Al 7-lea Seminar de nanostiinta si nanotehnologie

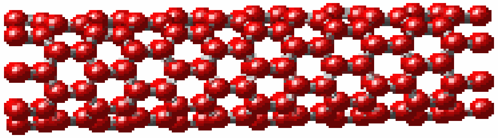
A miniaturized microwave resonator based on millions of nanotubes

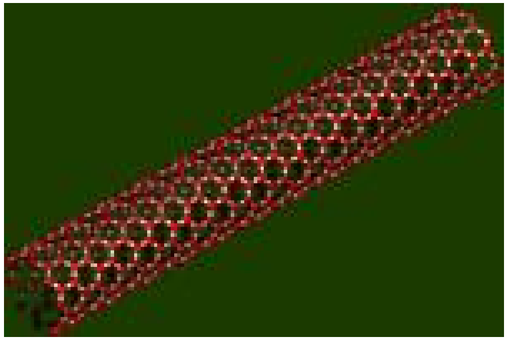
by

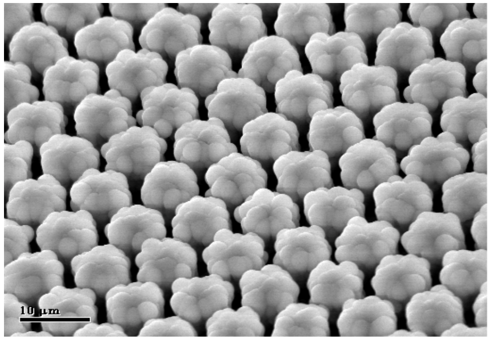
M. Dragoman[1], D. Dragoman [2], D. Neculoiu[1], A. Cismaru [1],
K. Grenier[3], S. Pacchini[3], R. Plana[3]
[1]*National Research and Development Institute in Microtechnology, Str. Erou Iancu Nicolae 32B, 077190 Bucharest, Romania*
[2]*Univ. Bucharest, Physics Dept., P.O. Box MG-11, 077125 Bucharest, Romania*
[3]*LAAS CNRS, 7 Avenue du Colonel Roche, 31077 Toulouse Cedex 4, France*
National Research and Development Institute in Microtechnology, Str. Erou Iancu Nicolae 32 B, 077190Bucharest, Romania

Abstract

Carbon nanotubes (CNTs) reveal extraordinary physical properties, which cannot be encountered in any other materials making them extremely attractive for many applications in the area of nanoelectronics. The microwave applications of the CNTs encompass many concepts such as microelectromechanical systems (MEMS), nanoelectromechanical systems (NEMS), field emission, quantum confined electron devices as well as electromagnetic field propagation phenomena in the range 1 GHz-3 THz. In the most of the cases, a microwave device based CNT is a combination of some above concepts.







Parameter	*Value and units*	*Observations*
Length of the unit vector	2.49 Å	1.44 Å is the carbon bond length
Current density	$>10^9$ A/cm^2	-1000 times larger than the current density in copper - Measured in MWCNTs
Thermal conductivity	6600 W/mK	More thermally conductive than most crystals
Young modulus	**1 TPa**	**Many orders of magnitude stronger than the steel**
Mobility	**10000-50000 cm^{2}V^{-1}s^{-1}**	**Simulations indicate mobilities beyond 100 000 cm^{2}V^{-1}s^{-1}**
Mean free path (ballistic transport)	**300-700 nm semiconducting CNT 1000-3000 nm metallic CNT**	**- Measured at room temperature - At least three time larger than the best semiconducting heterostructures**
Conductance in ballistic transport	$G = 4e^2 / h = 155\mu S$	$1/G = 6.5 k\Omega$
Luttinger parameter *g*	0.22	The electrons are strongly correlated in CNTs
Orbital magnetic moment	0.7 meVT^{-1} (d = 2.6 nm) 1.5 meVT^{-1} (d = 5 nm)	The orbital magnetic moment depends on the tube diameter

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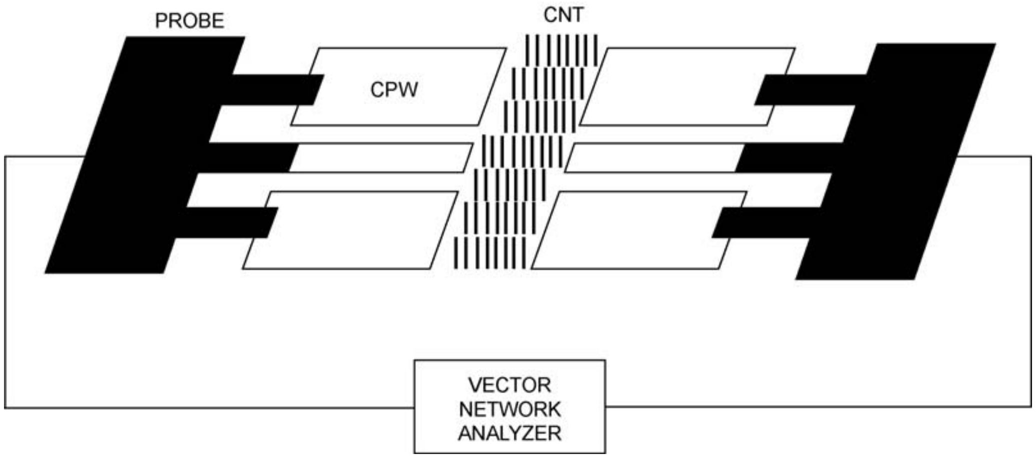
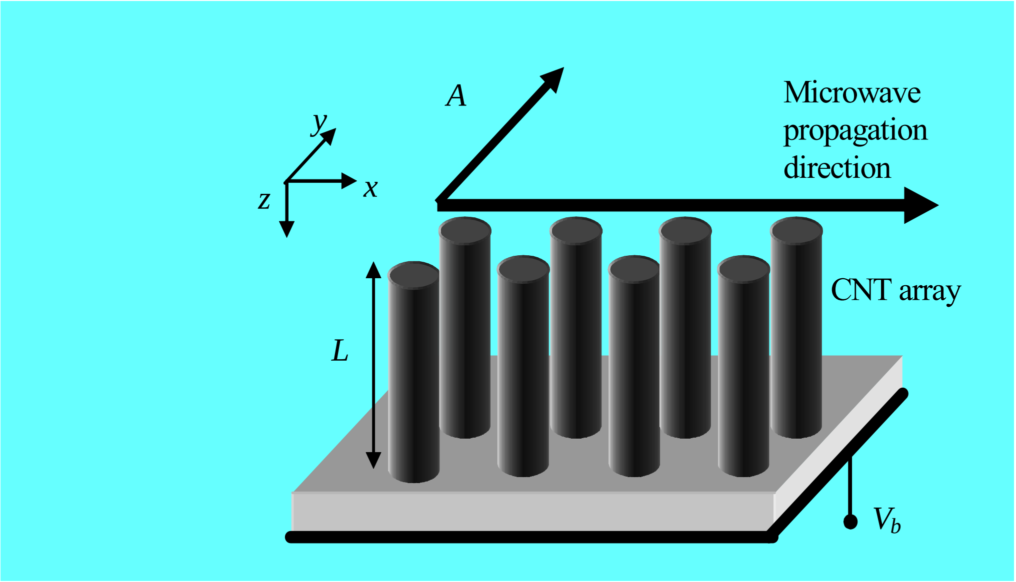
GHz RESONATOR BASED CNT

Tunable filter



The mechanical frequency of oscillation of CNT cantlivers is in GHz range, so there is a strong coupling with an electromagnetic field in the same range



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$$f_s = f_r = \beta_i [d_o^2 (E / \rho)]^{1/2} / 8\pi L^2$$

•The cantilever is deflecting only when the incoming RF field frequency f_s is equal with mechanical resonant frequency f_r of the CNT cantilever ;

d_o the outer diameter, d_i-the inner diameter of the SWCNT , L -the length of the MWCNT, E-the elastic modulus, ρ is the density and β_1=1.87 is assigned for the fundamental frequency while β_2=4.69 is assigned for the second harmonic

d_0=40 nm	fosc(GHz) mechanical oscillation
L= 500 nm	1
L=300 nm	1.5

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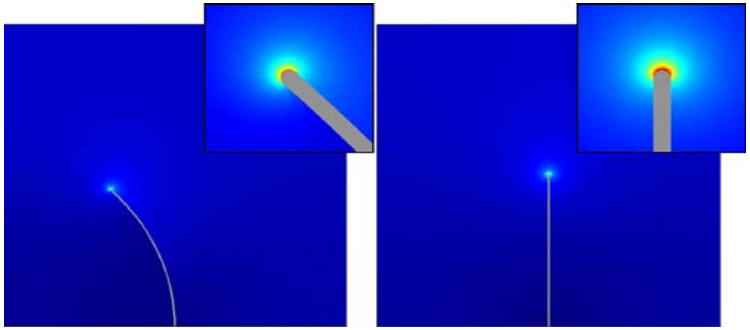
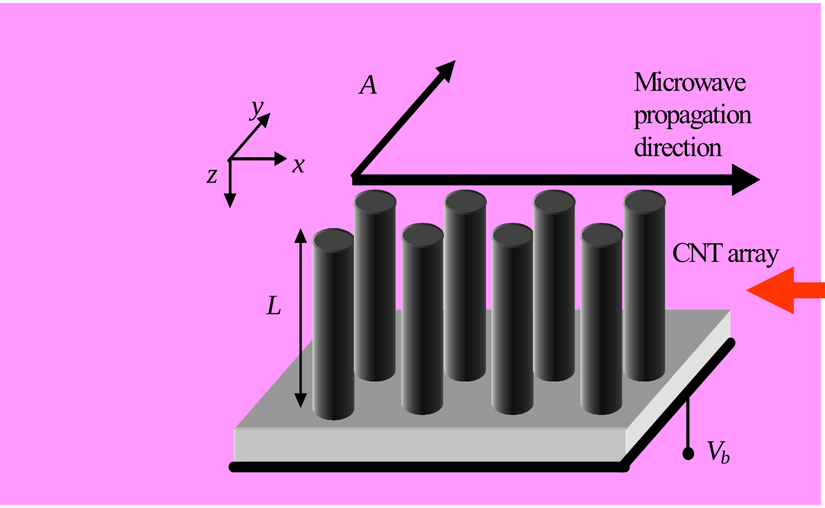
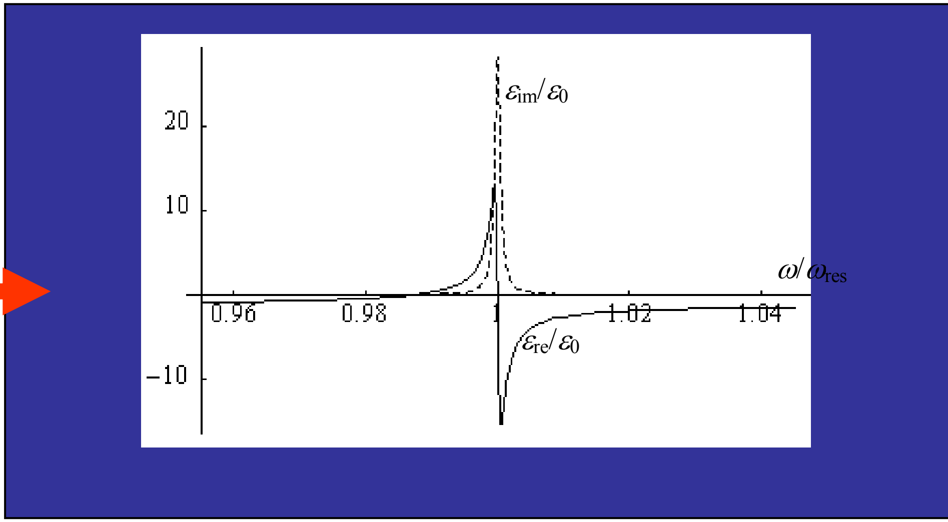
- At signal frequencies close to the mechanical resonant frequency of an array of metallic cantilevered carbon nanotubes, the array sandwiched between two coplanar waveguide lines shows a notch in the transmission coefficient of the microwave signal.
- This resonant phenomenon is explained by a Drude-Lorentz model applied to the charges at the carbon nanotube tips that are excited by the electric field of the microwave signal.
- It is thus found that a metal-lossy dielectric transition of the carbon nanotube array at the mechanical resonant frequency of the cantilever is taking place







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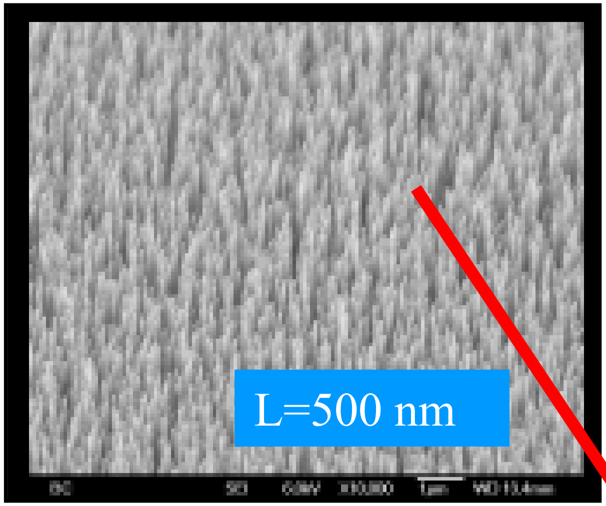
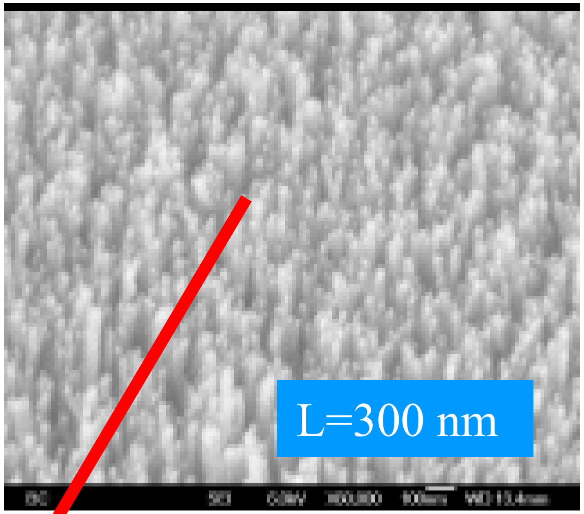
MWCNT array length L(nm)





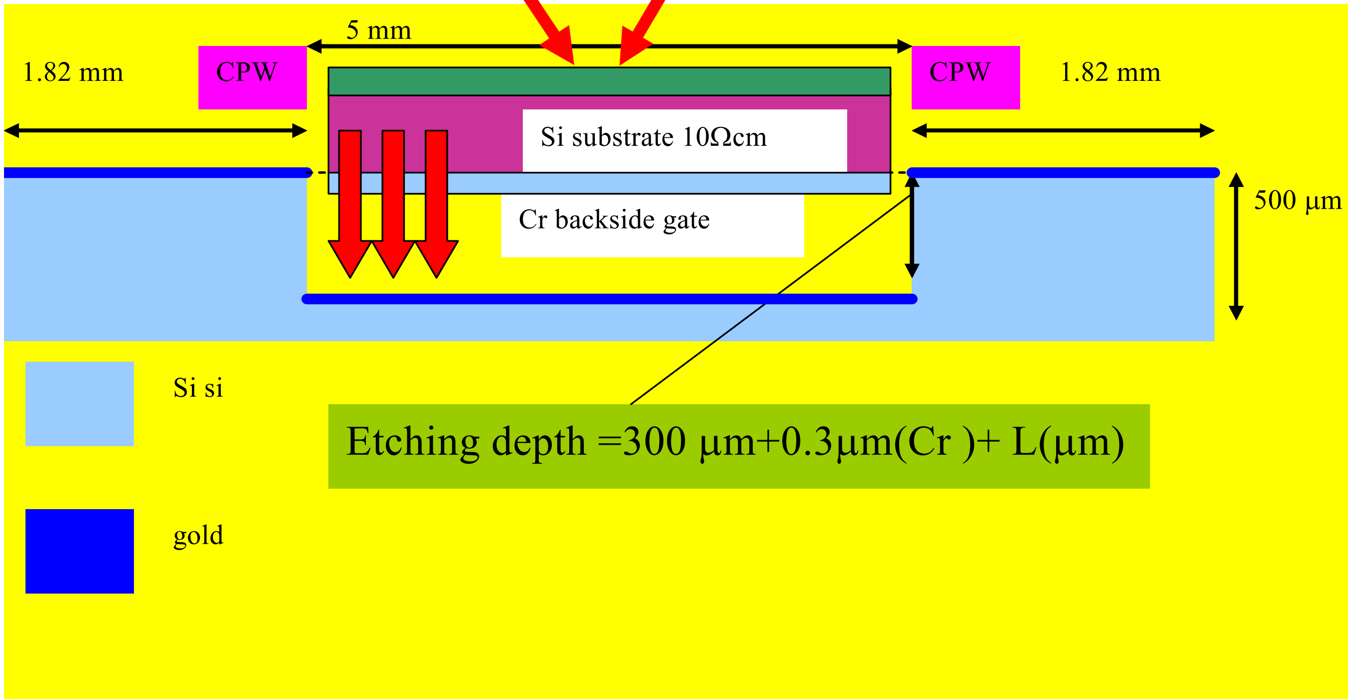
MWCNT metallic array already bought from Nanolab(USA) coated 300 nm Cr

0.5cm×0.5 cm×L(nm)

Diameter: 30 nm

DENSITY:

10^9 MWCNT cantilevers/cm^2



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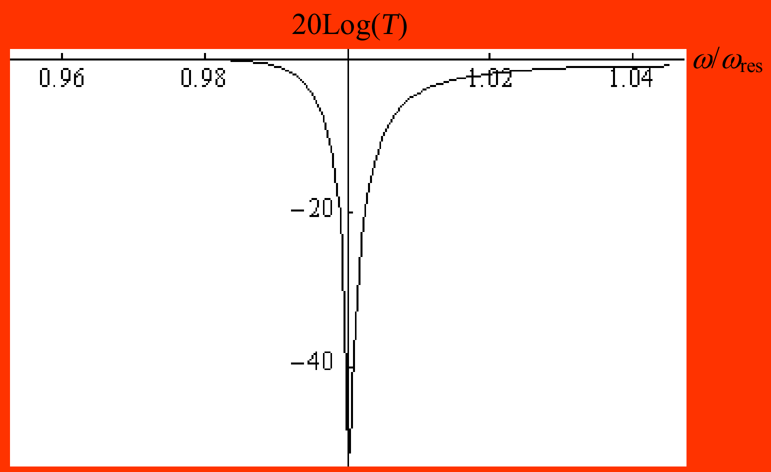

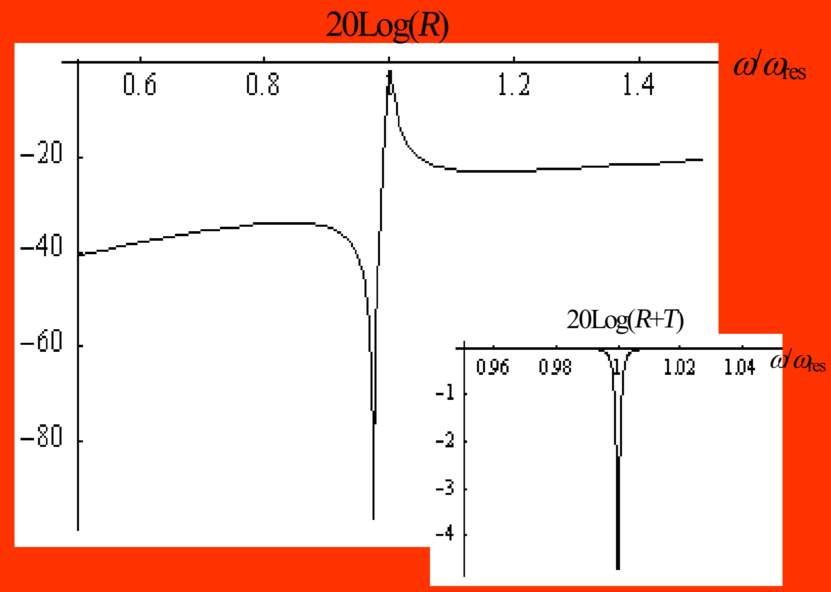

transmission

reflection

losses

D. Dragoman, M. Dragoman J. Applied Physics 99, 076106, 2006.

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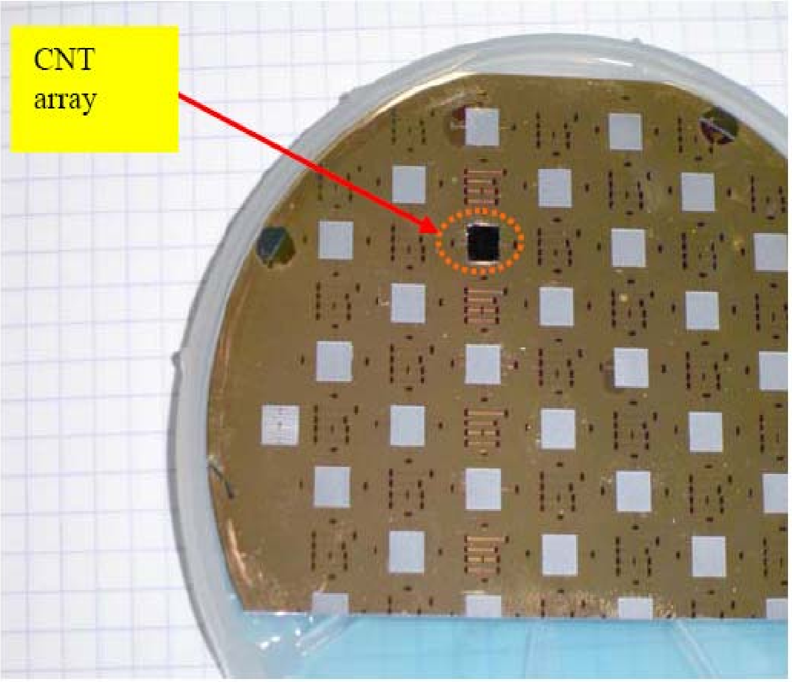

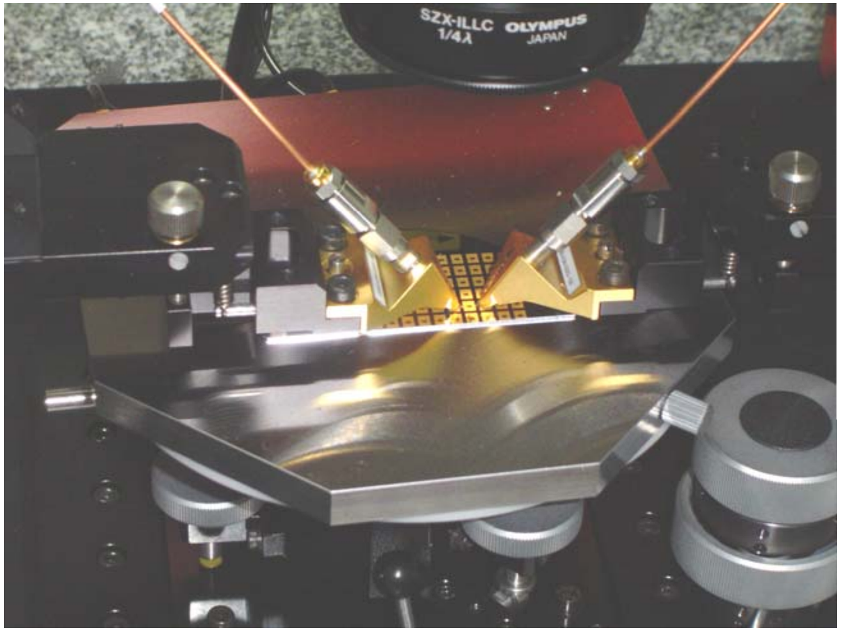

Microwave measurement

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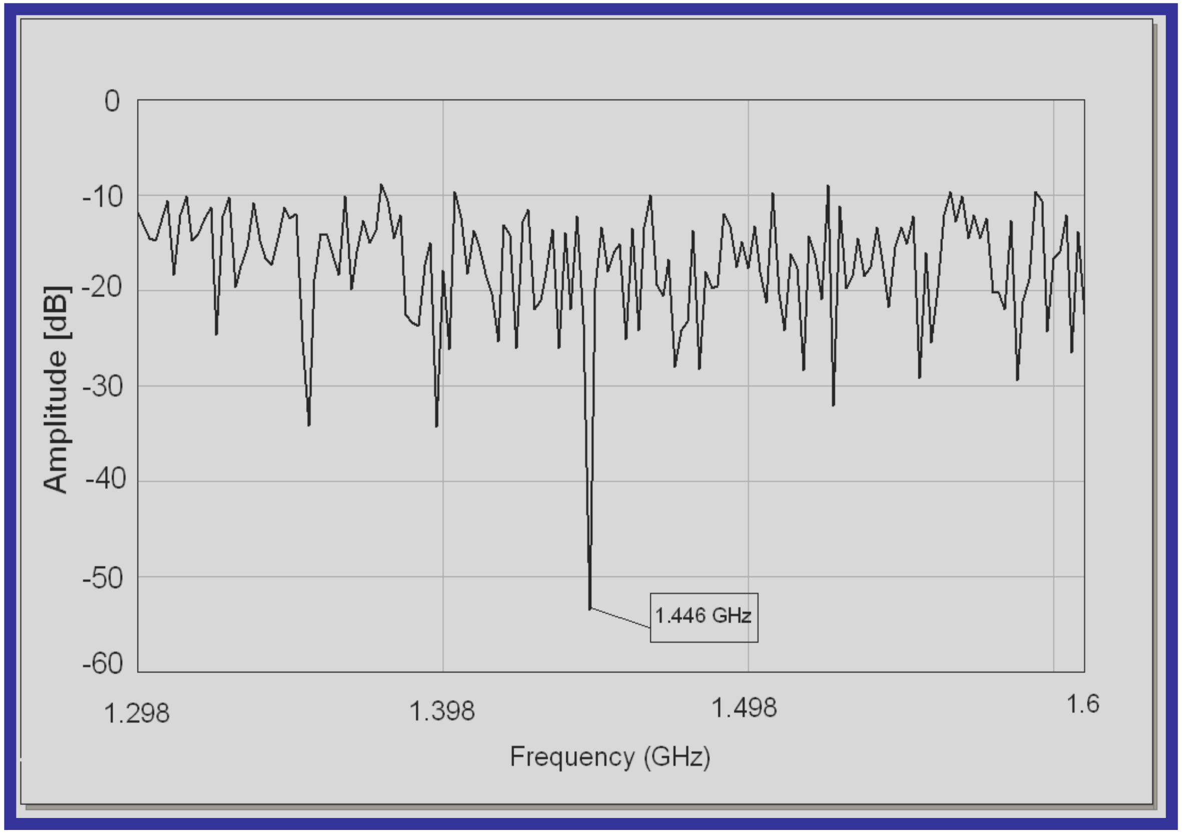

Quality factor around 800 for CNT array with a diameter of 40 nm and 300 nm length