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Analysis of Long-channel Nanotube FETs

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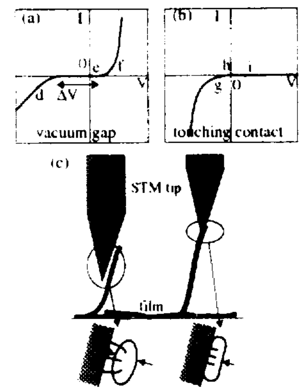
I-V characteristics of STM tip-nanotube characteristics

vacuum gap mode vs. touching mode

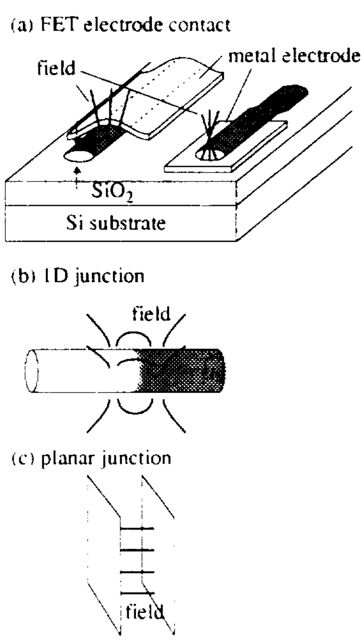


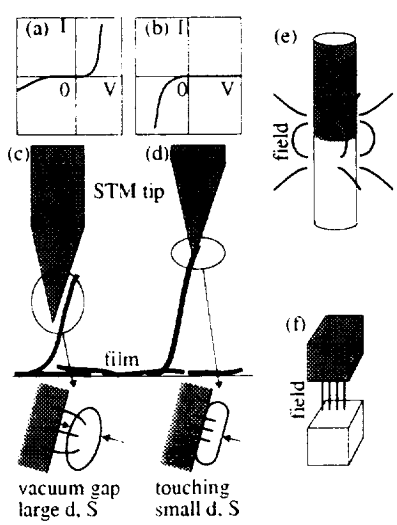
conduction/valence band tunneling

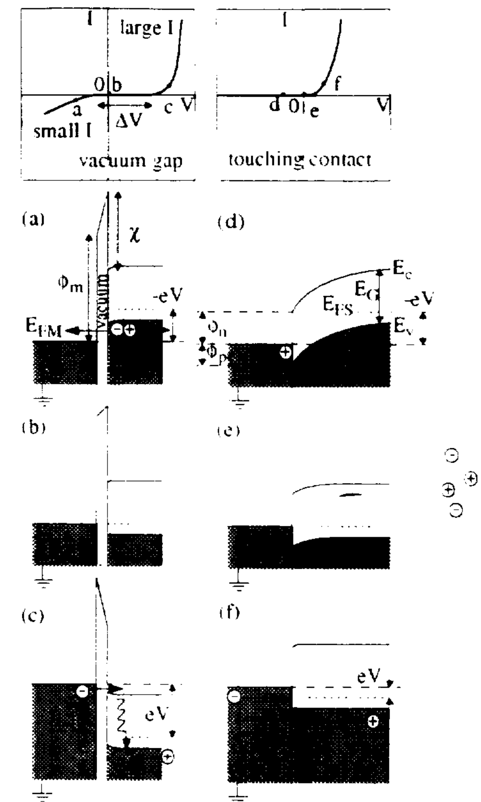
Schottky forward/reverse transport

nanotube FET contact

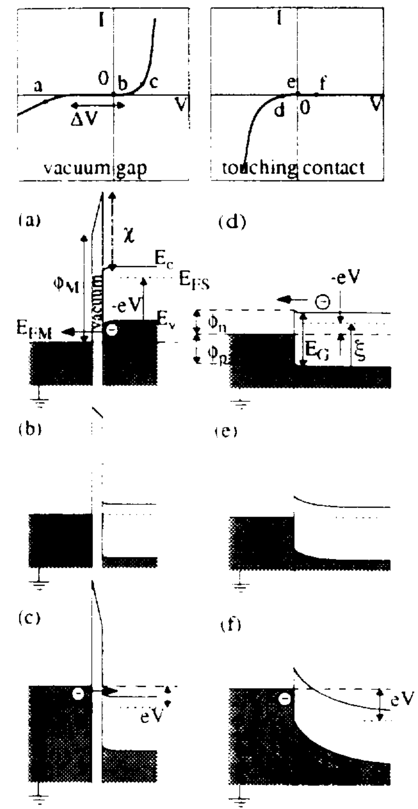
low T vacuum gap mode	vs.	room T touching mode



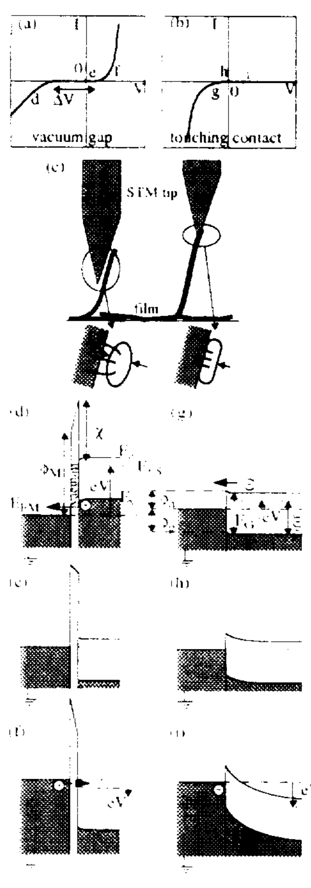




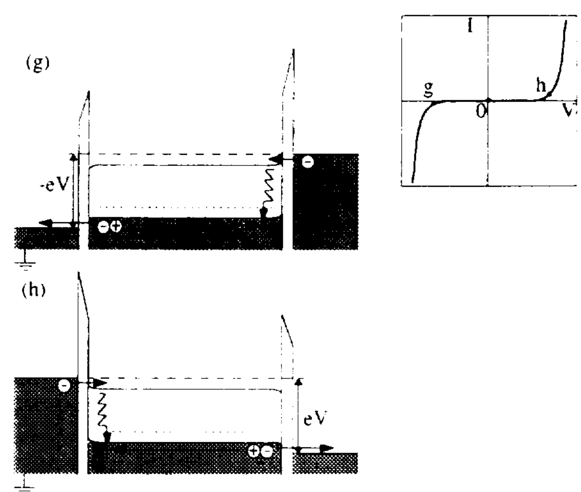
large I
small I
ΔV
vacuum gap
touching contact
(a)
(d)
(b)
(e)
(c)
(f)
χ
-eV
eV



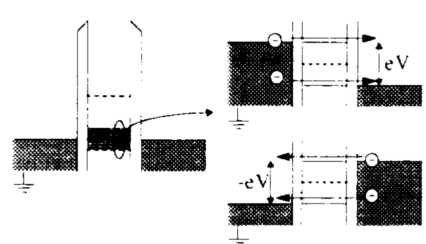
vacuum gap
touching contact
(a)
(d)
(b)
(e)
(c)
(f)
χ
-eV
eV



vacuum gap
touching contact
STM tip
film

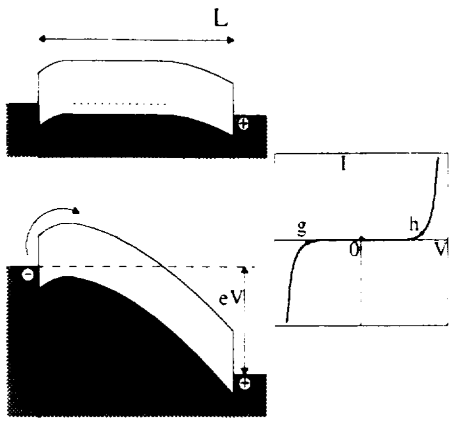


(g)
(h)
-eV
eV

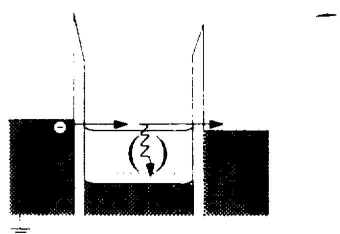


eV
-eV

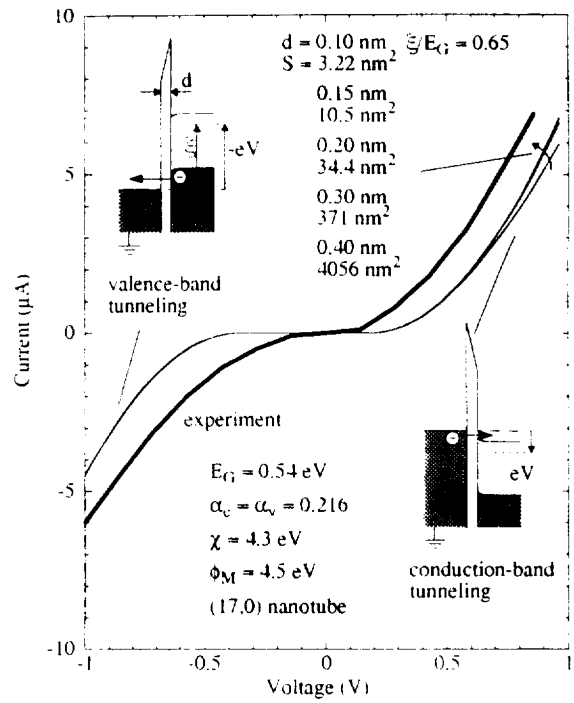
Reach-through

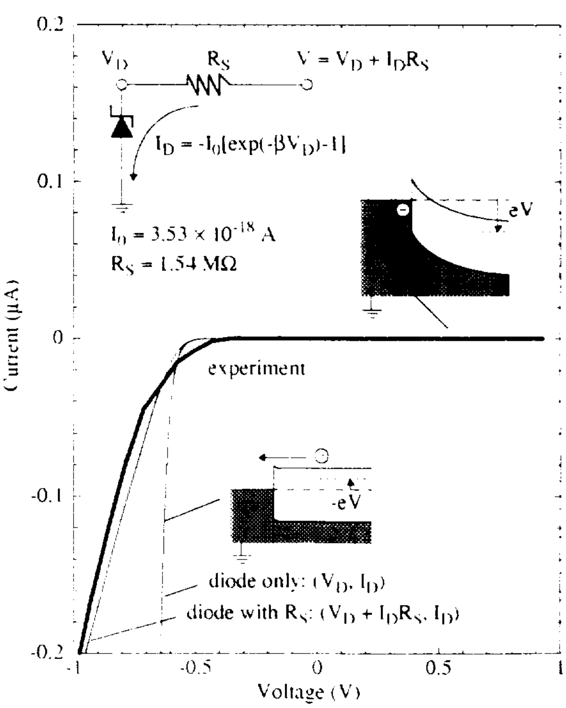


$V = V_F + V_R$ L-dependent!



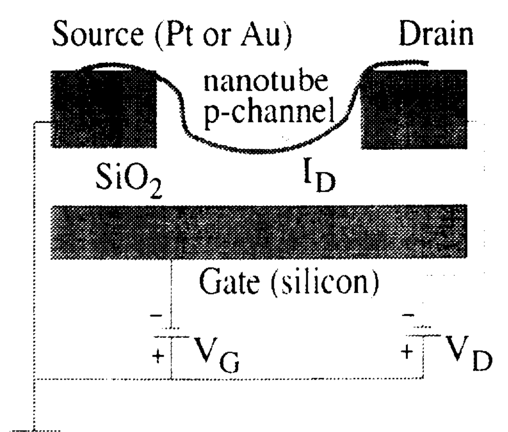
this is like a saturation mode in BJT. without Vg
this will never happen for a two-terminal device





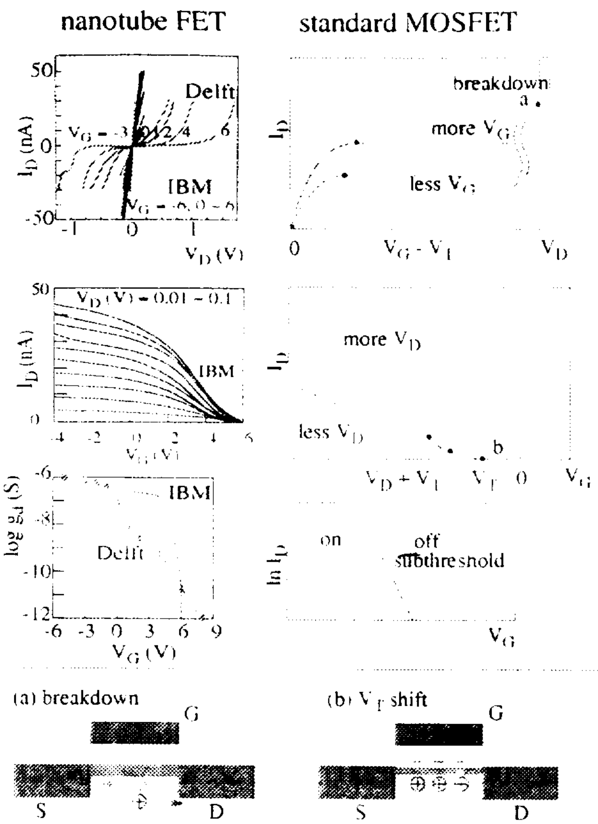
Nanotube FET by Delft, IBM

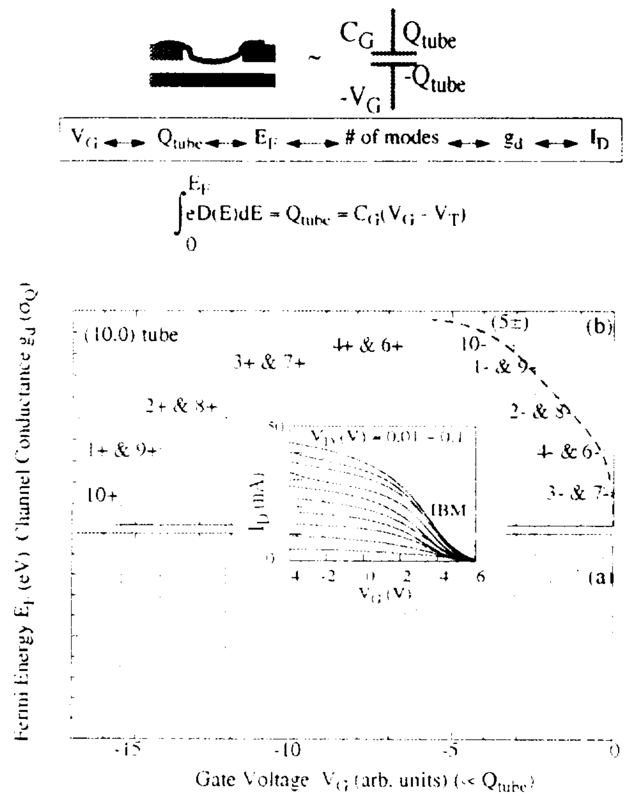
[Delft] S.J. Tans, A.R.M. Verschueren, and C. Dekker, Nature **393**, 49 ('98)
[IBM] R. Martel, T. Schmidt, H.R. Shea, T. Hertel, and Ph. Avouris, Appl. Phys. Lett. **73**, 2447 ('98)

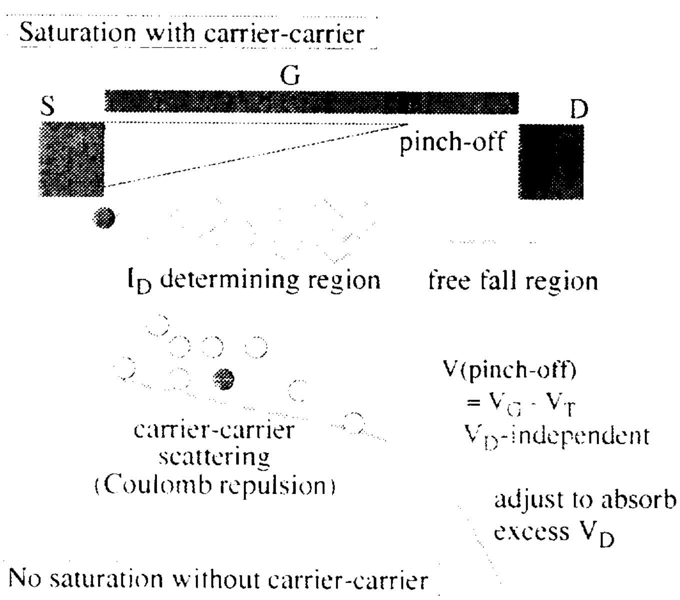


measure
$I_D(V_D)$ at fixed V_G
$I_D(V_G)$ at fixed V_D

channel conductance
$g_d = \partial I_D / \partial V_D$
transconductance
$g_m = \partial I_D / \partial V_G$





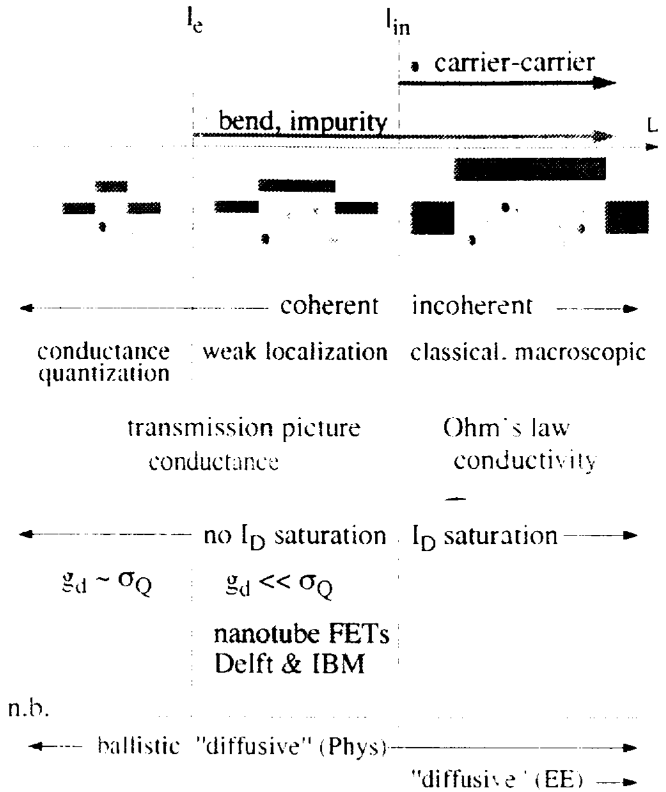


Without carrier-carrier,
no pinch-off, no saturation in $I_D(V_D)$

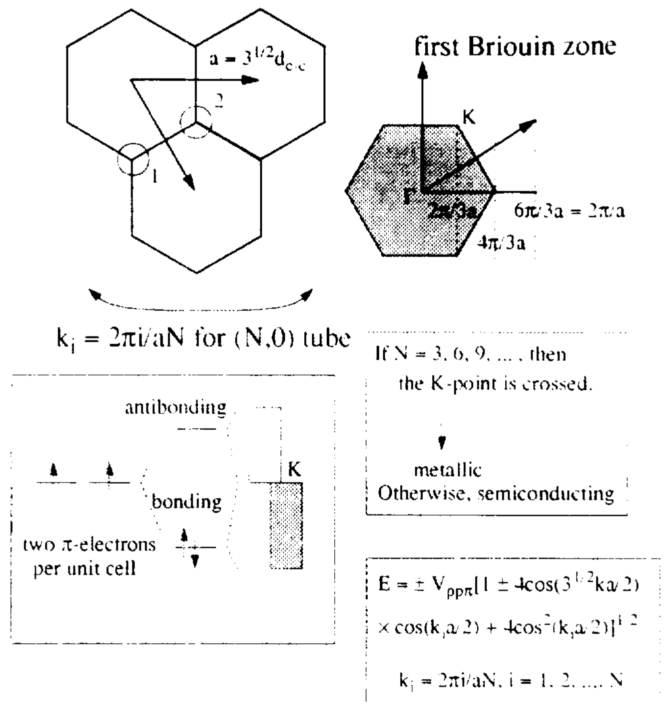
Experimental observations & possible mechanisms:

1. saturationless $I_D(V_D)$ fixing V_G of Delft
   absence of carrier-carrier scattering
   a lot of elastic scattering, low g_d
2. breakdown in $I_D(V_D)$ fixing V_G of Delft
   usual pair creation
3. kink in subthreshold $g_d(V_G)$ of Delft (Pt S & D)
4. smooth subthreshold $g_d(V_G)$ of IBM (Au S & D)
   Schottky barrier effects
5. saturated "on" $I_D(V_G)$ fixing V_D of IBM
   quasi-1D nanotube characteristics
6. large V_G shift in $g_d(V_G)$ of Delft, IBM
   usual Q_{int} effects

Gate length L, elastic length l_e, & inelastic length l_{in}



Electronic properties of carbon nanotube



theoretical nanotube FET characteristics