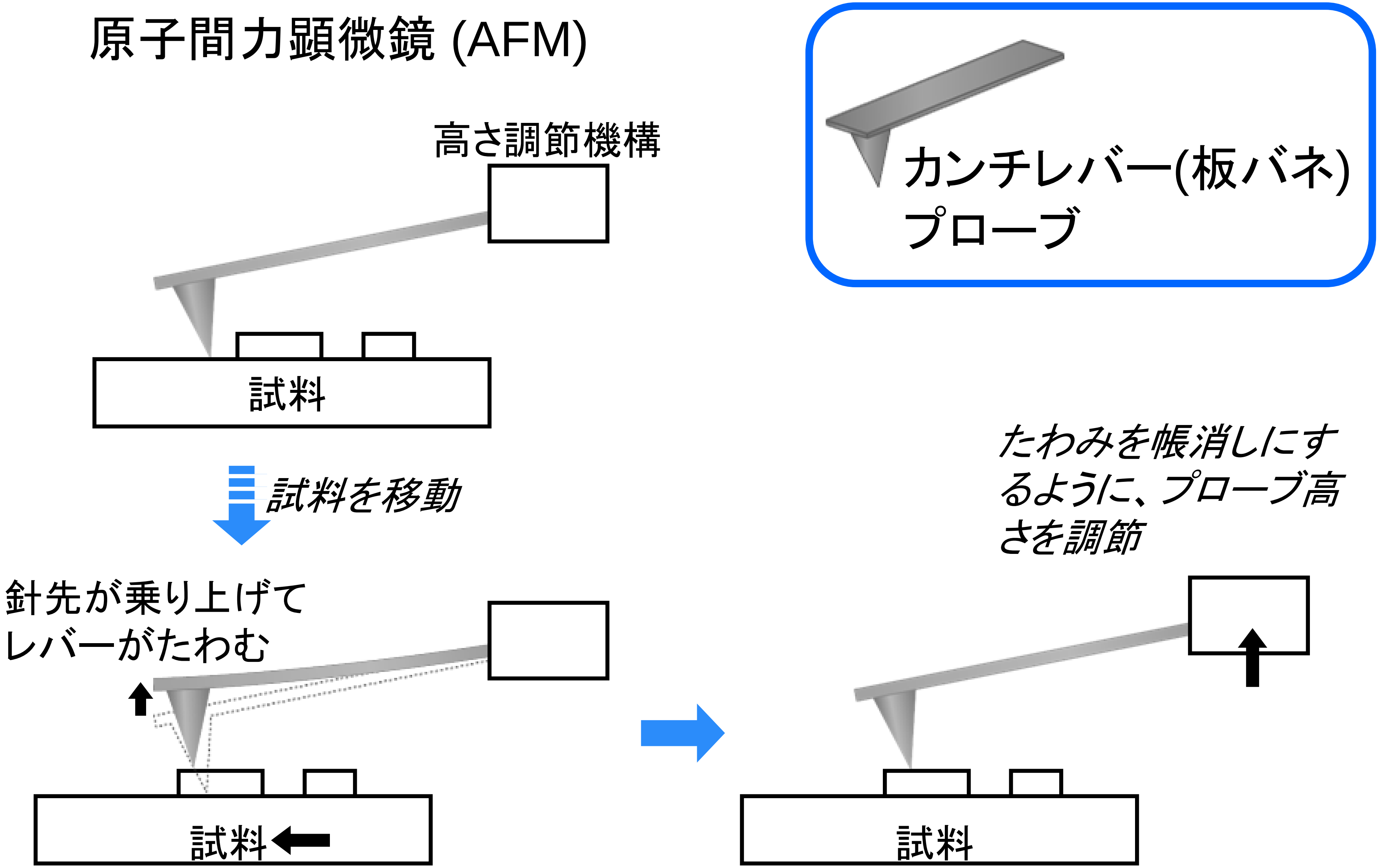


先端径：数ナノメートル

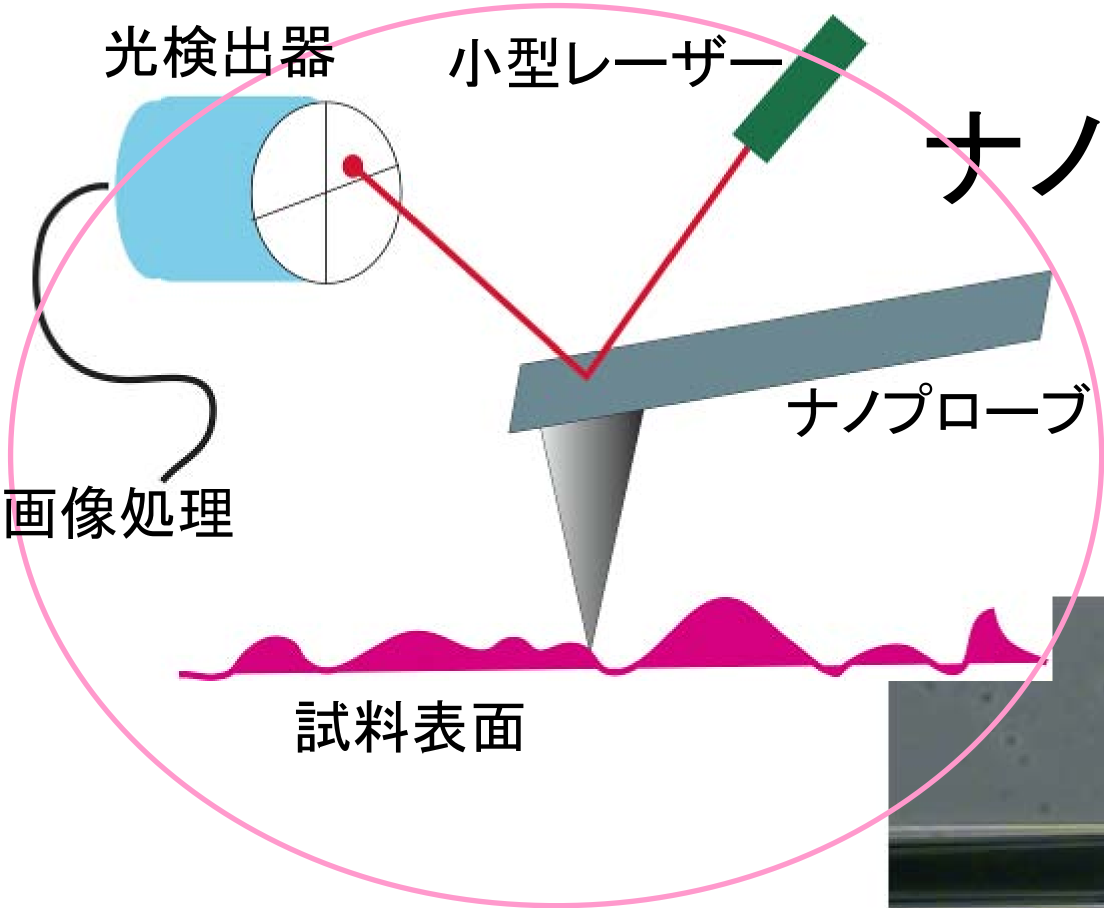
針先で、ナノを見る、測る、操る

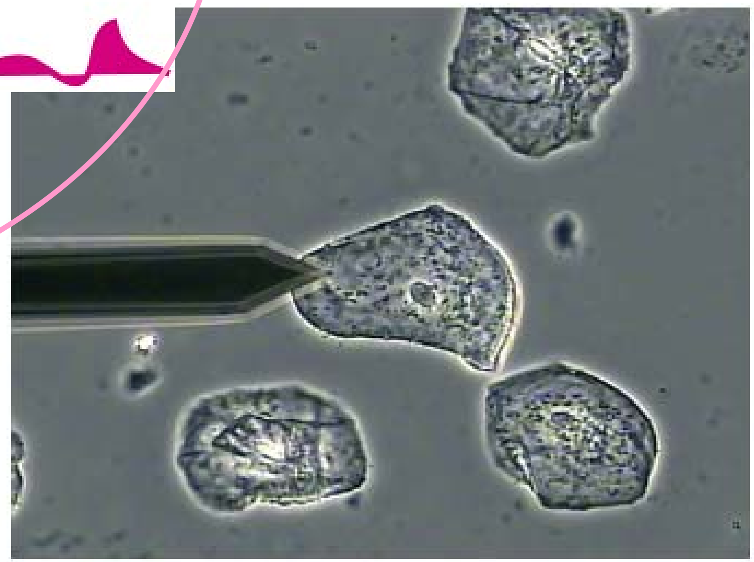
ナノプローブ顕微鏡の仕組み

原子間力顕微鏡 (AFM)



ナノプローブと試料

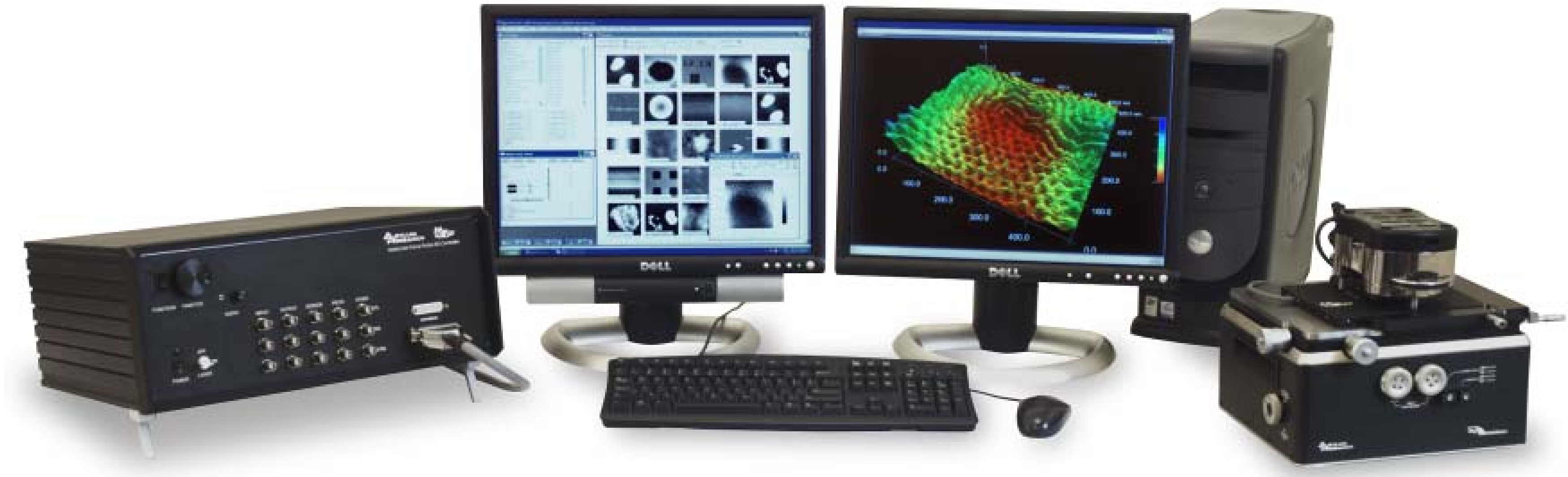




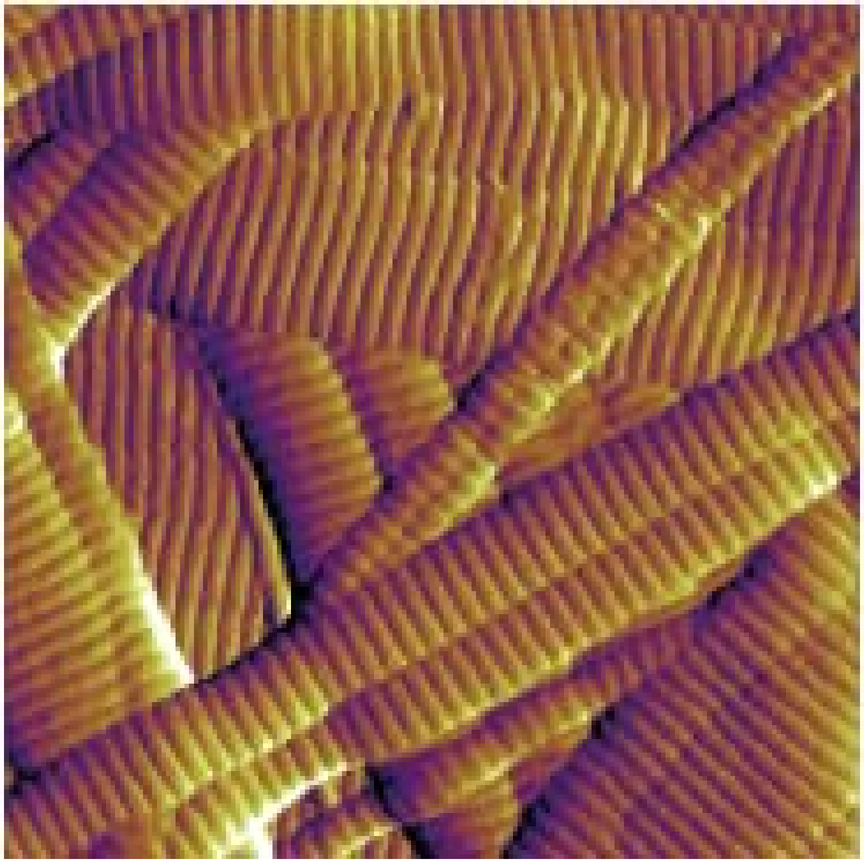
上皮細胞

アサイラム リサーチ社製　MFP−3D型
分子間力プローブ顕微鏡による

こんな装置で測定

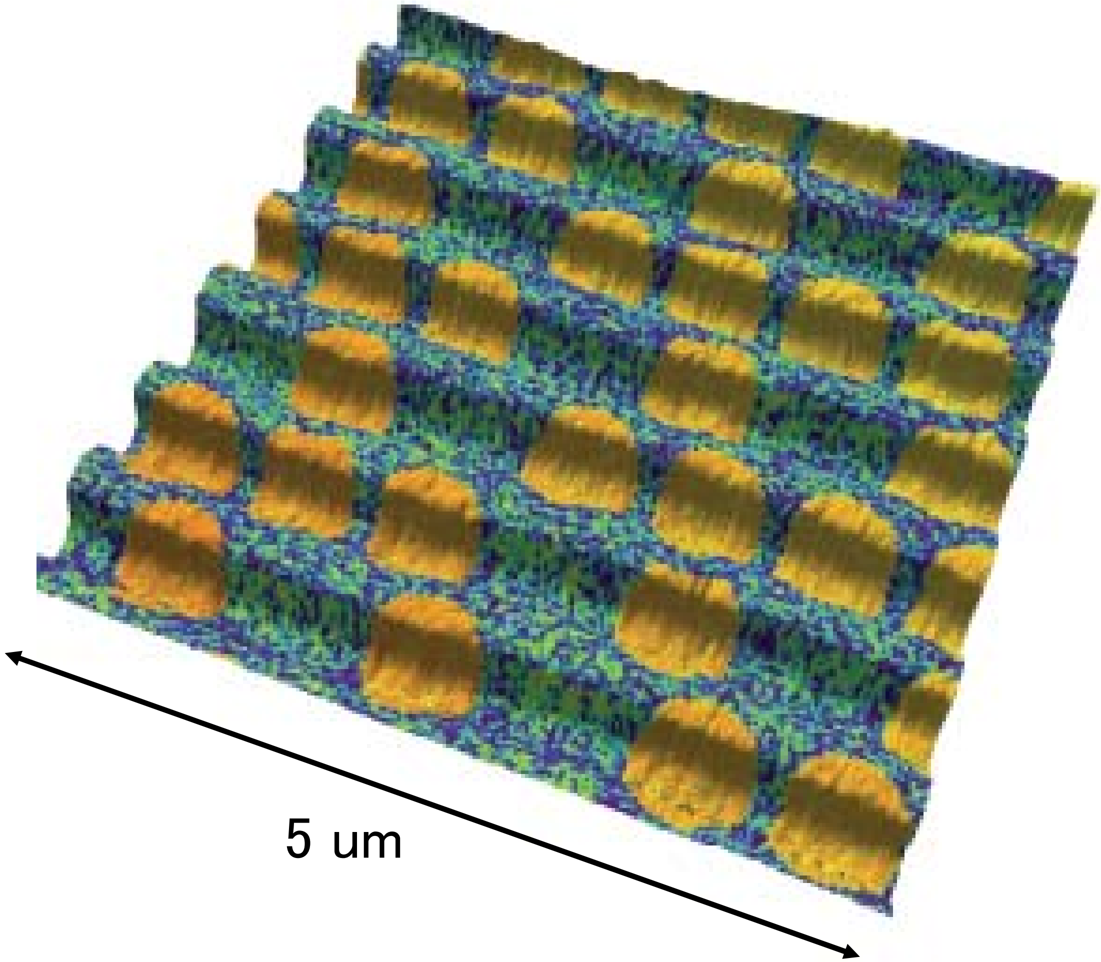


コラーゲン

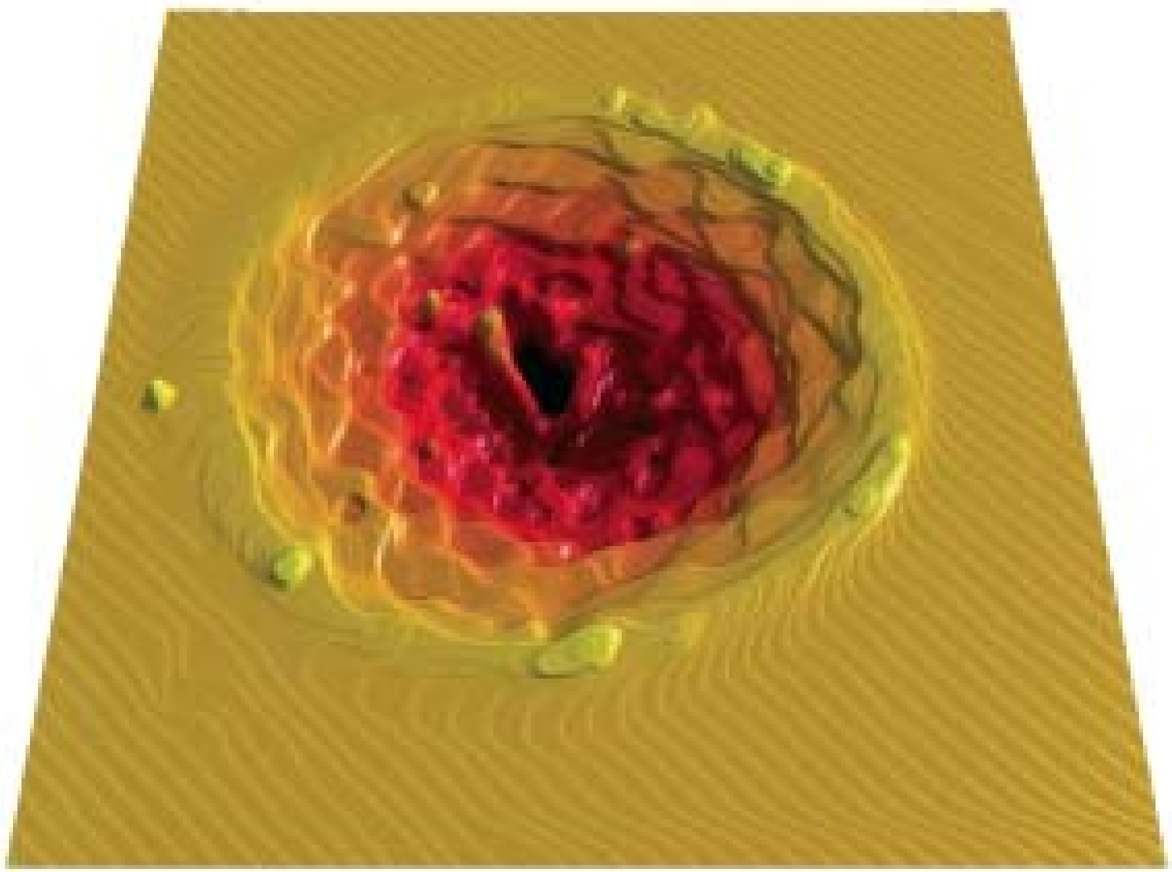


2.5 um

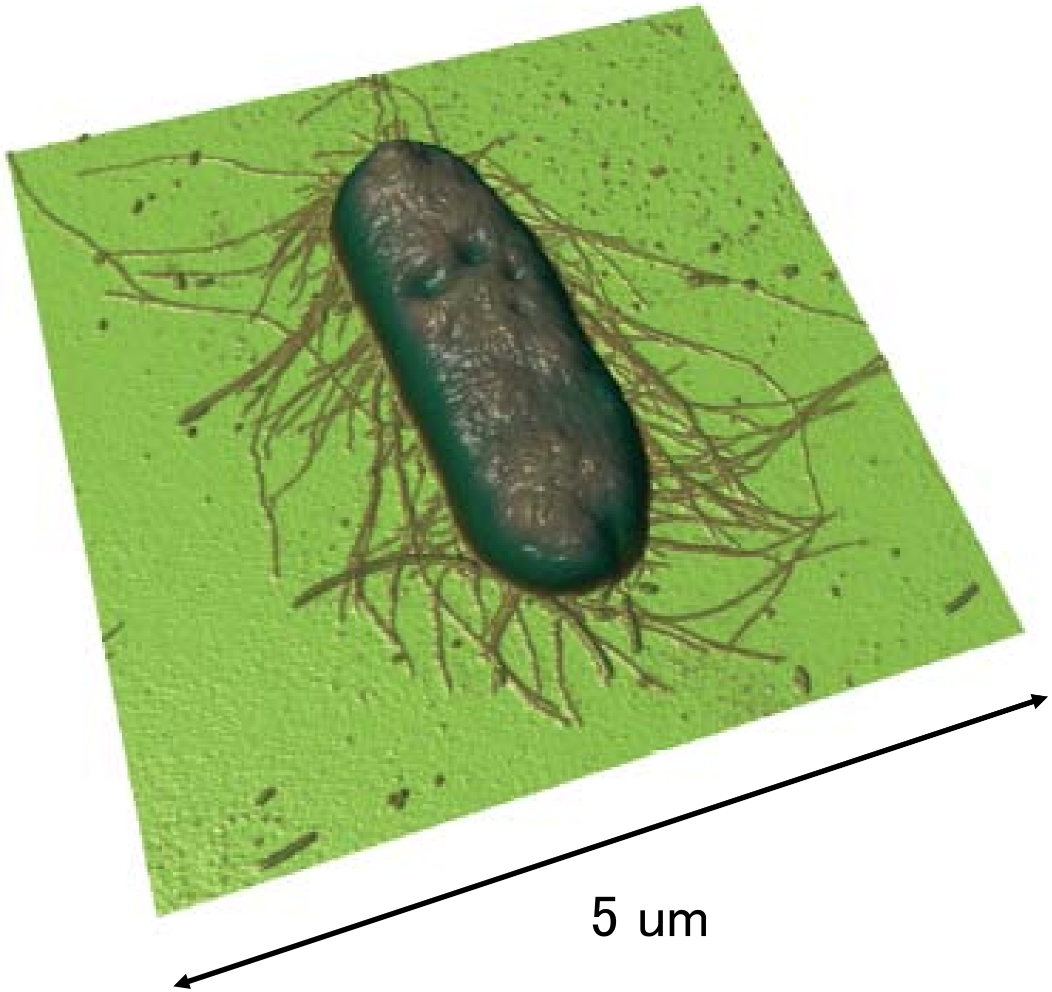
DVD メモリ



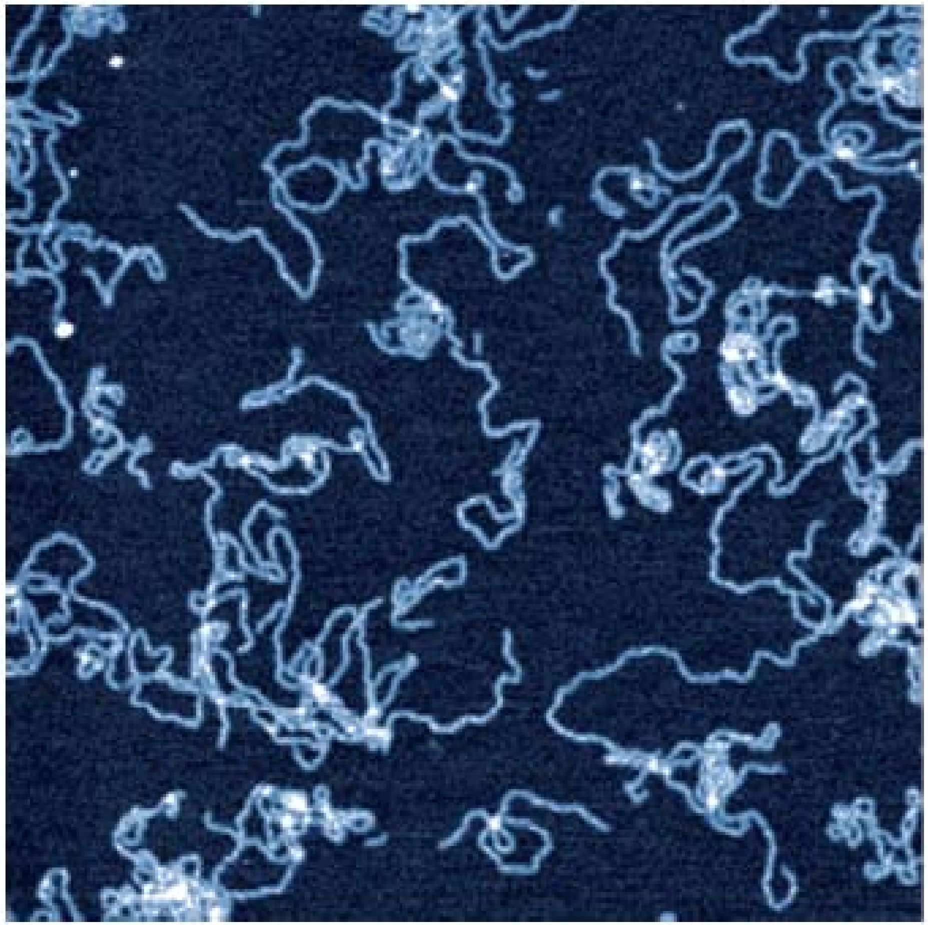
サファイア表面に
レーザーで穴をあけた



大腸菌



DNA

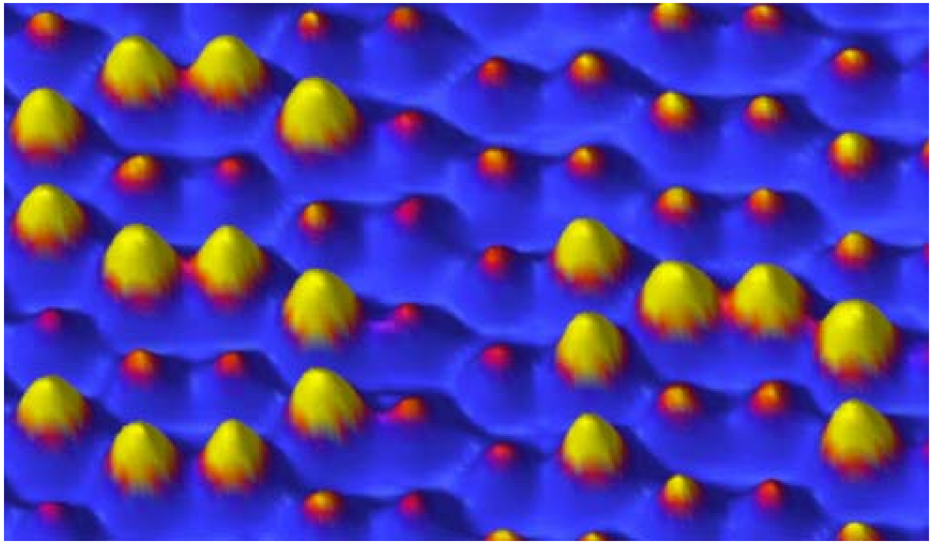


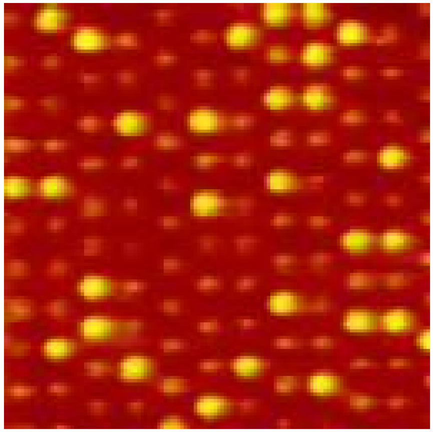
2.8 um

2.8μm scan.

Sugimoto et al. Nature material, 2007
著者の許可を得て掲載

ナノを操作する





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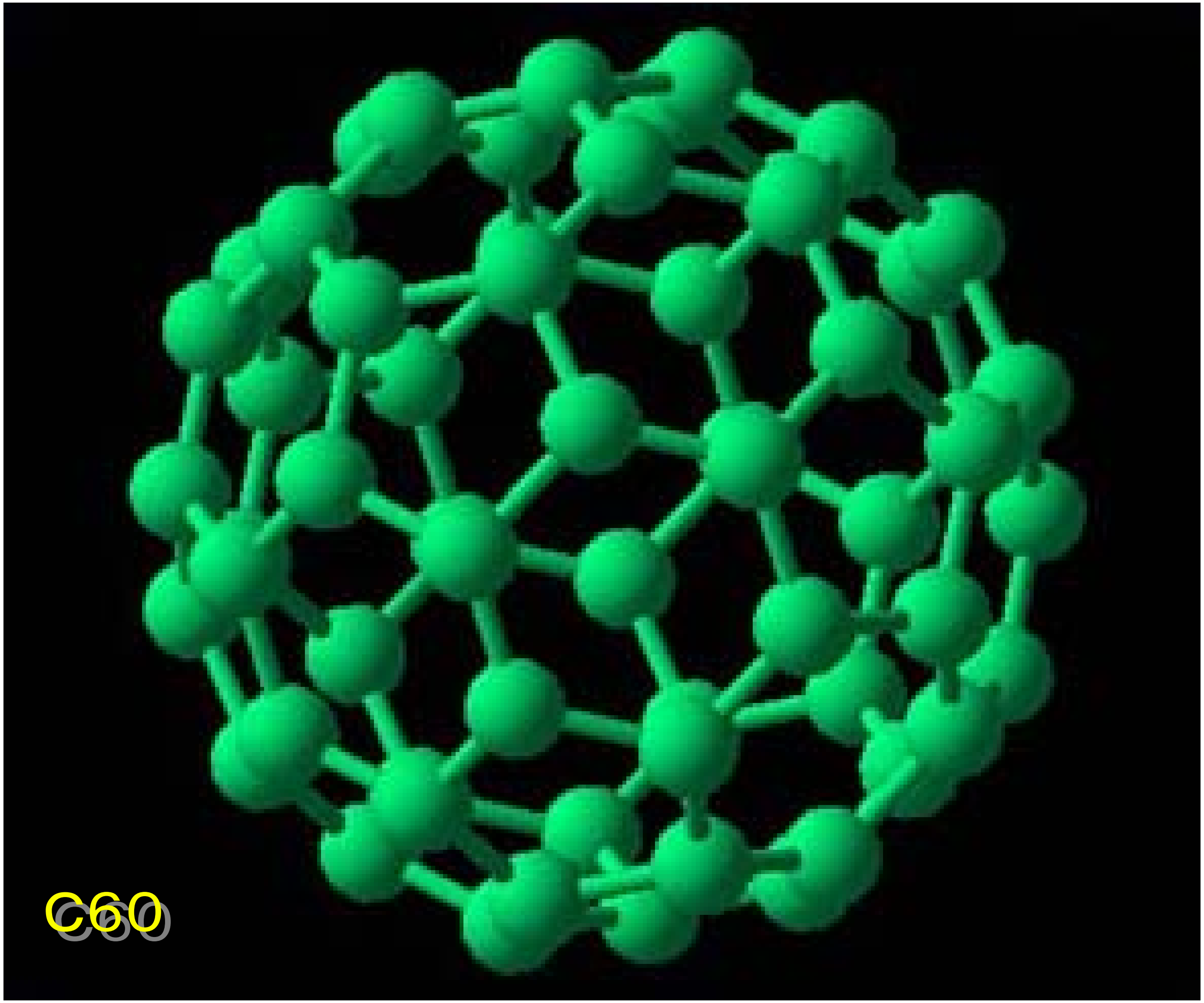
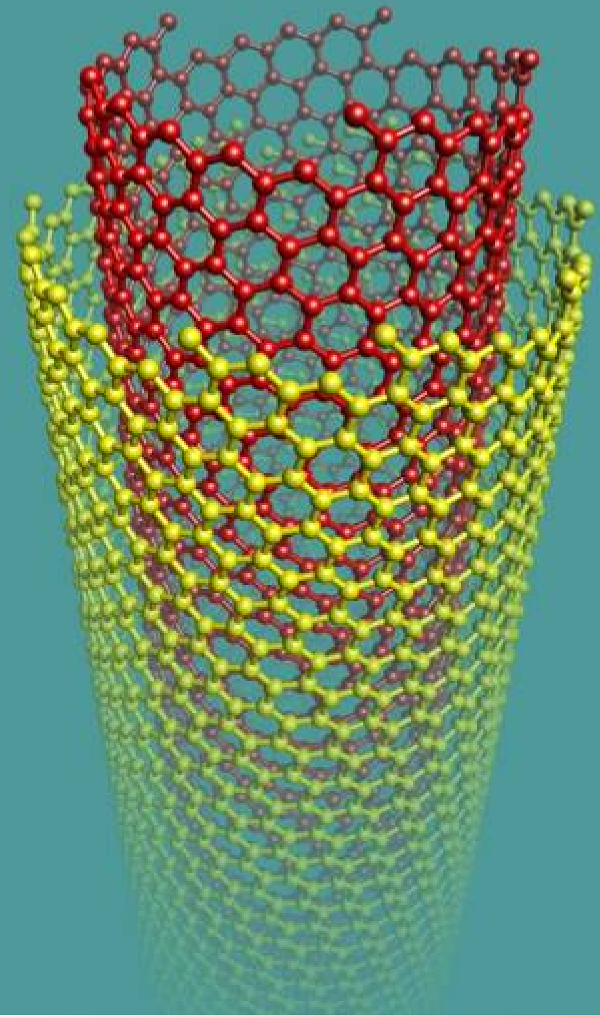
1986年　STM,AFMの発明　Binnig,　Rohrer

1996年　C_{60}の発見 Curl, Kroto, Smalley


C60

カーボンナノチューブ

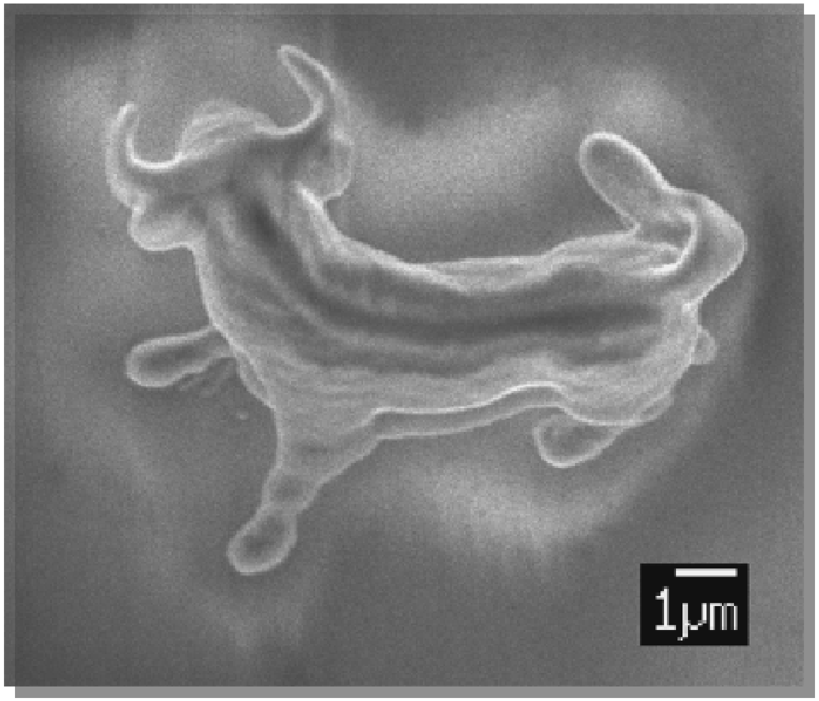


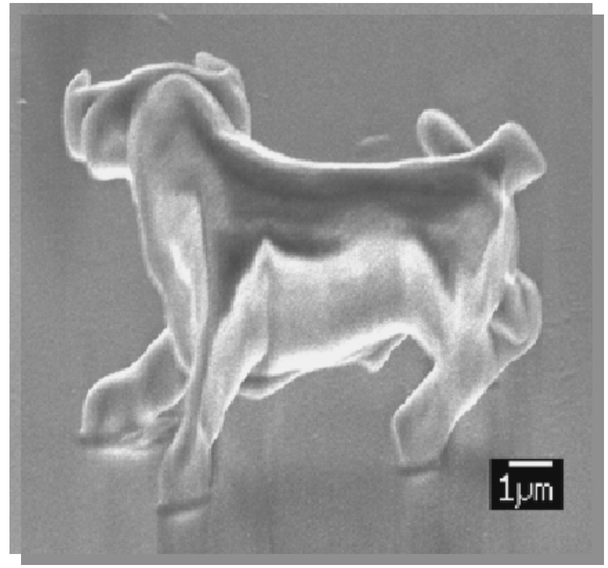
ナノテクノロジーの楽しさ

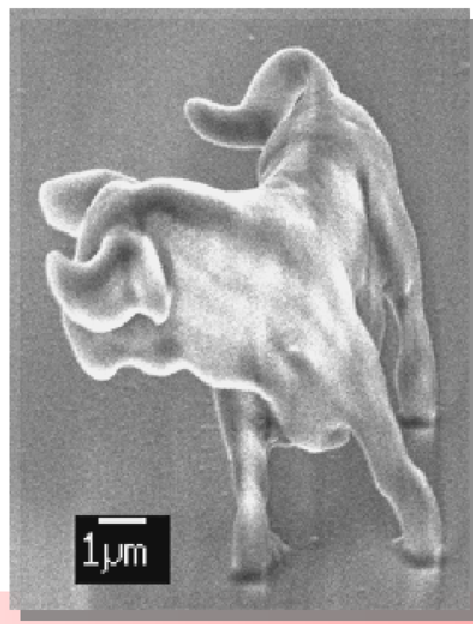
ギネスブックに載った牛

８ミクロンの牛

S. Kawata et. al. Nature, 412, 697, 2001



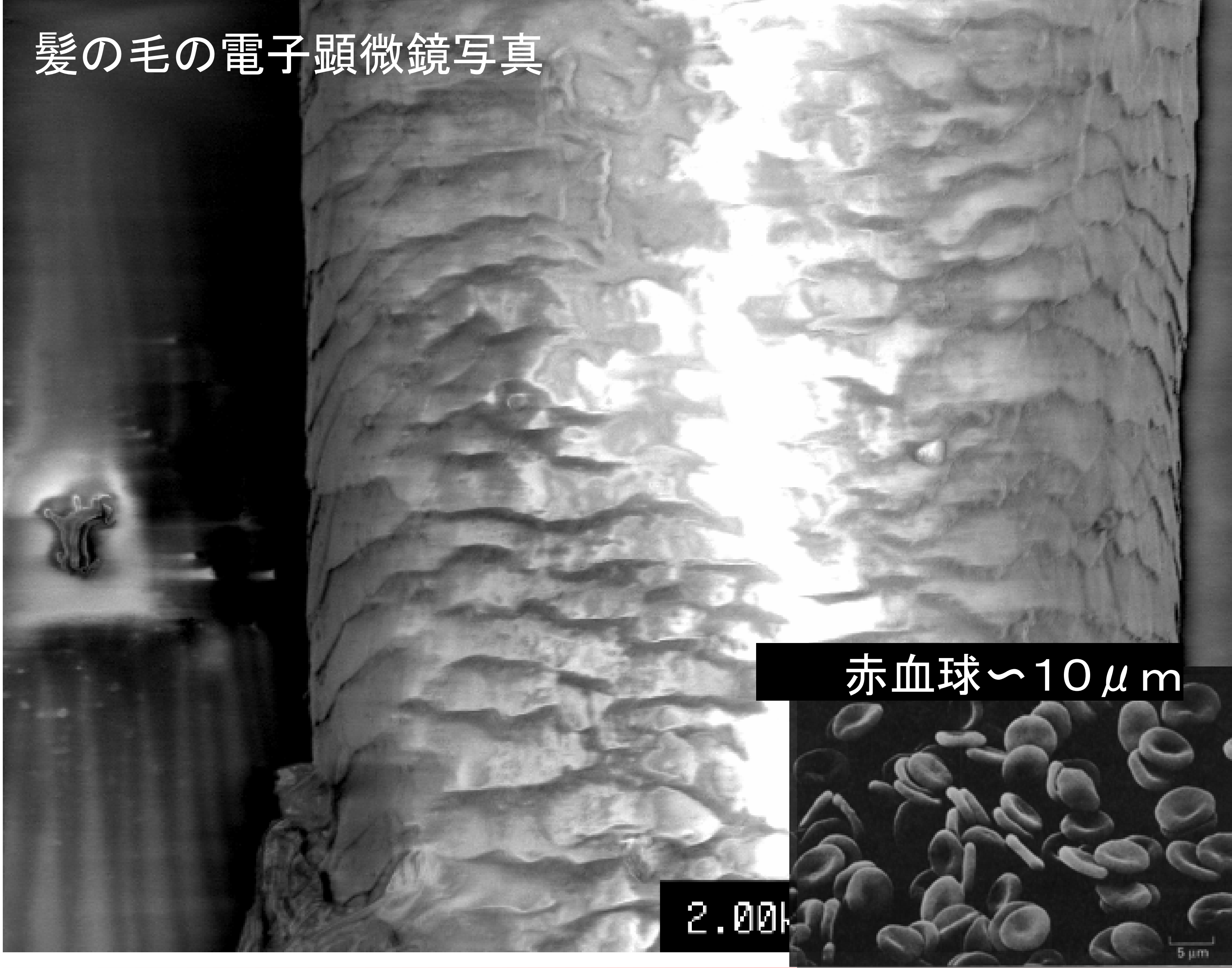




Exposure time : 1ms / spot
Scanning step : 50 nm
Time averaged power:5 mW
Total time: 13min

電子顕微鏡写真

髪の毛の電子顕微鏡写真



SMALLEST LASER SCULPTURE

On August 15 2001 researchers at Osaka University, Japan, made a three-dimensional bull (below) measuring seven thousandths of a millimeter high and ten thousandths of a millimeter long – the same size as a single red blood cell. The bull was sculpted from resin with two focused laser beams using a technique called two-photon micropolymerization. The bull is so small that 30 of them could be placed side by side across the period at the end of this sentence.

DARKEST MAN-MADE SUBSTANCE

The darkest man-made substance is a black coating composed of a nickel-phosphorus alloy. It reflects just 0.16% of visible light, around 25 times less than conventional black paint. The principle was first developed by researchers in the USA and India in 1980. In 1990 Anritsu (Japan) further refined this method to produce the darkest version so far.

SMALLEST PIECE OF ICE

The smallest piece of ice was created by Roger Miller and Klaus Nauta of the University of North Carolina, USA, in 1999. Consisting of just six water molecules arranged in a hexagon, the ice crystal is the smallest theoretically possible, as a minimum of six molecules are required for the formation of ice. In comparison, the average water droplet contains around 100,000,000,000,000,000,000 molecules of water.

LARGEST VACUUM CHAMBER

The Space Power Facility at NASA's Glenn Research Center, Plum Brook Station, Sandusky, Ohio, USA, measures 100 ft (30.4 m) in diameter and 122 ft (37 m) in height. It can sustain a high vacuum of 10[illegible] torr and simulate solar radiation using a 4 megawatt quartz heat-lamp array, as well as temperatures as low as -320°F (-195.5°C). It is used to test the performance of spacecraft and space hardware prior to launch.

SMALLEST THERMOMETER

On February 7 2002, Yihua Gao and Yoshio Bando (both Japan) of the National Institute for Materials Science announced that they had created a thermometer from a single carbon nanotube. Measuring just 75 nanometers wide (one nanometer equals one billionth of a meter) and with a length of around 10,000 nanometers, the tube contains liquid gallium with linear expansion properties that allow the measurement of a wide range of temperatures, from 122–932°F (50–500°C).

SHORTEST FLASH OF LIGHT

On August 16 2002, a team of European physicists, led by Ferenc Krausz at the Vienna Institute of Technology, Austria, announced that they had created bursts of X-ray light lasting just 500 billion billionths of a second (or 500 attoseconds). The technique will allow detailed studies of how electrons behave within atoms.

HEAVIEST ELEMENT

The undisputed heaviest chemical element discovered to date is 110. Its 'discovery' was reported on November 19 1994 by researchers at the Heavy Ion Research Center at Darmstadt, Germany. They used an ion accelerator to bombard lead atoms with nickel nuclei to create the new element, which existed for less than one thousandth of a second before decaying into lighter elements. The name darmstadtium (with the symbol Ds) has been proposed, following the tradition of naming elements after their place of discovery.

LONGEST RUNNING AGRICULTURAL EXPERIMENT

The Broadbalk Experiment, Rothamsted, Hertfordshire, UK, which aims to measure the effects of fertilizer on crops, has continuous data from 1843 to the present day.

MOST POWERFUL PULSED NEUTRON SOURCE

ISIS, at the Rutherford Appleton Laboratory, Chilton, Oxfordshire, UK, is the world's most powerful pulsed neutron source. Covering the size of a football field, it produces 4 x 10[illegible] fast neutro… second. These are focused in… beams in a 'neutron microsc… allowing scientists to study, … microscopic scale, the atomic … molecular arrangements that … materials their unique propert…

DEEPEST OPERATIN… NEUTRINO OBSERVA…

The Sudbury Neutrino Obs… (above) is located 6,800 ft … below ground in the Inco C… Mine, Ontario, Canada. It … of a 39-ft-diameter (2-m) … containing around 1.9 mi… (900 tonnes) of heavy wat… It is designed to detect ne… the neutral particles produc… nuclear fusion in the Sun. The depth of the observato… facilitates detection.

Guinness World Record 2004

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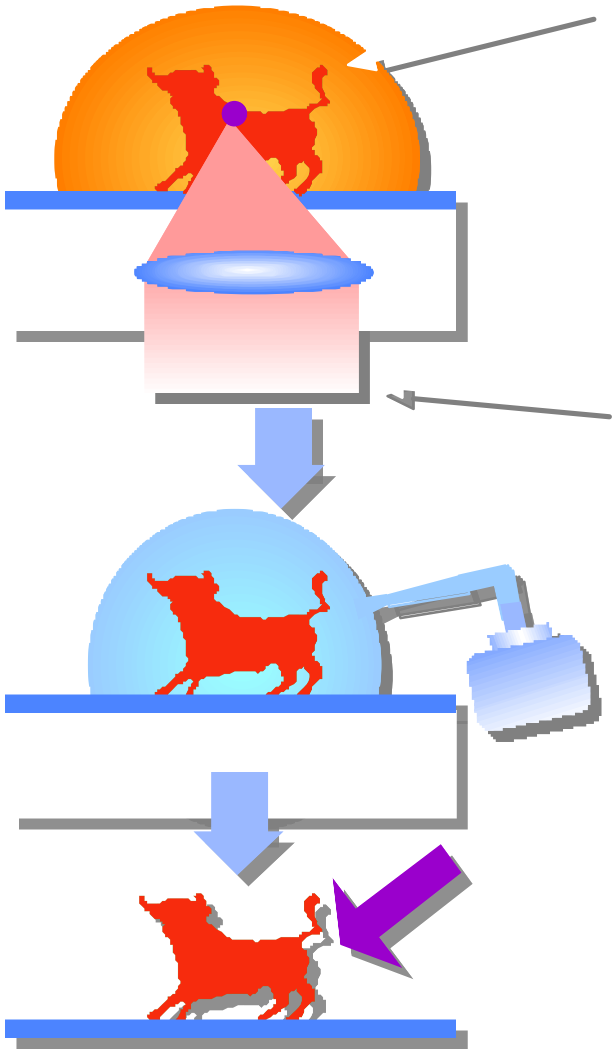
On August 15 2001 researchers at Osaka University, Japan, made a three-dimensional bull (below) measuring seven thousandths of a millimeter high and ten thousandths of a millimeter long – the same size as a single red blood cell. The bull was sculpted from resin with two focused laser beams using a technique called two-photon micropolymerization. The bull is so small that 30 of them could be placed side by side across the period at the end of this sentence.

Guinness World Record 2004



光硬化性樹脂

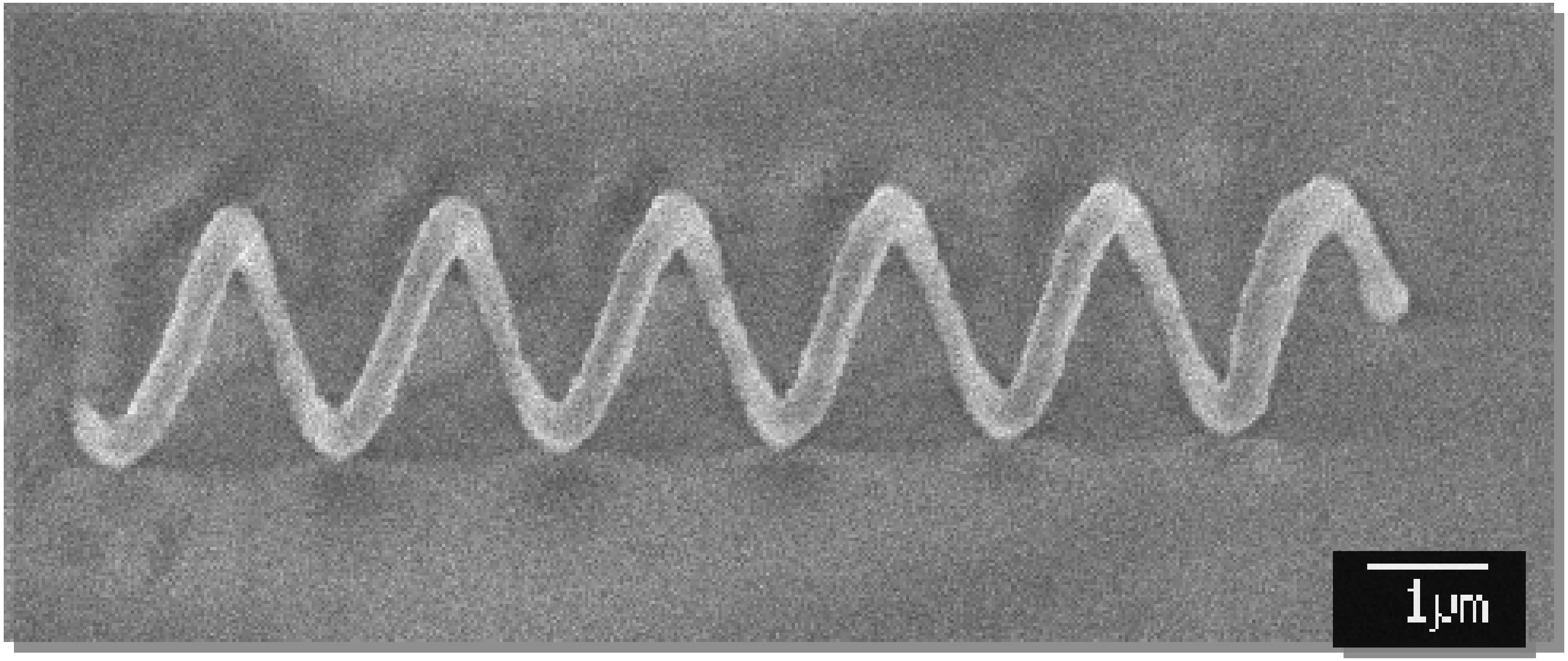
牛の形にフェムト秒近赤外光レーザーを走査

硬化していない樹脂を薬品で溶解

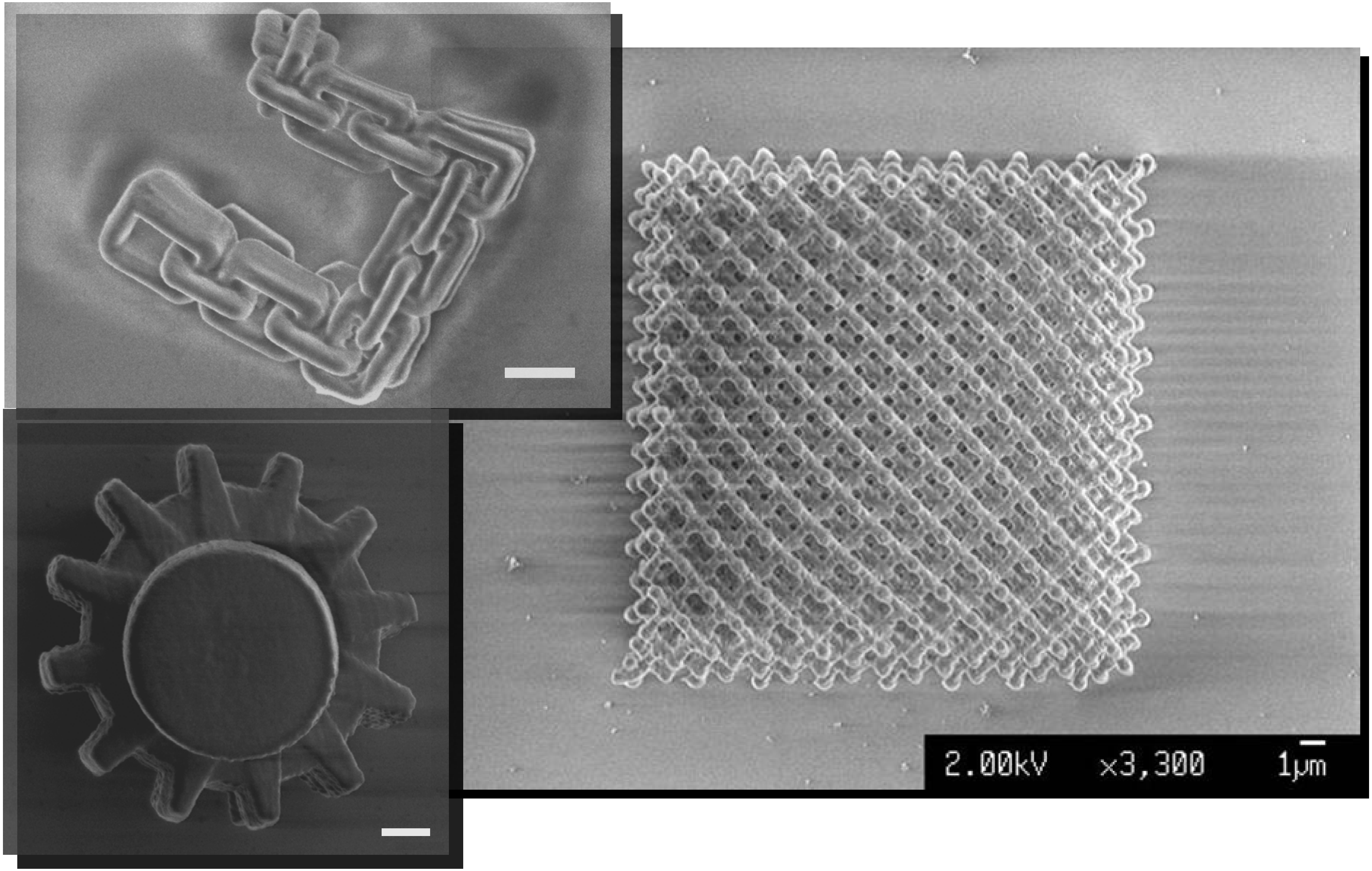
紫外光をあてて、牛の内部まで硬化させる

S. Kawata et. al. Nature, 412, 697, 2001

Functioning of structures: 2μm spring

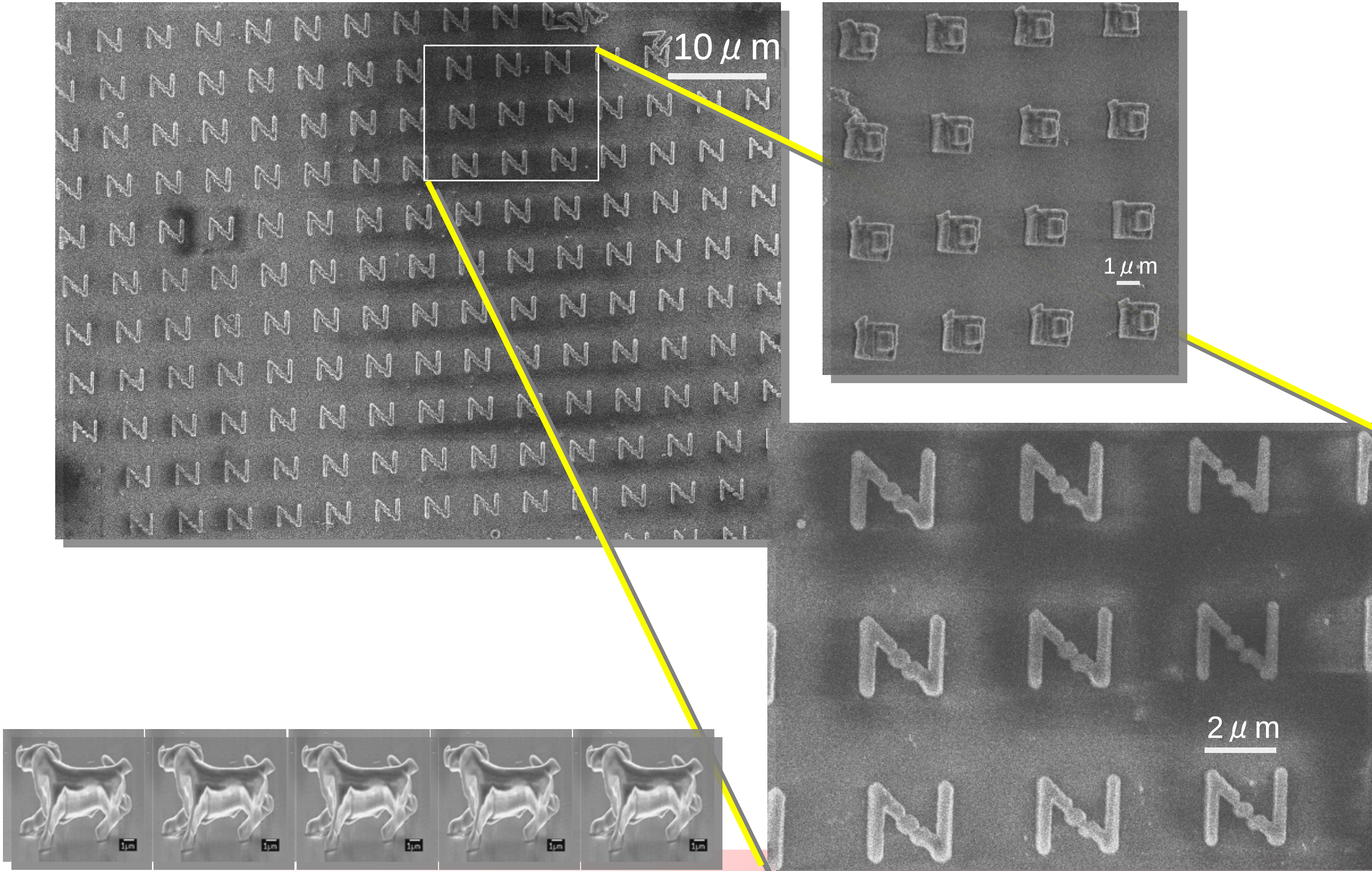


光学顕微鏡像

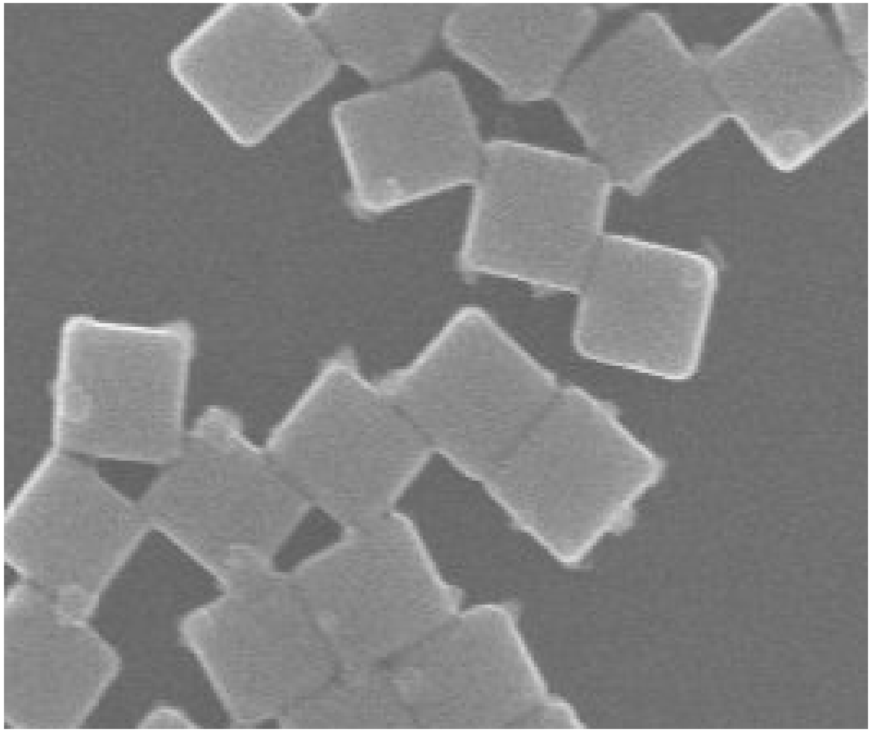

2.00kV ×3,300 1μm

Mass-production of micro-bulls

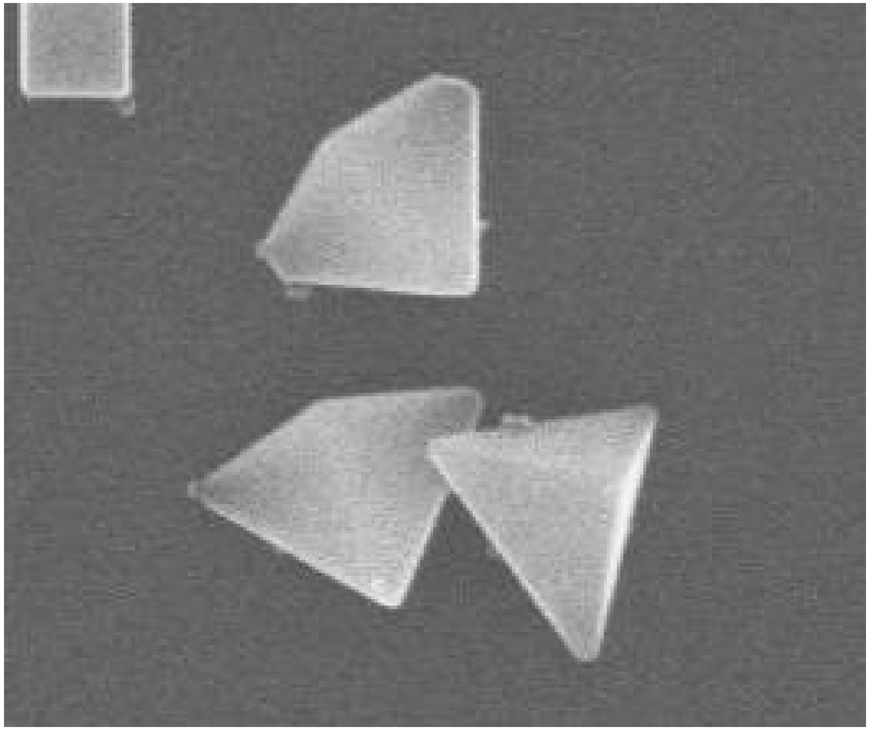
Adachi, Kato, Kawata,
submitted Jpn Patent



ナノサイズの銀結晶



立方体 (150 nm)



双三角錐 (200 nm)

銀の原子が集まって自己組織化した

銀の結晶の”色”

全て銀

サイズや形状によって色が変わる

ナノテクノロジー

は

現代の錬金術

ナノテクノロジーの楽しさ

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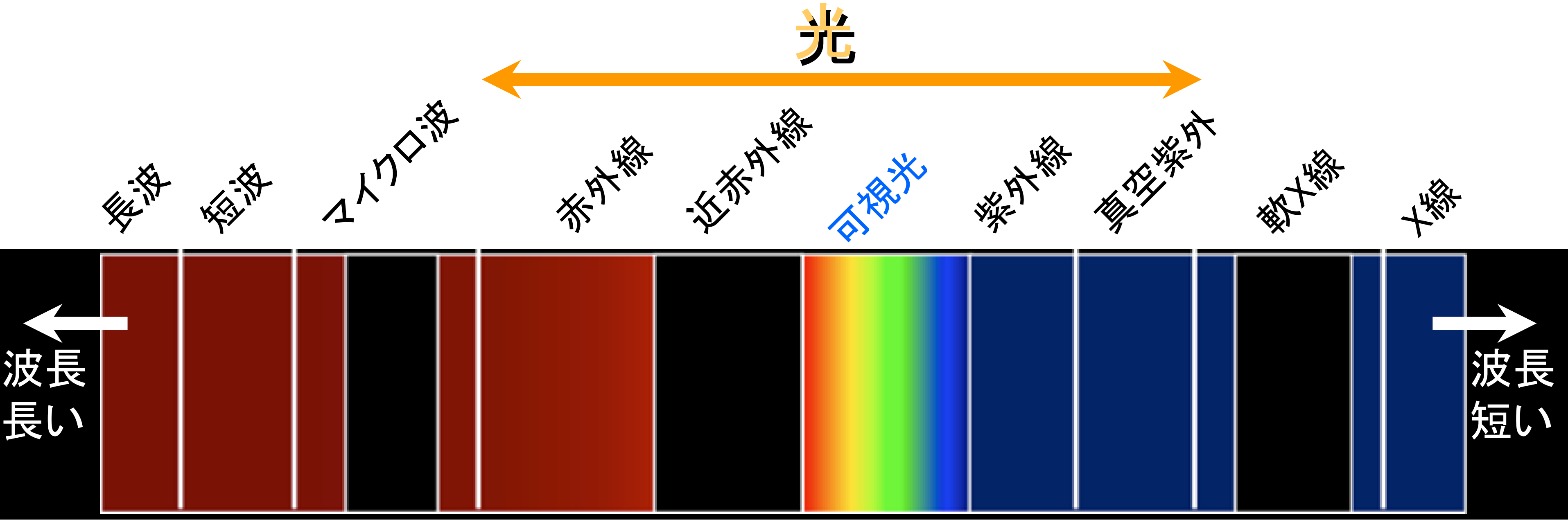
光とは？　･･･電磁波



光の波長：100 nm ～100 μm
（可視光：400 nm ～ 700 nm）

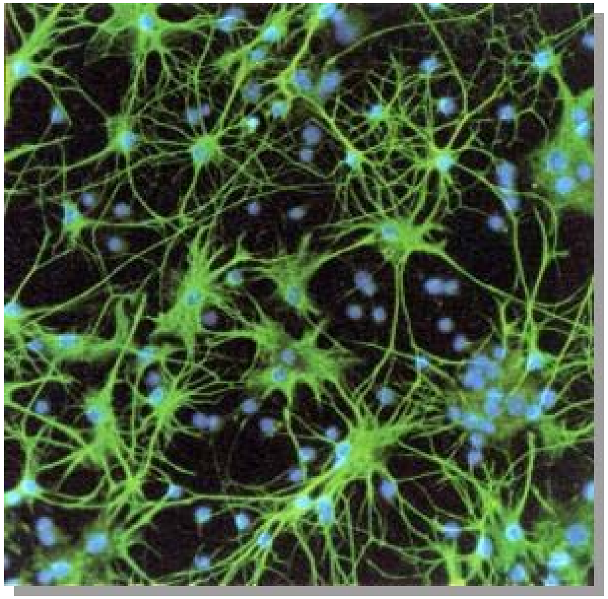
電子レンジの波長：10 cm

FMラジオ電波の波長：3 ～ 4 m

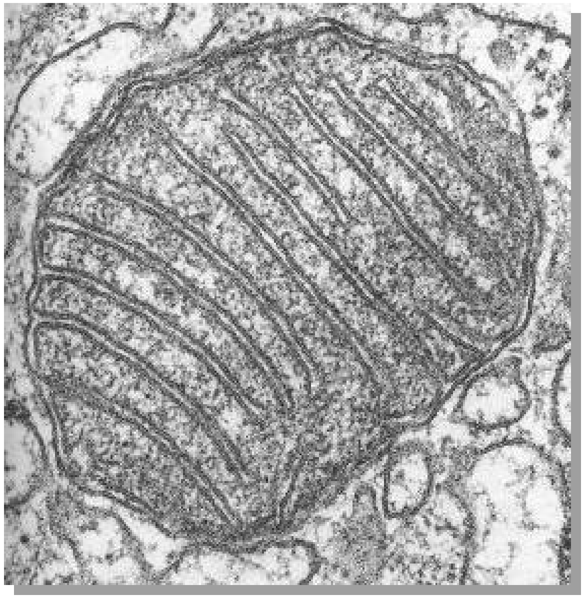
AFラジオ電波の波長：200 ～ 600 m

光で物を見るということはどういうことか

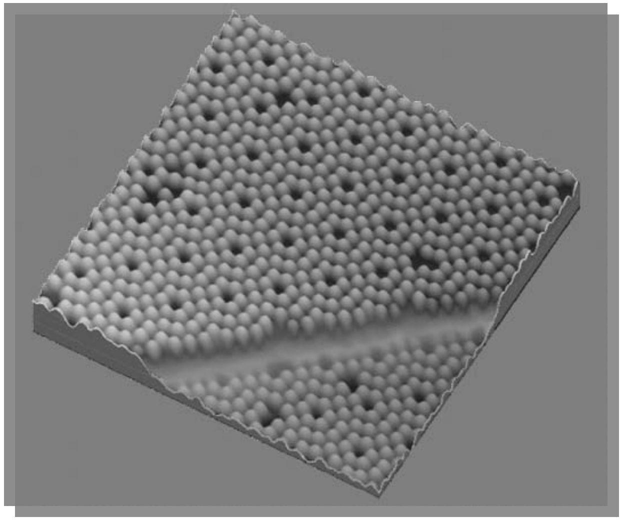
光学顕微鏡像



電子顕微鏡像

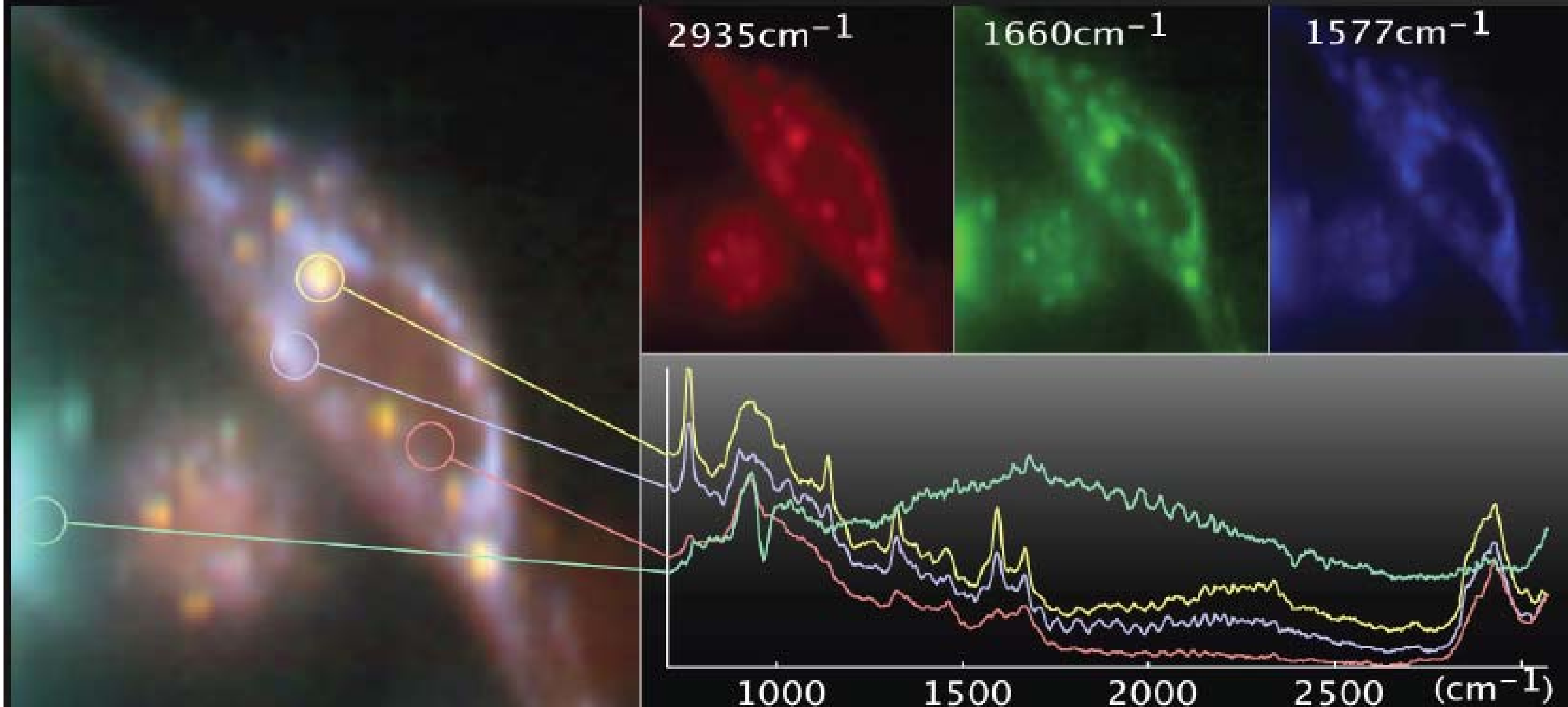


走査トンネル顕微鏡像



カラーの画像 =
物質（分子や結晶）の情報

白黒の画像 ＝ 濃度、高さの情報

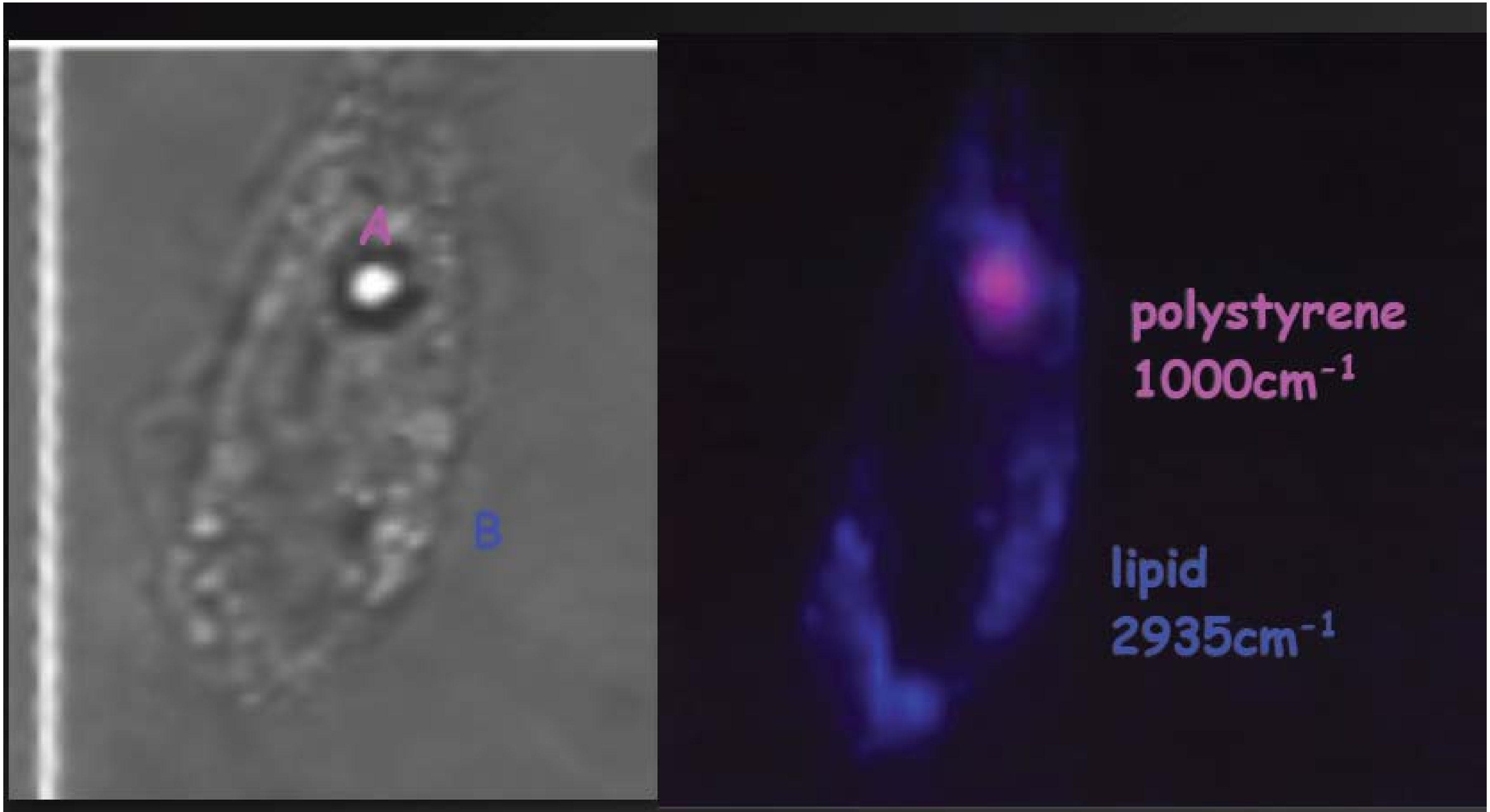


ラット心筋細胞のラマン観察像

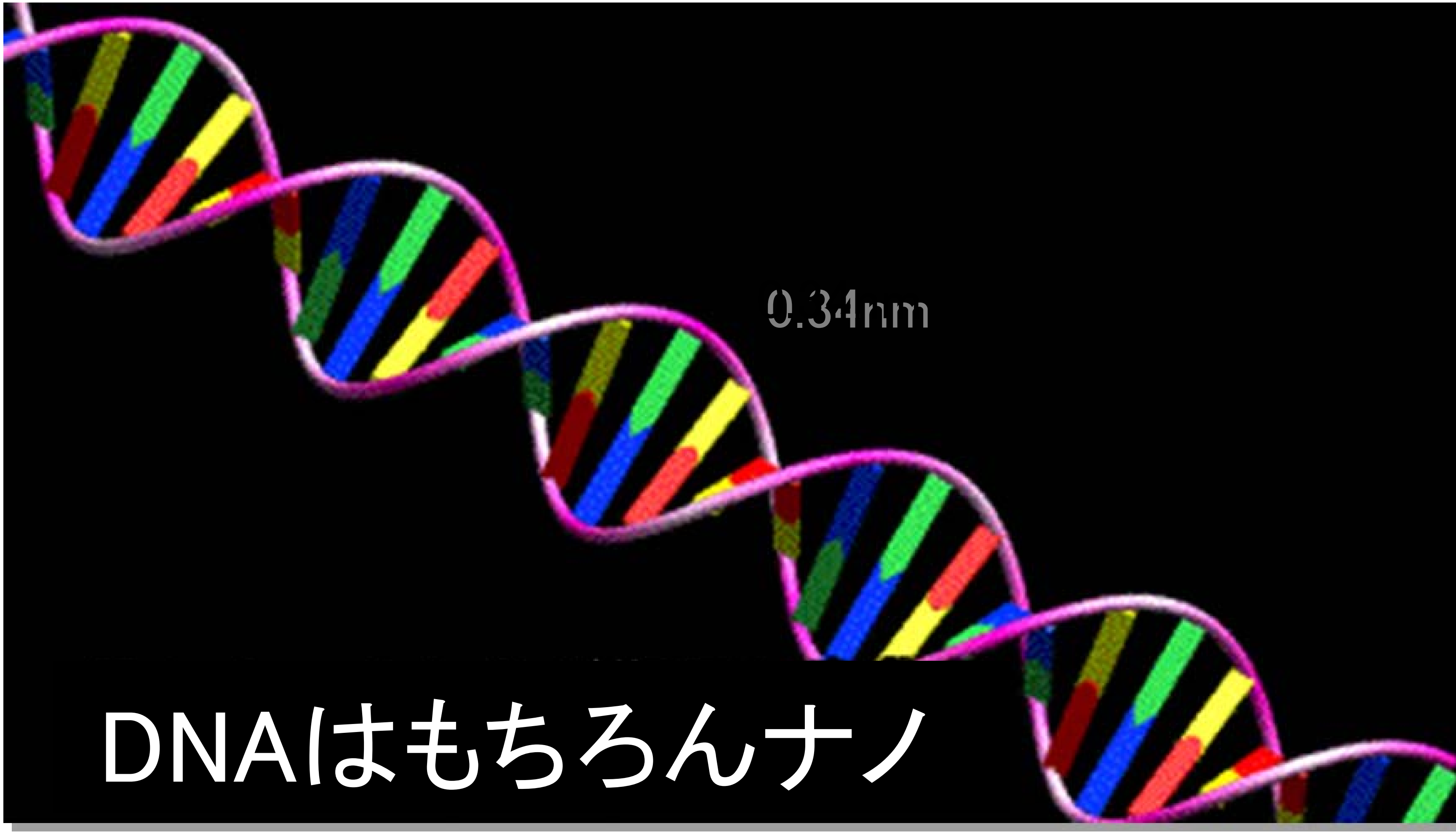
赤＝2935＝脂質

緑＝1660＝蛋白

青＝1577＝グアニンアデニン



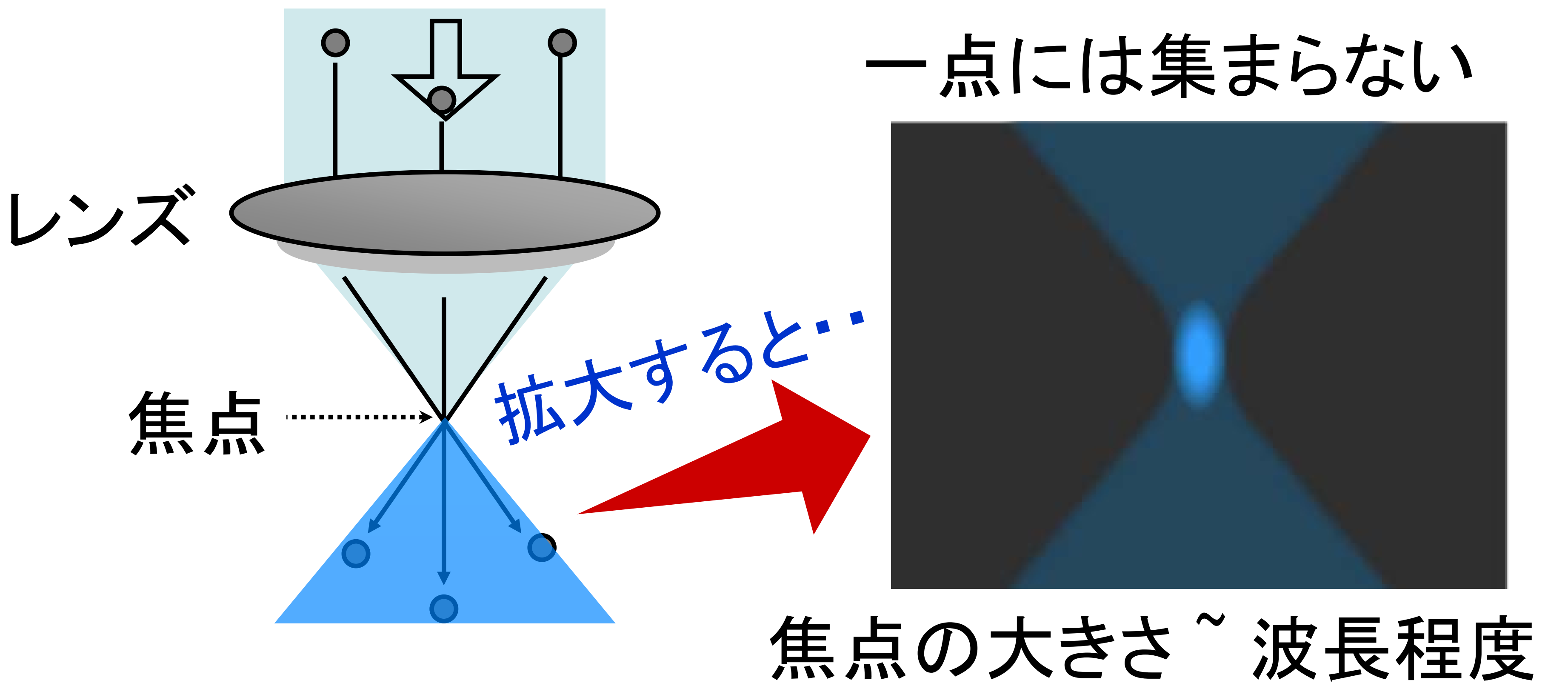
Leukocyte (phagocytosis with a polystyrene bead)



DNAはもちろんナノ

波長よりも小さいものを見ることができない

可視光の波長 ~ 400 – 700 nm >> “ナノ”

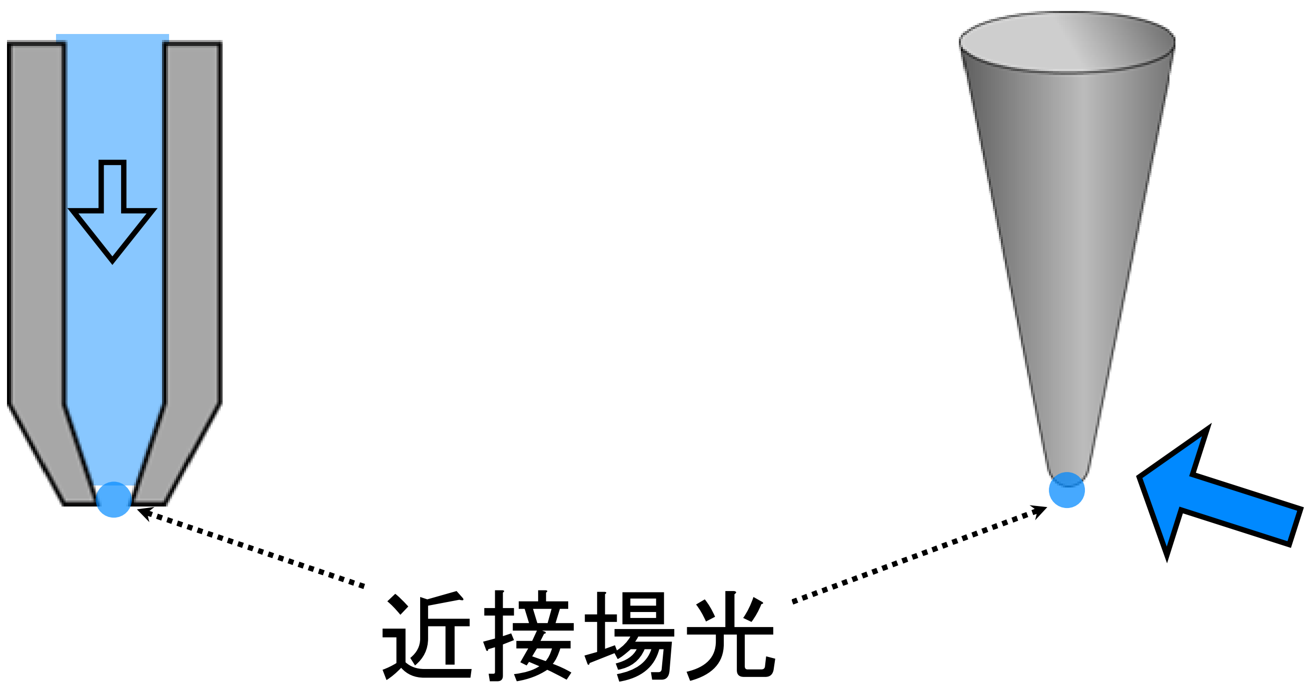


光でナノを観るにはどうすればいいか？

⇒　別の方法で小さい光をムリヤリ作る

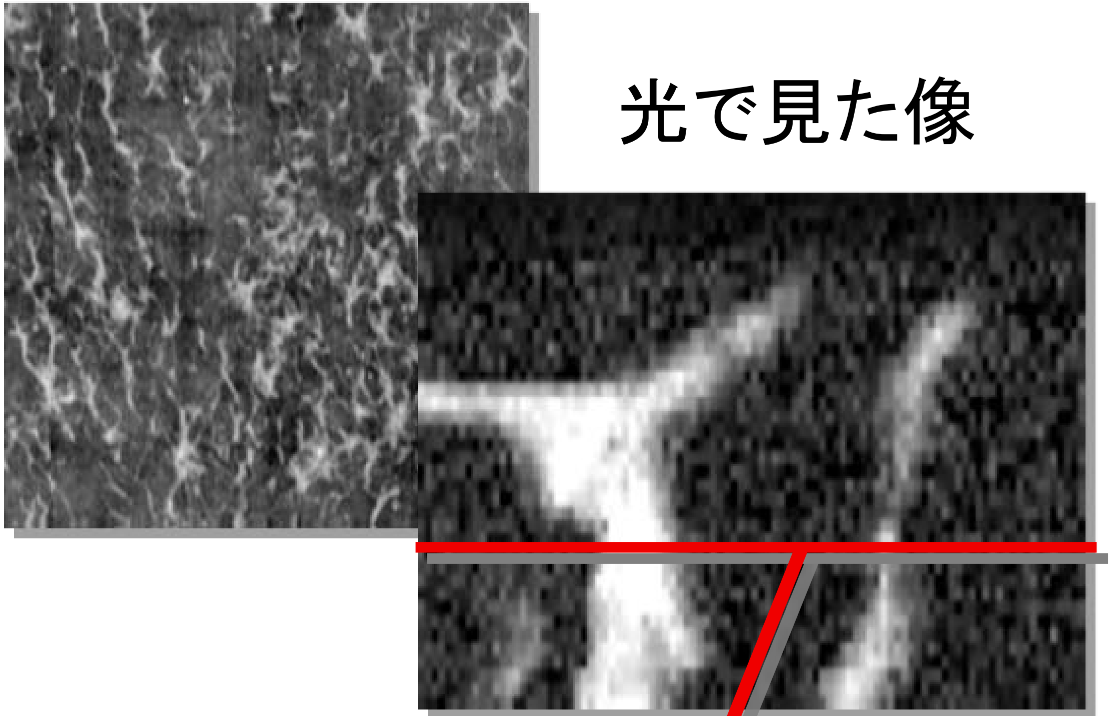
小さい穴を通して光を出すか、

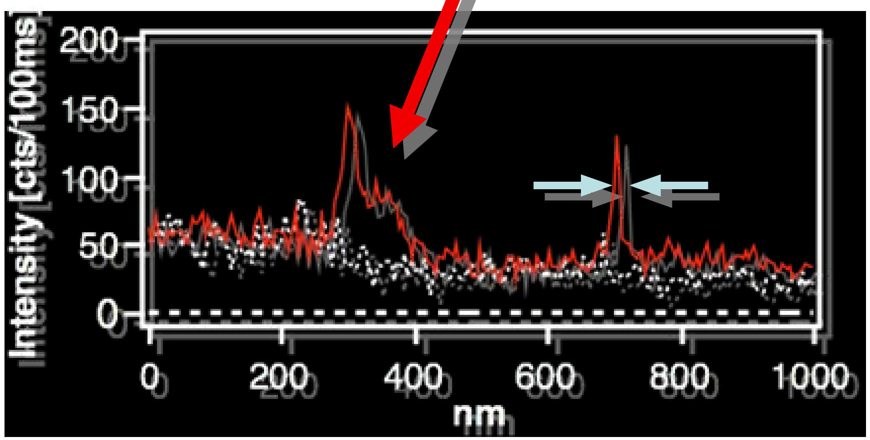
針先に光を当てて光を散乱するか、



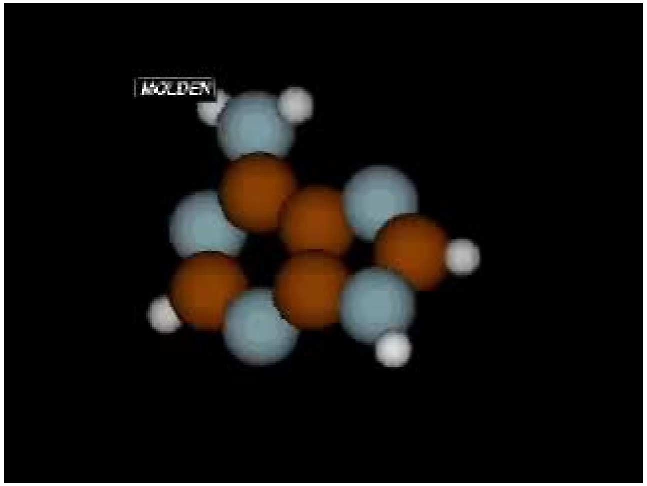
光でナノが見えてきた

光で見た像

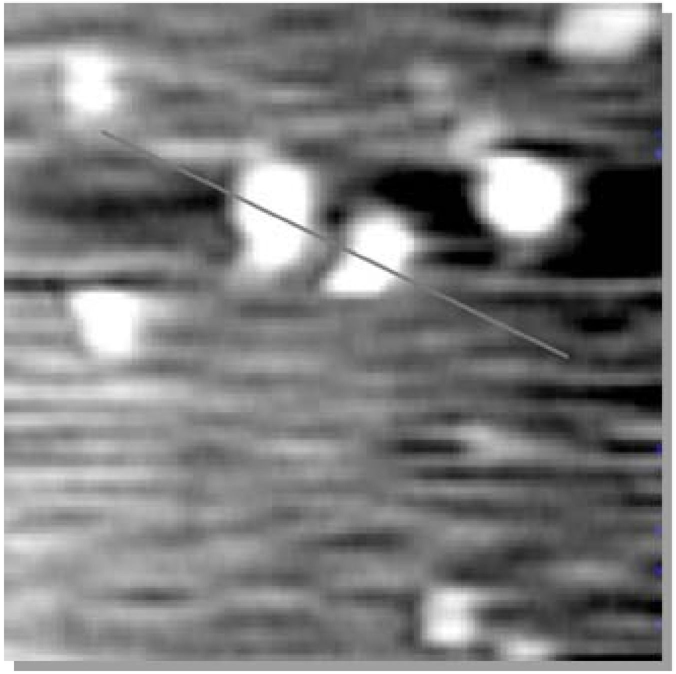


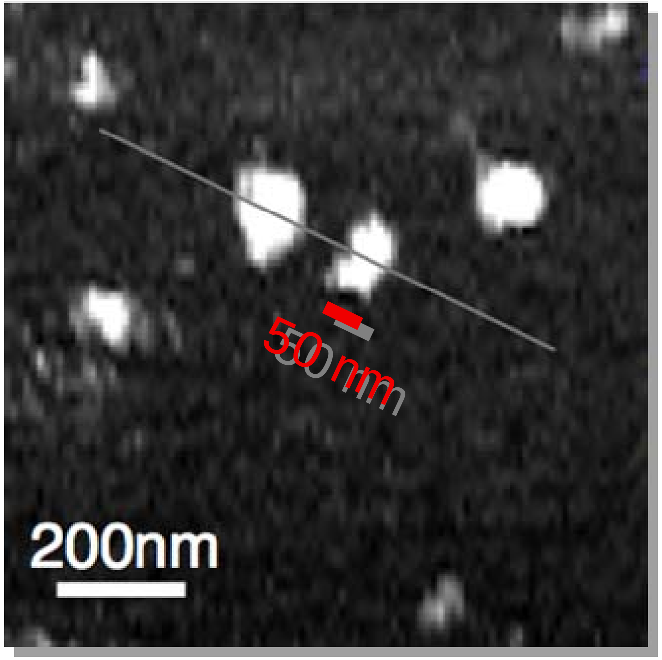


アデニンの分布を観察



波長800 nmの光で、
15nmが見えた。



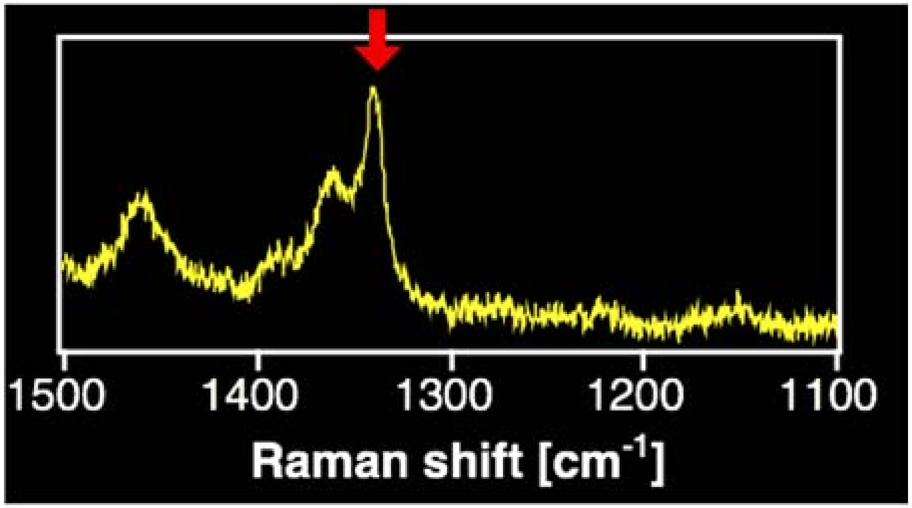


AFM 1μmx1μm

DNAのクラスター

w1: 30μW w2: 15μW
Rep.Rate: 800kHz
15min/image

C=N stretching mode of diazole



ナノテクノロジーの楽しさ

１　身近なナノテクノロジー

２　ナノとは？

３　100年に一度の大革命：STM・AFMの発明

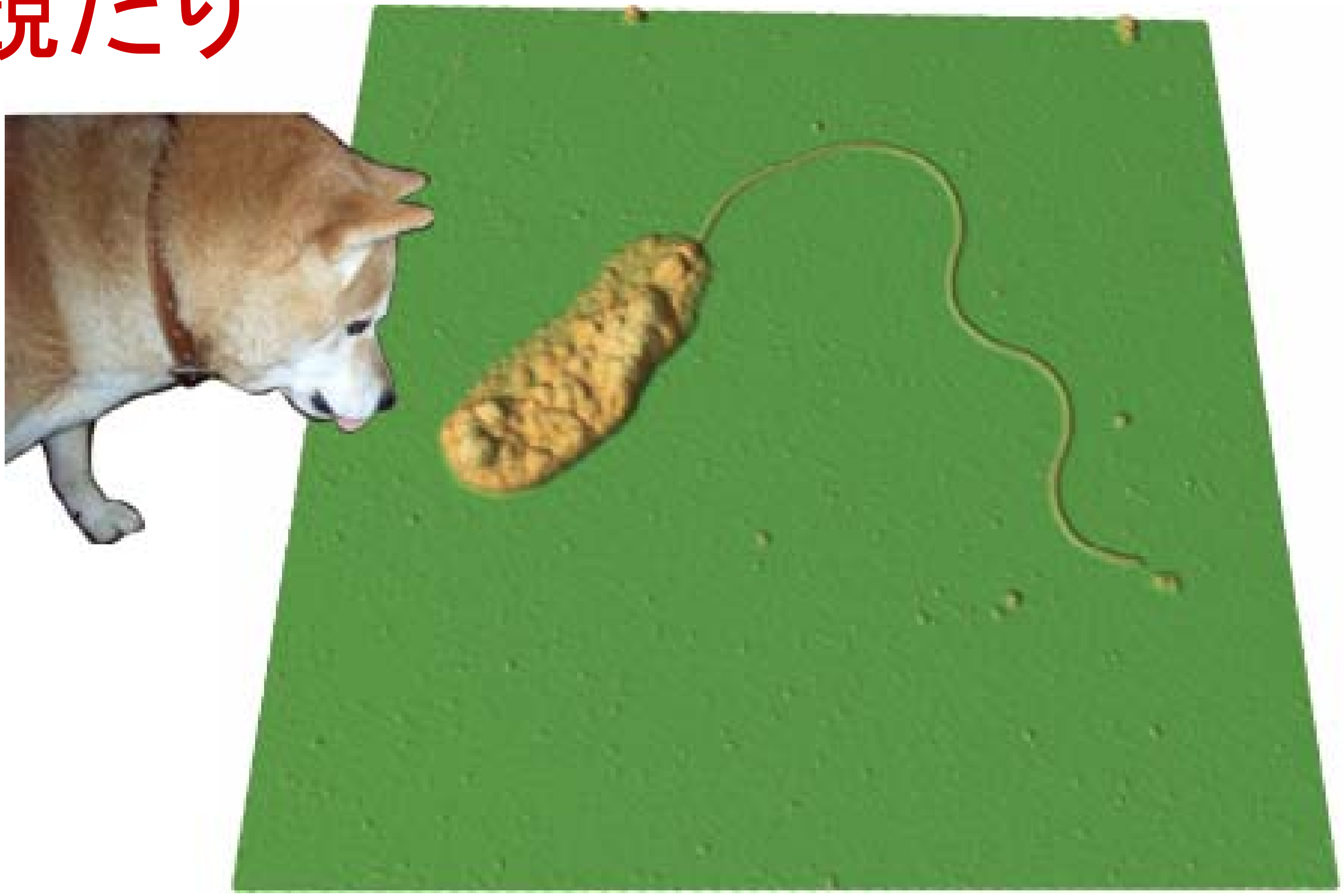
４　ナノ材料を作る

５　光とナノ

６　ナノテクノロジーの夢

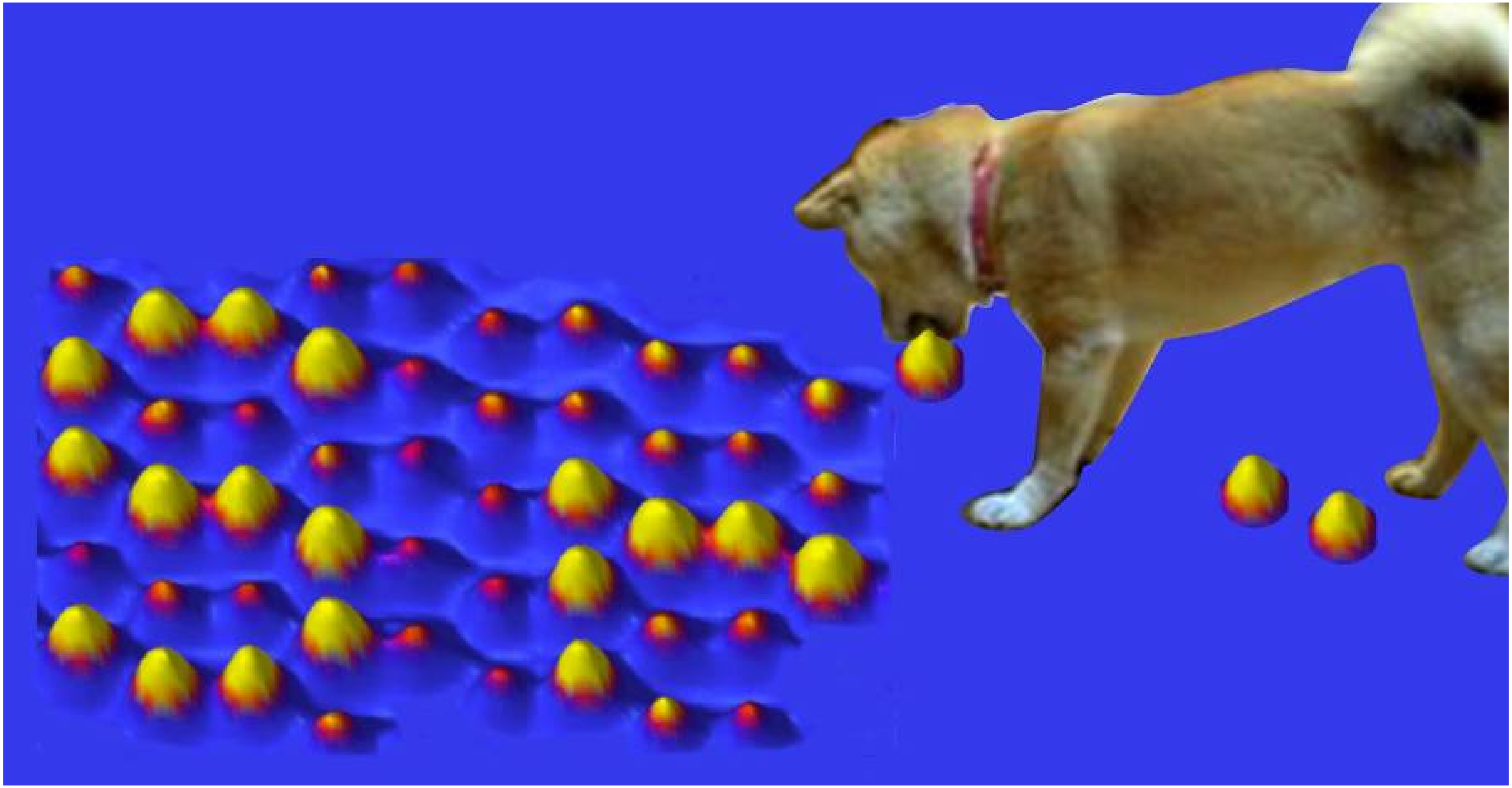
小型化

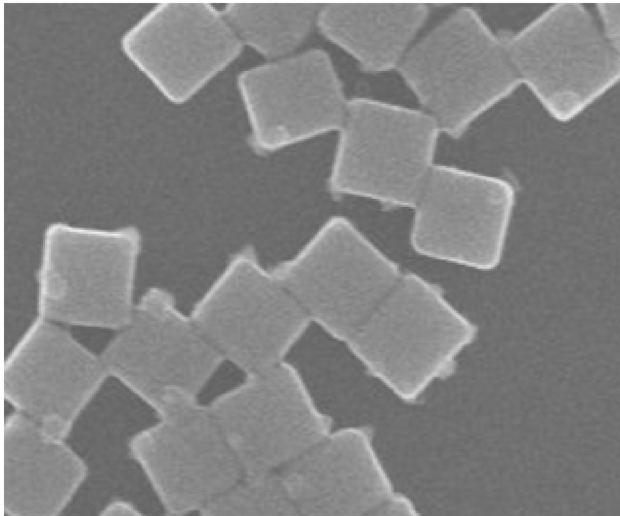
いつでも好きなときに
ナノを観たり

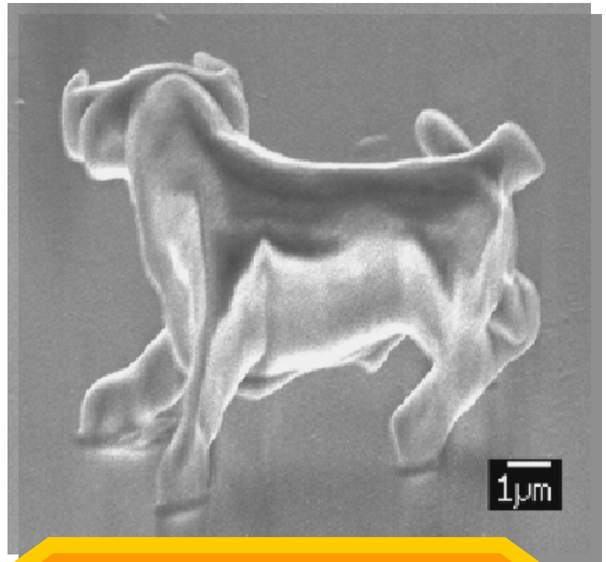


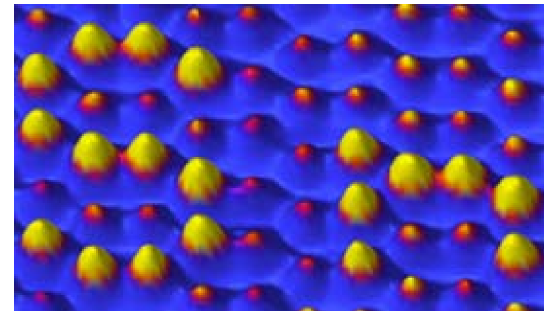
マイカの上のバクテリア

自由にナノを操作すること









nano