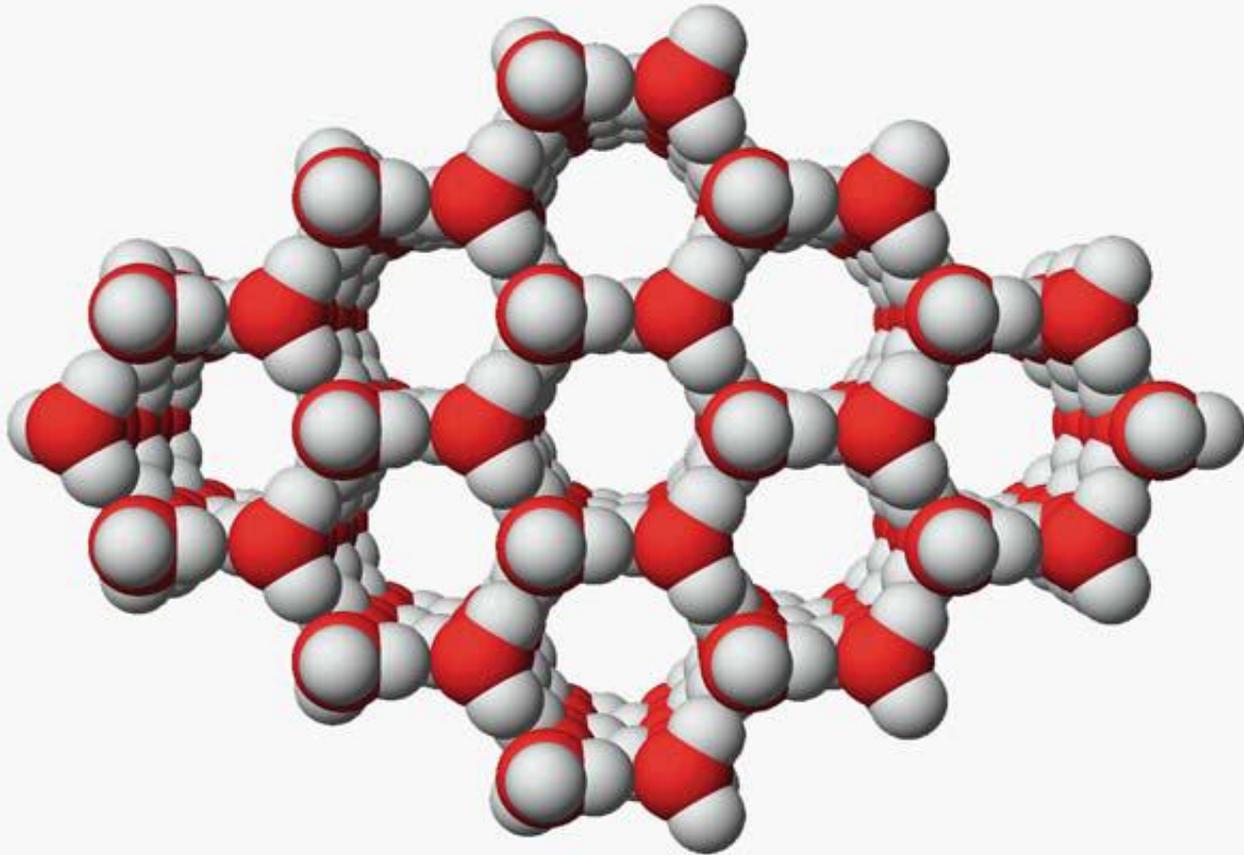


# FORÇAS INTERMOLECULARES



Tipo de interação	Distância x Potencial	Energia típica (kJ/mol)
Íon - íon	$\frac{(ze)_1 (ze)_2}{4\pi\epsilon_0 x}$	250
Íon-dipolo permanente	$\frac{(ze)_1 \mu_2 \cos \theta}{4\pi\epsilon_0 x^2}$	15
<b>Dipolo perman. - dipolo permanente (Keesom)</b>	$-\frac{2 (ze)_1 \mu_2 \cos \theta}{3(4\pi\epsilon_0)^2 k_B T x^6}$	2
<b>Dipolo perman. - dipolo induzido (Debye)</b>	$-\frac{(\alpha_{01} \mu_2^2 + \alpha_{02} \mu_1^2)}{(4\pi\epsilon_0)^2 x^6}$	2
Dipolo induzido - dipolo induzido (London)	$-\frac{3h}{2} \frac{\nu_1 \nu_2}{(\nu_1 + \nu_2)} \frac{(\alpha_{01} \alpha_{02})}{(4\pi\epsilon_0)^2 x^6}$	1 a 2

**Ligações (pontes) de H:  
~20 kJ/mol**

# FORÇAS DE VAN DER WAALS

- SÃO INTERAÇÕES ENTRE DIPOLO-DIPOLO OU DIPOLO-DIPOLO INDUZIDO QUE GOVERNAM PROPRIEDADES MACROSCÓPICAS DA MATÉRIA (KEESOM + DEBYE + LONDON);
- SÃO SEMPRE INTERAÇÕES ATRATIVAS;
- SÃO DE LONGO ALCANCE (DE 0,2 NM A 10 NM);
- ESPECIALMENTE IMPORTANTES PARA MOLÉCULAS ORGÂNICAS.

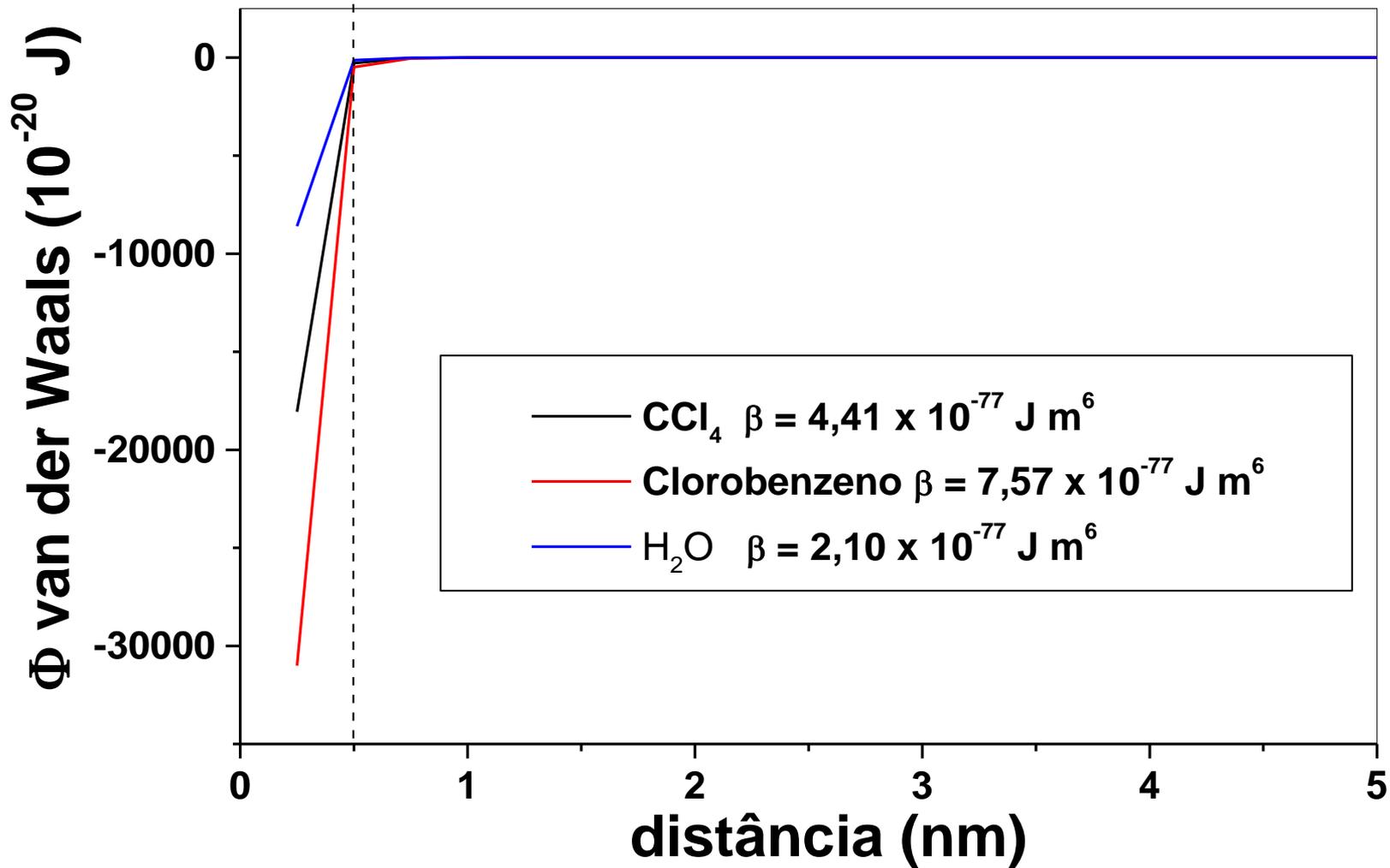
## **Implicações macroscópicas:**

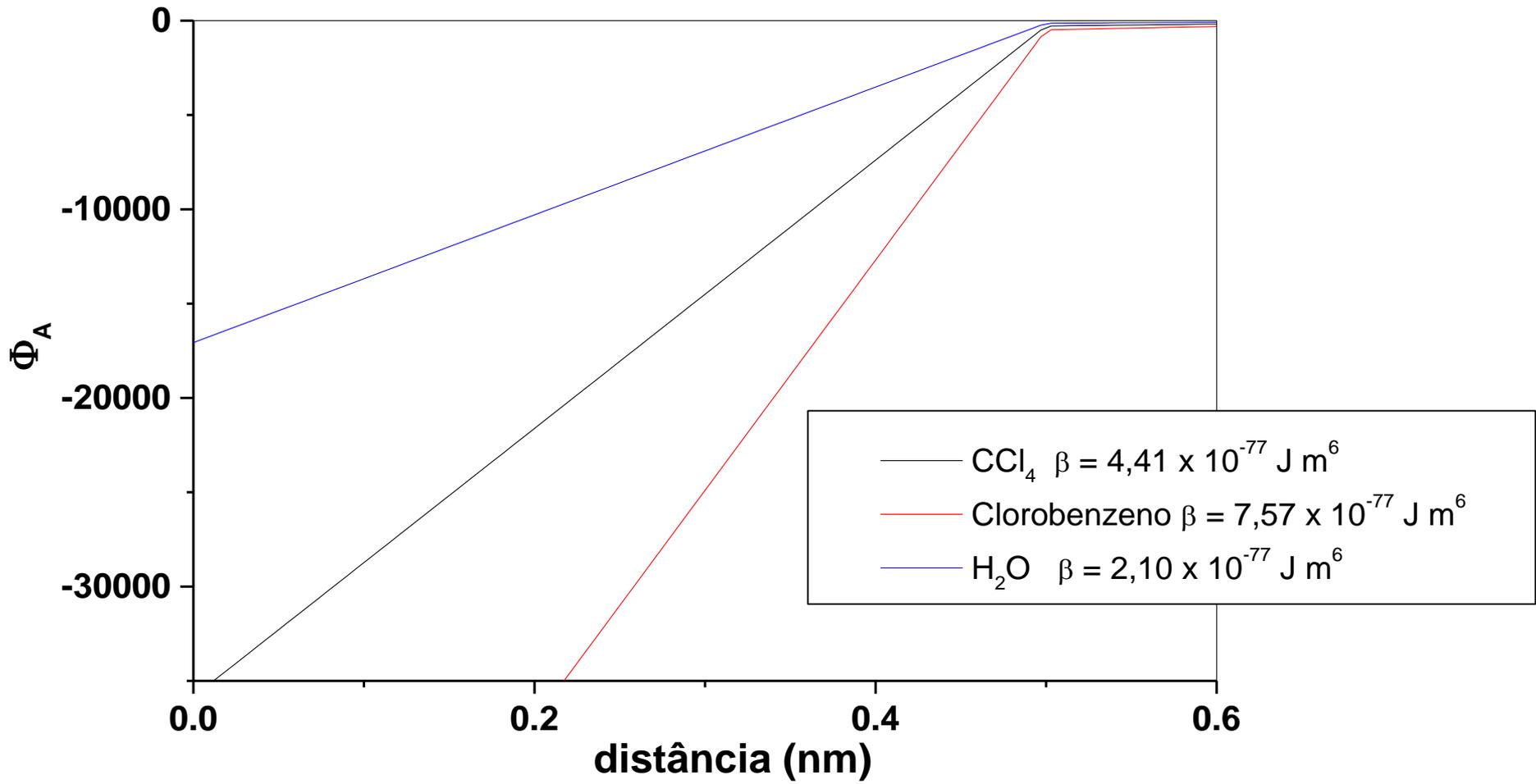
- Calor de vaporização de líquidos
- Viscosidade
- Coesão ou adesão
- Auto-associação
- Estabilidade coloidal

**Para calcular como varia o potencial de atração de van der Waals ( $\Phi_A$ ) com a distância entre 2 Moléculas iguais em função da distância (x):**

$$\Phi_A = -\frac{1}{(4\pi\epsilon_0)^2} \left( 2\alpha_{0,1}\mu_1^2 + \frac{2\mu_1^4}{3k_B T} + \frac{3}{4}h\nu_1\alpha_{0,1}^2 \right) x^{-6} = -\beta_{11}x^{-6}$$

$\beta_{11}$





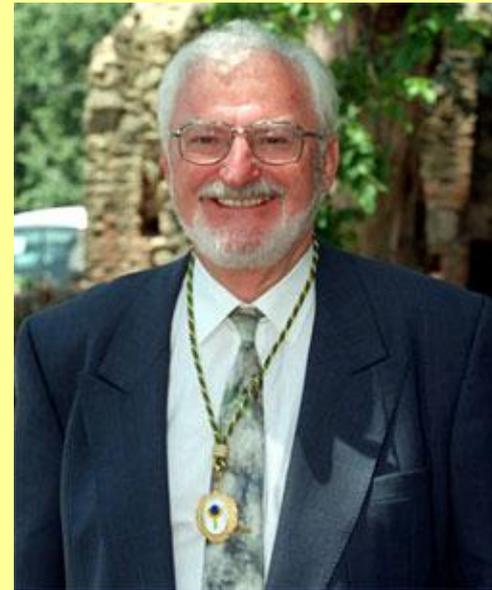
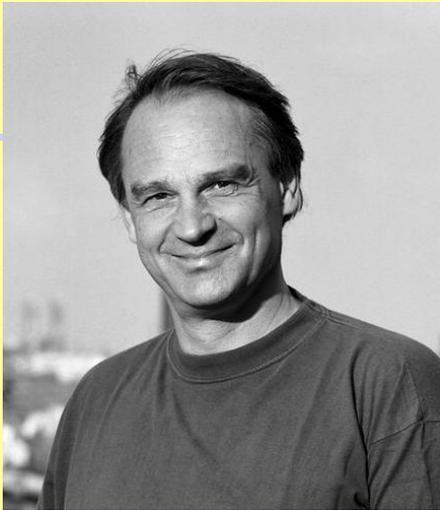
## Bibliografia

- Principles of Colloid and Surface Chemistry, 3rd ed. P. C. Hiemenz and R. Rajagopalan, Marcel Dekker, 1997, cap. 10.
- Introdução da química dos colóides e de superfícies, D. J. Shaw, Ed. Edgard Blücher Ltda, 1975.
- Livros de química geral.

## **1986 – Prêmio Nobel de Física**

Professor. **Ernst Ruska**, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin

Dr **Gerd Binnig** and Dr **Heinrich Rohrer**,  
IBM Research Laboratory, Zurich, Switzerland,  
**scanning tunnelling microscope**



**Microscópio de varredura de tunelamento:**  
o equipamento permitiu medir a corrente de tunelamento  
entre uma ponta de tungstênio e uma superfície condutora

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## **Efeito túnel ou tunelamento**

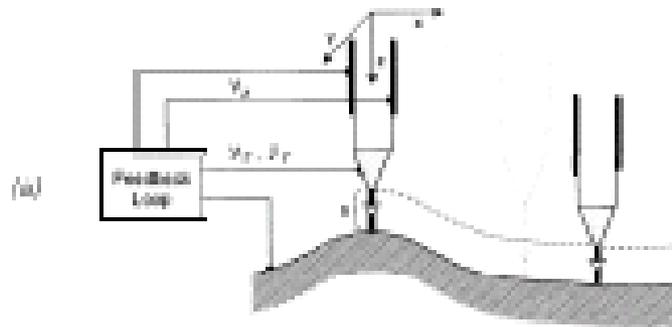
**Quando uma onda encontra no seu percurso um obstáculo, a intensidade ou amplitude desta não termina imediatamente no obstáculo, mas decresce exponencialmente após o contato.**

**Este efeito tem sido usado atualmente para executar varredura de superfícies em nível atômico, já que os elétrons, agindo como onda, "tunelam" da superfície até a ponta microscópica do equipamento, sem que estas se toquem**

20

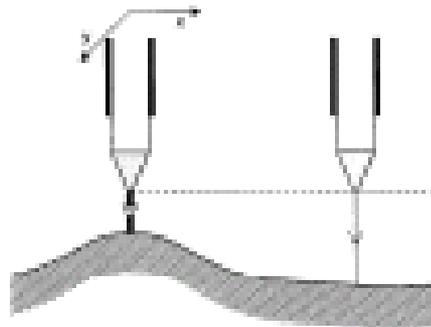
Figure 10b

Constant Current Mode

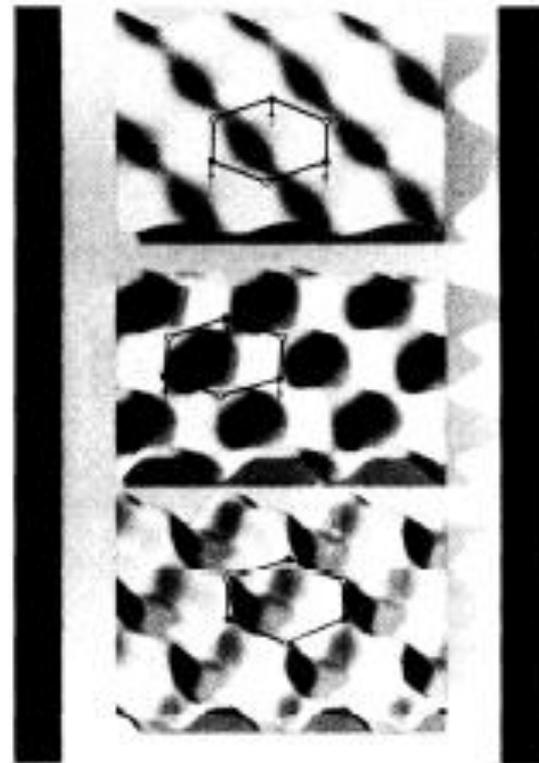


$$V_T(V_s, V_T) \rightarrow z(x, y)$$

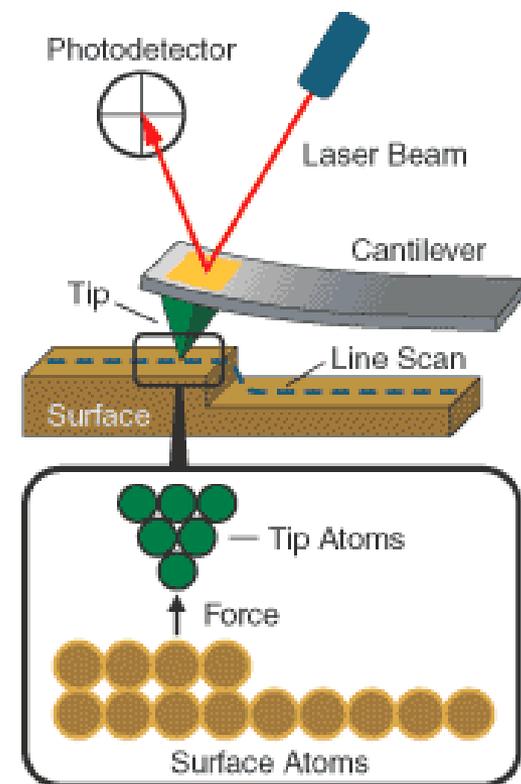
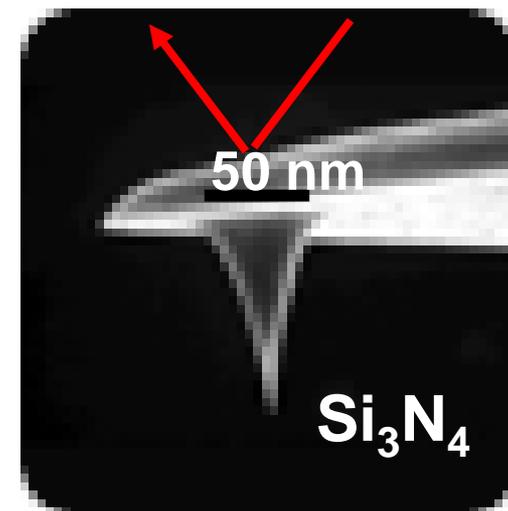
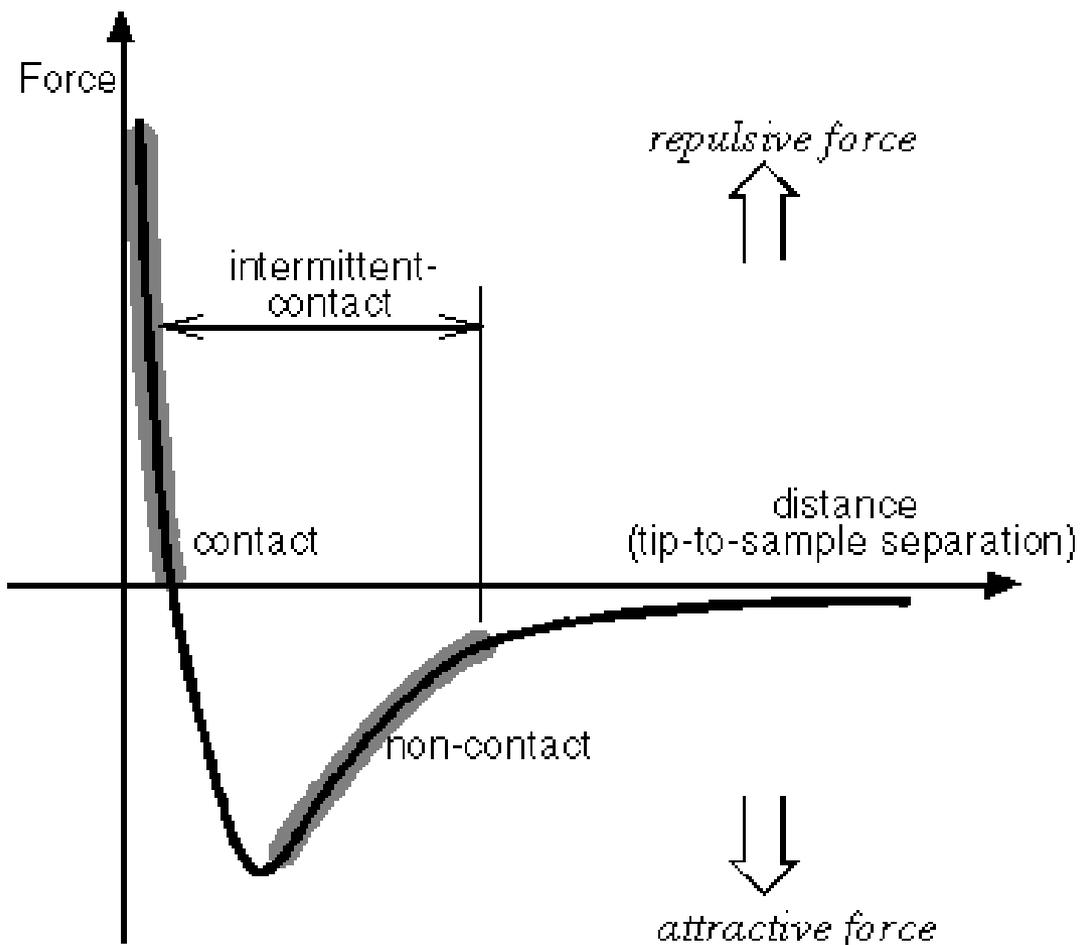
(b)

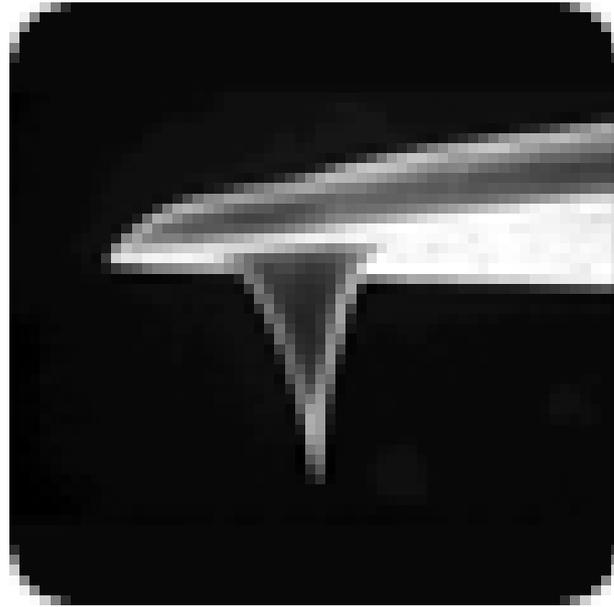


$$z(x, y, V_T) \rightarrow I(x, y)$$

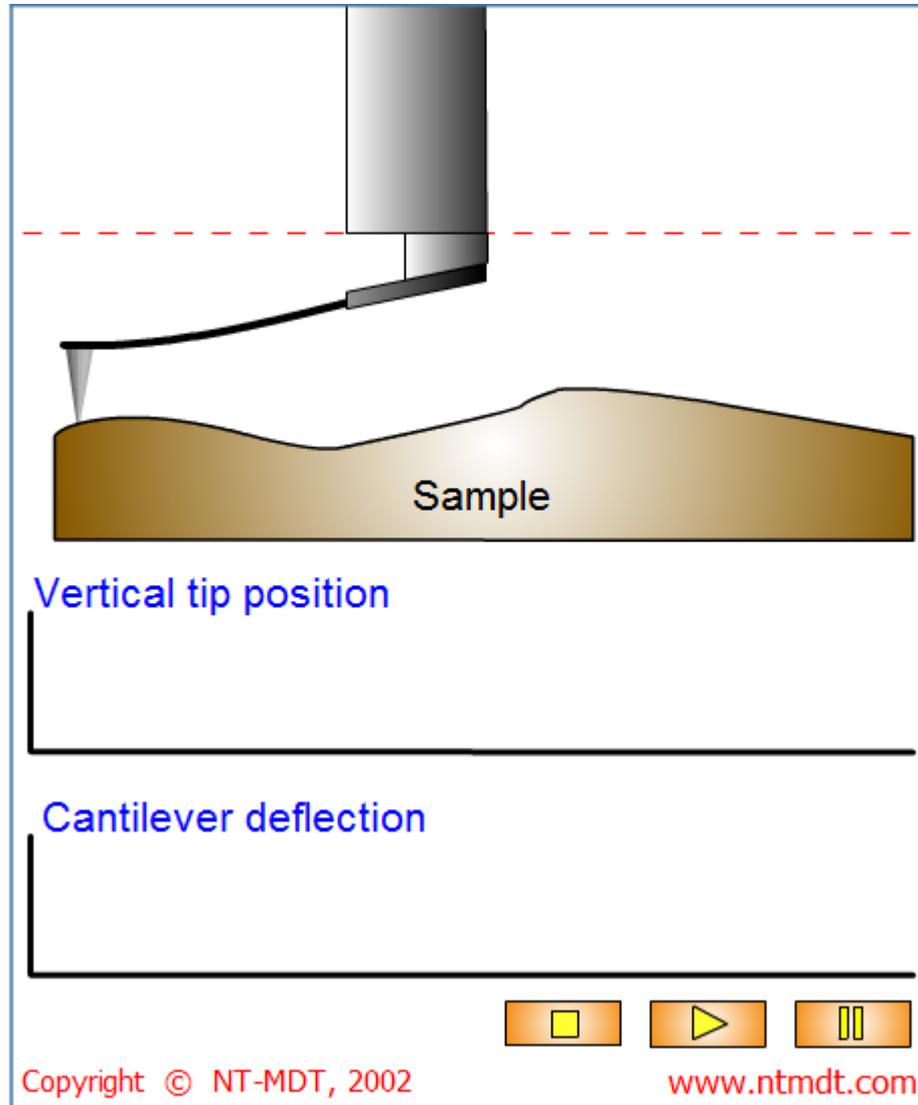


# Microscopia de força atômica (AFM)

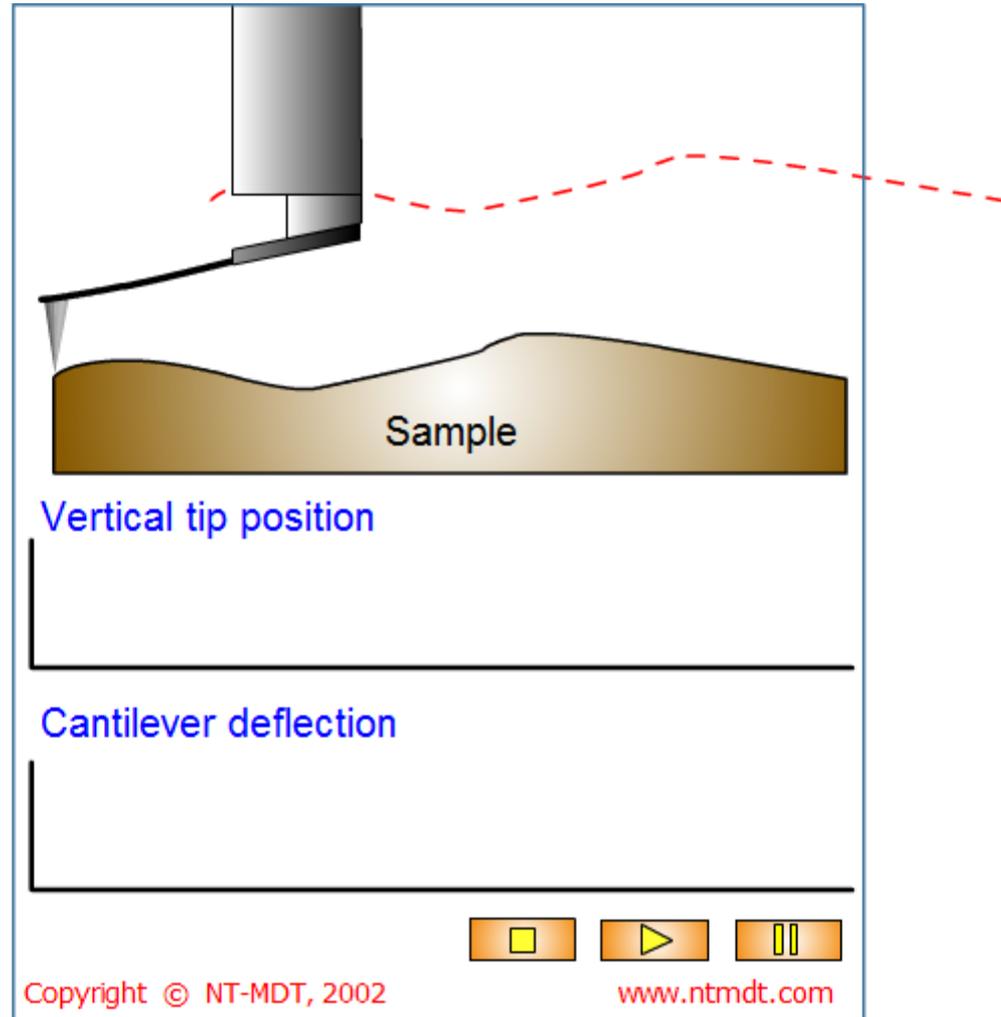




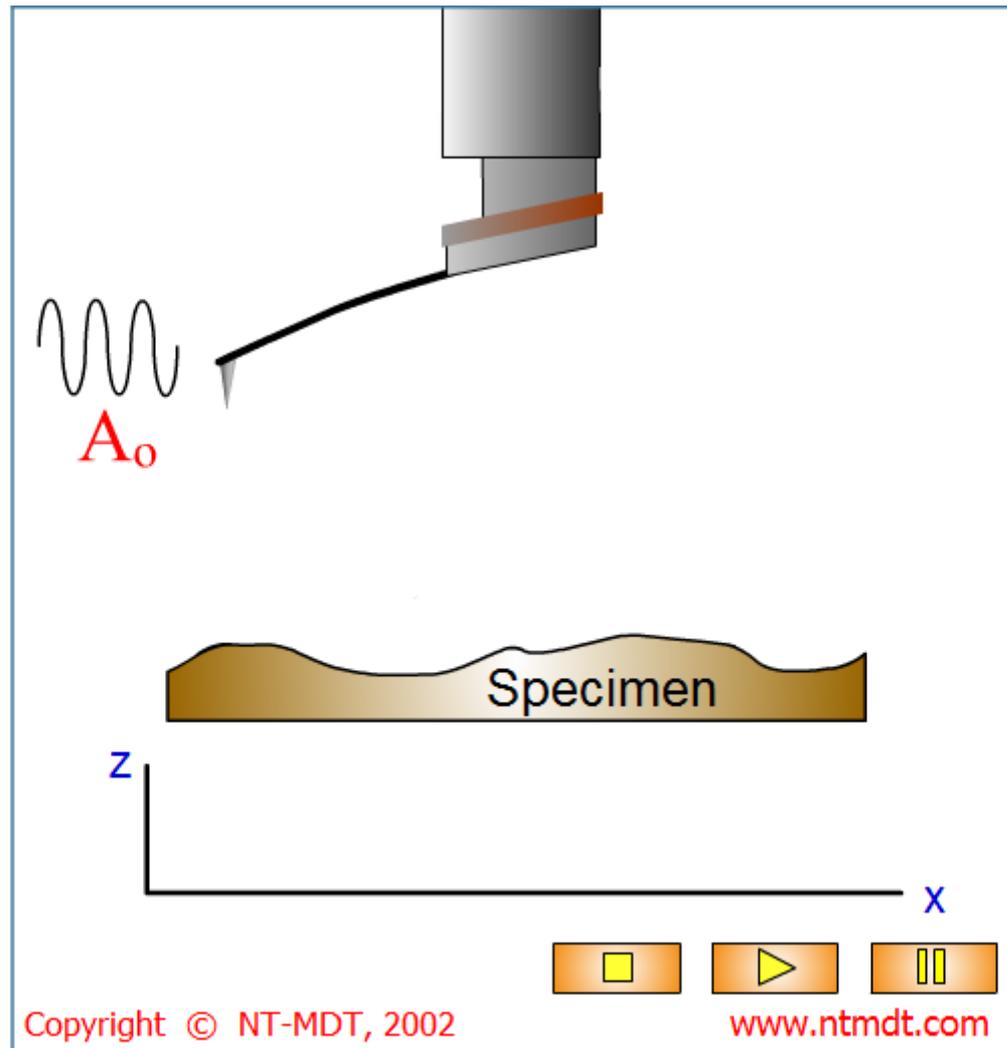
# Modo Contato – Altura Constante



# Modo Contato – Força Constante

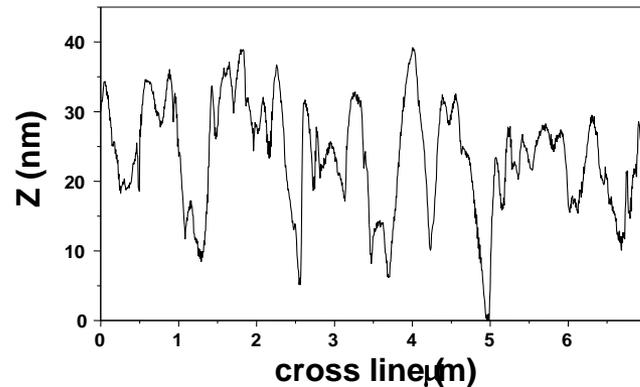
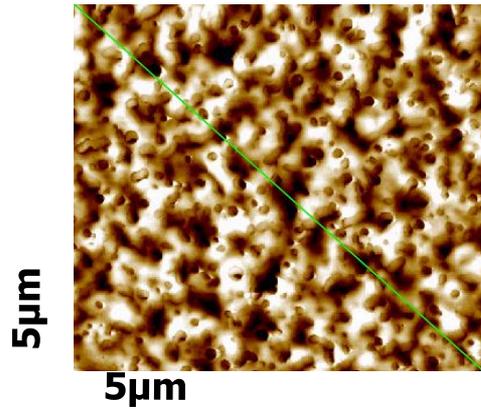


# Modo Contato Intermitente – Topografia



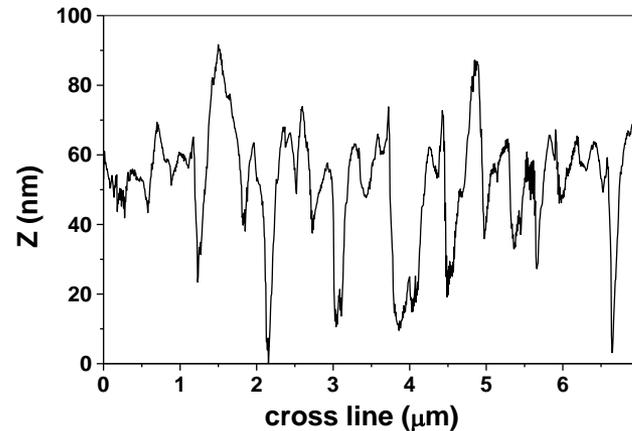
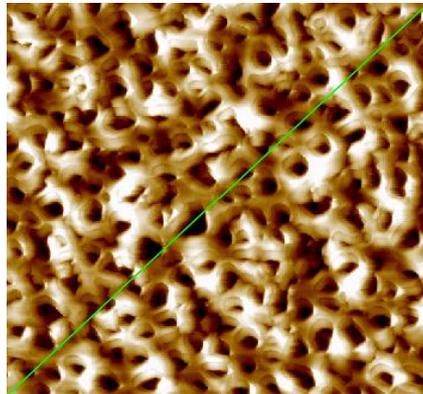
# Efeito da umidade relativa (UR) na morfologia e anti-reflexo

Acetato de celulose (CA) a partir de soluções em THF, 10 g/L

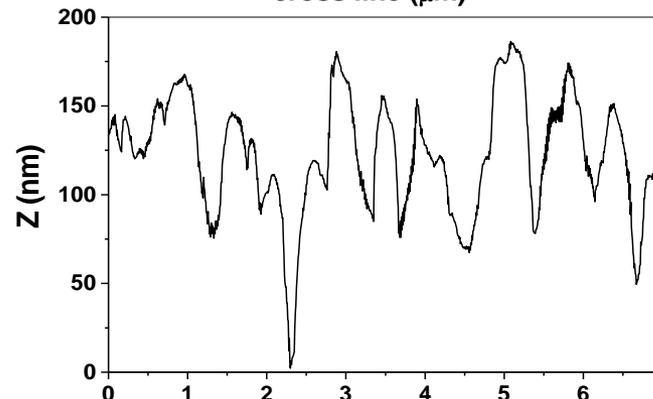
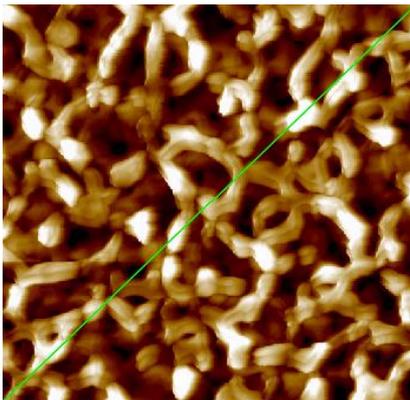


UR ( $35 \pm 5$ )%

**AR ~ 19 %**

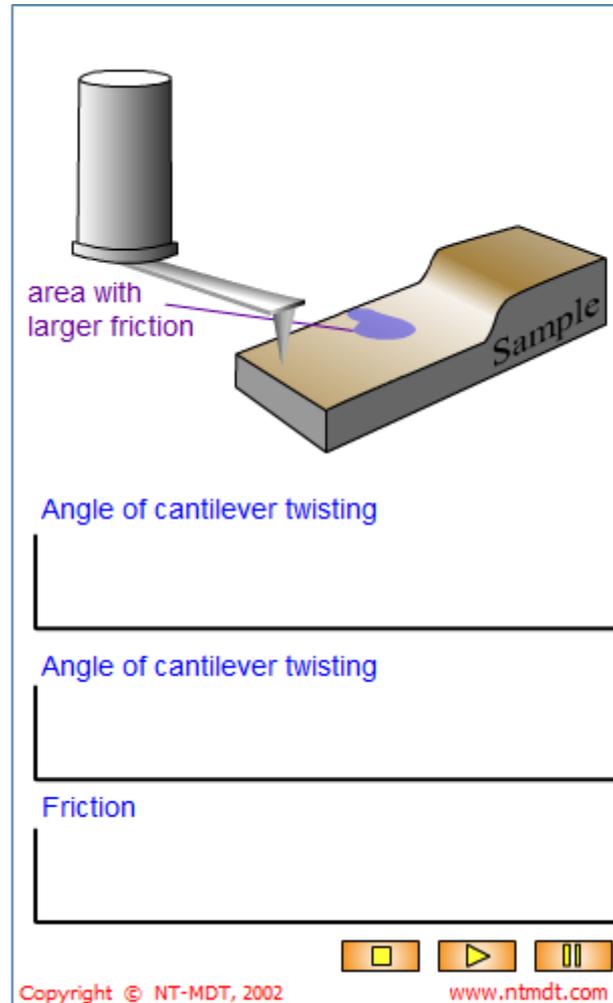


UR ( $55 \pm 5$ )% **AR ~ 40%**

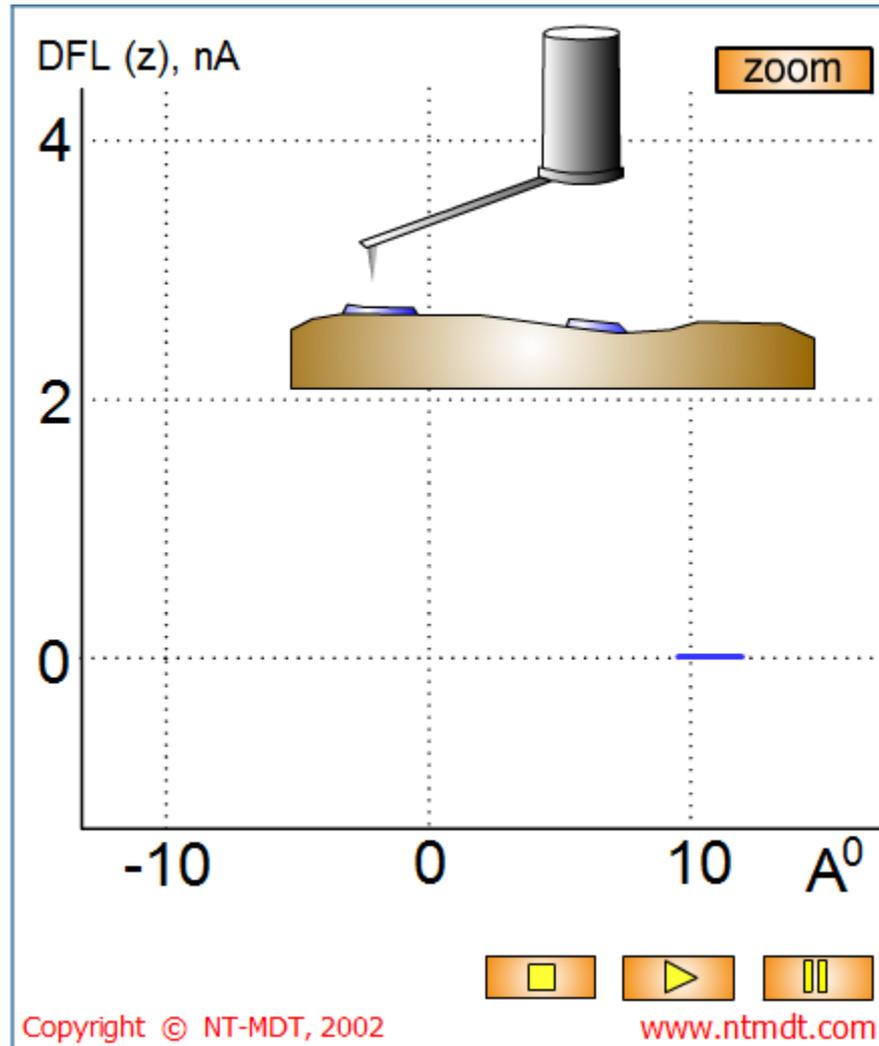


UR ( $75 \pm 5$ )% **AR ~ 70%**

# Modo Contato – Lateral Force



# Forças de Adesão



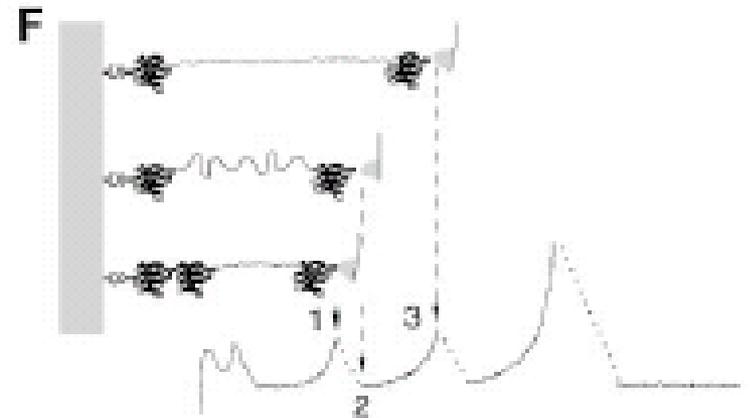
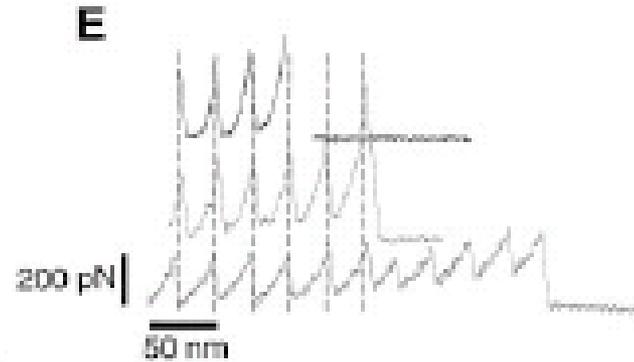
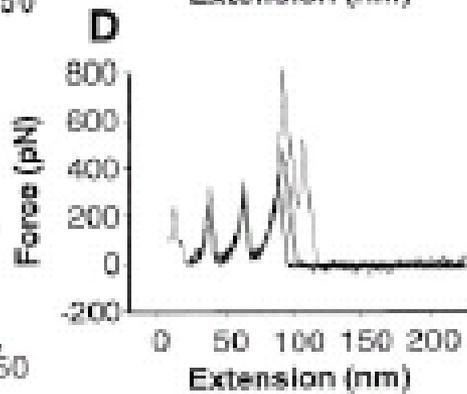
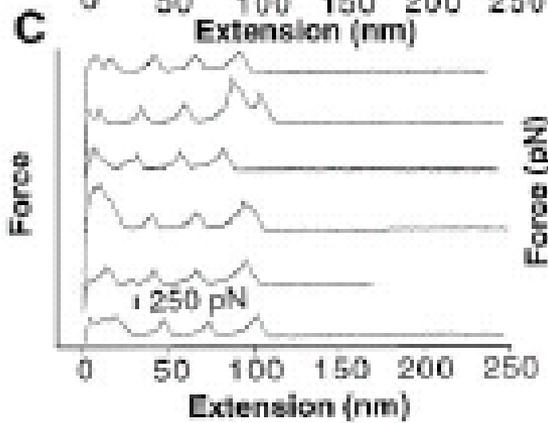
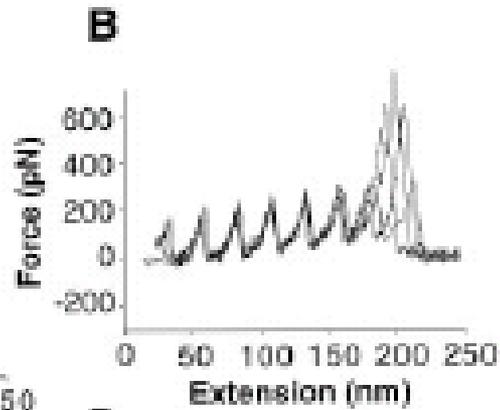
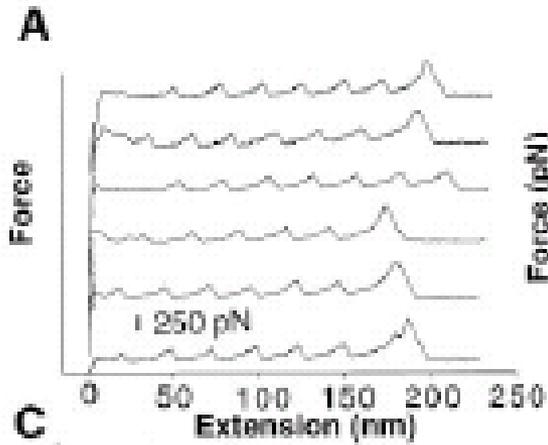
# Reversible Unfolding of Individual Titin Immunoglobulin Domains by AFM

Matthias Rief, Mathias Gautel, Filipp Oesterhelt, Julio M. Fernandez, Hermann E. Gaub\*

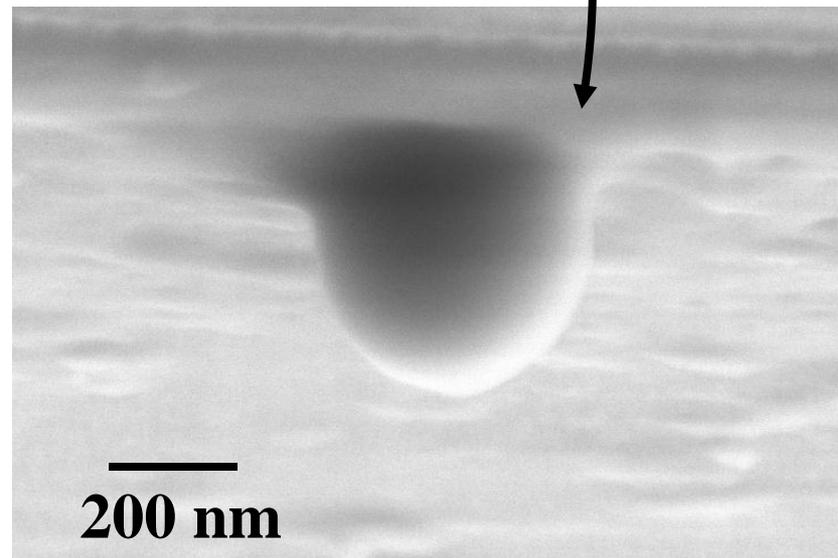
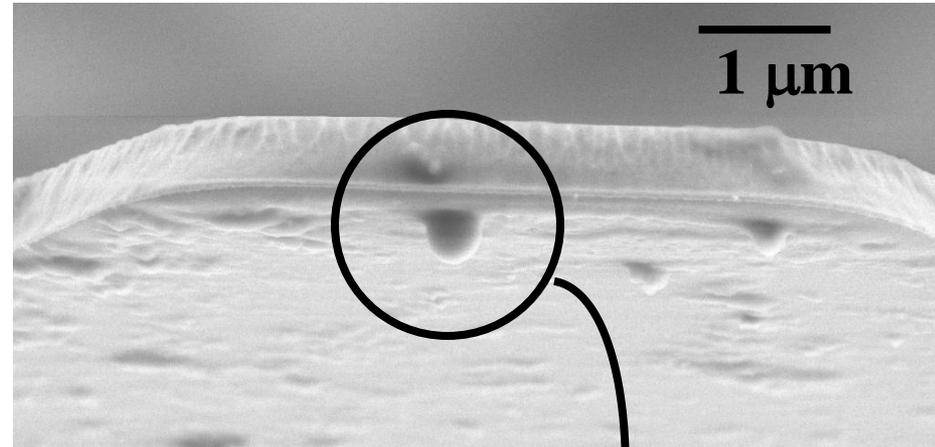
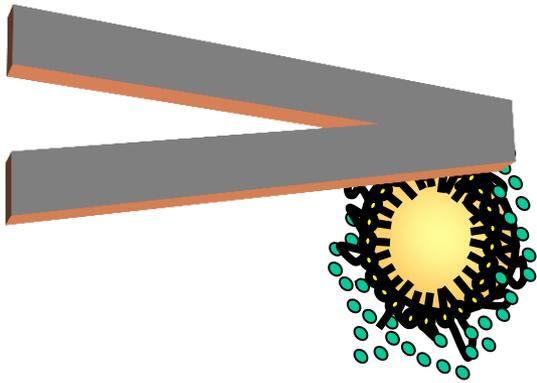
*Science* **276**, 1109 (1997)

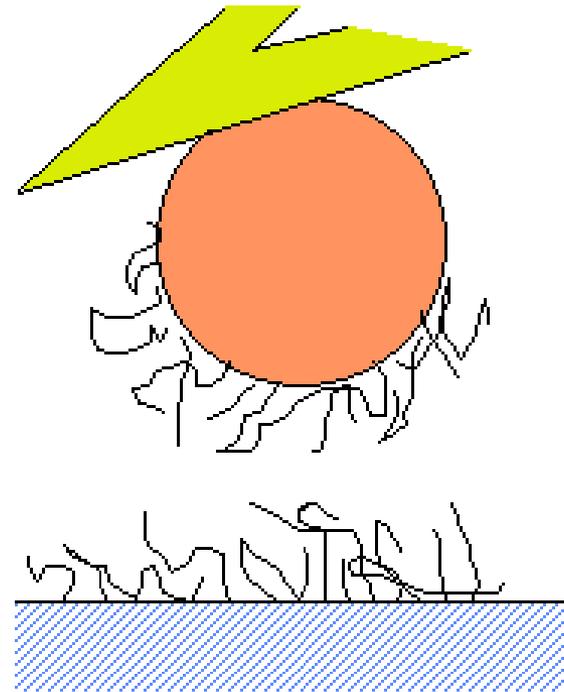
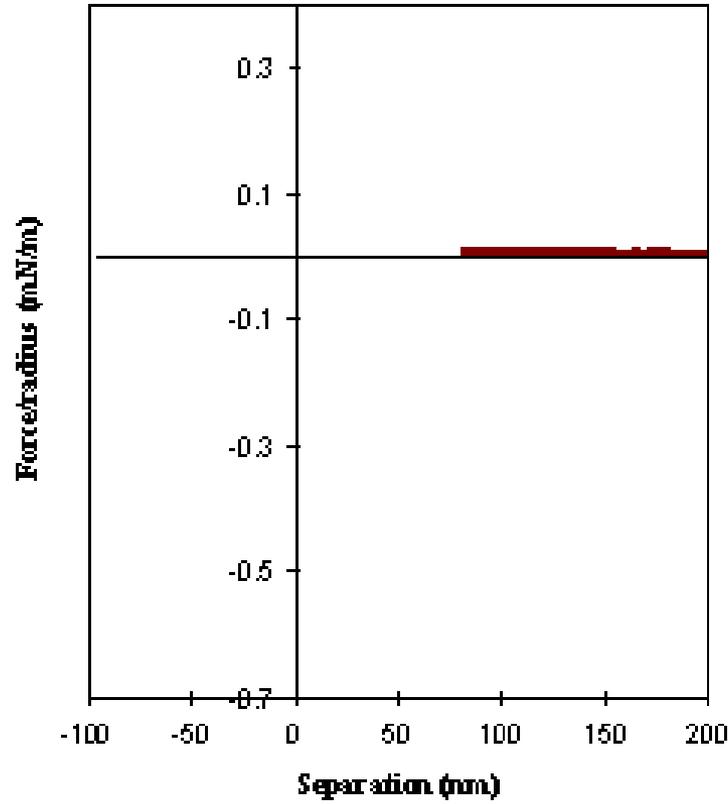
Measurements of recombinant titin immunoglobulin segments of two different lengths exhibited the same pattern and allowed attribution of the discontinuities to the unfolding of individual immunoglobulin domains. The forces required to unfold individual domains ranged from 150 to 300 piconewtons and depended on the pulling speed. Upon relaxation, refolding of immunoglobulin domains was observed.

*Science* 276, 1109 (1997)



# AFM - Colloidal probe technique for adhesion forces





## In situ observation of streptavidin-biotin binding on an immunoassay well surface using an atomic force microscope

S. Allen<sup>a,\*</sup>, J. Davies<sup>b</sup>, A.C. Dawkes<sup>b</sup>, M.C. Davies<sup>a</sup>, J.C. Edwards<sup>b</sup>, M.C. Parker<sup>a</sup>,  
C.J. Roberts<sup>a</sup>, J. Sefton<sup>b</sup>, S.J.B. Tendler<sup>a</sup>, P.M. Williams<sup>a</sup>

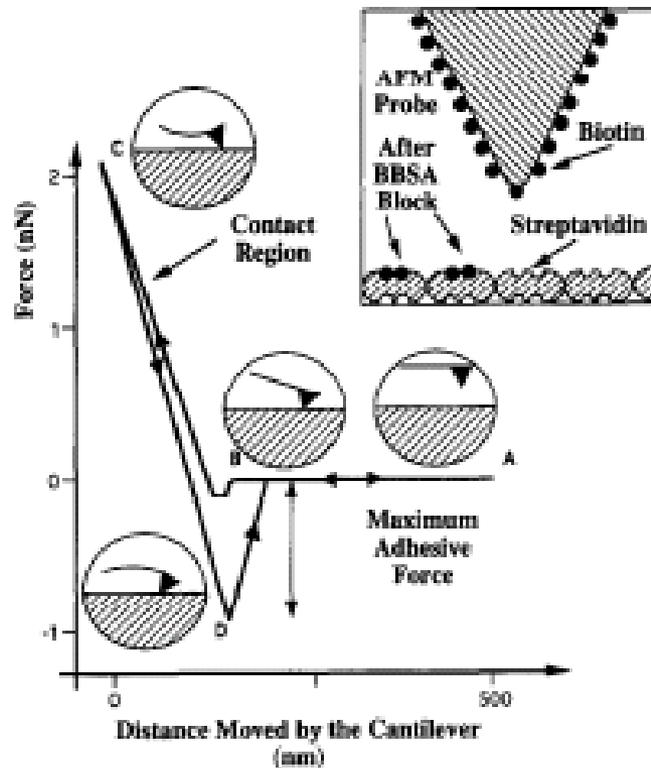


Fig. 1. (Main diagram) A schematic diagram of a typical force measurement cycle. The relative position of the AFM probe to the

S. Allen et al./FEBS Letters 390 (1996) 161-164

