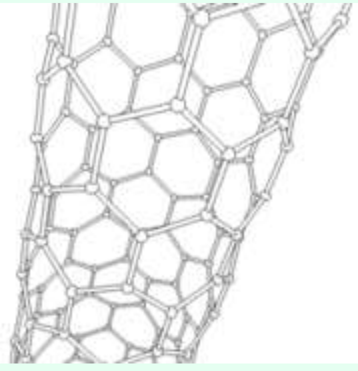
Chuiko O.O. Institute of Surface Chemistry
National Academy of Sciences of Ukraine

Deagglomeration of carbon nanotubes in aqueous solutions of variety compounds

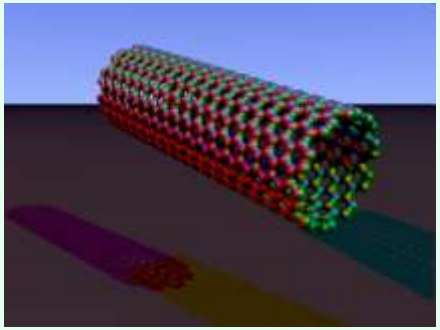


Senior Engineer: **Evgeniya Kovalska**

Carbon nanotubes: uniqueness, features

Structure of CNTs

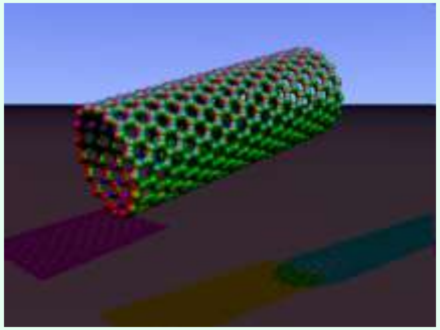
Single-walled CNT, armchair (n,n)



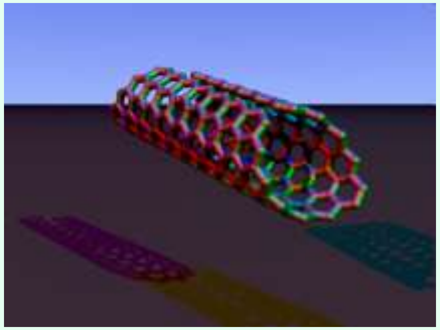
Properties	Characteristics	Values
geometric	-layering -diametr -length	SWNT/MWNT ~0,4 nm÷>3 nm (SWNT) ~1,4 nm÷>100 nm (MWNT) several microns (ten)
mechanical	-Young's modulus -tensile strength -density	~1 TPa (steel 0,2 TPa) 45 GPa (steel 2 GPa) ~1,33 – 1,4 g/sm3 (Al-2,7 g/sm^3)
electric	-conductance -maximum current density -field-emission	metal / semiconductor ~1 TA/sm^3 (Cu-1 GA/sm^3) at 1– 3 V
thermal	-thermal conductivity	>3 кW/m•К (diamond 2 кW/m•К)
physical and chemical	-specific surface	100 – 1000 m^2/g

Rakov E. Chemistry of carbon nanotubes / Handbook of Nanomaterials. – 2005.

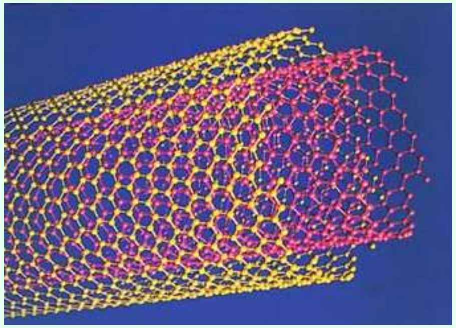
Single-walled CNT, zigzag (n,0)



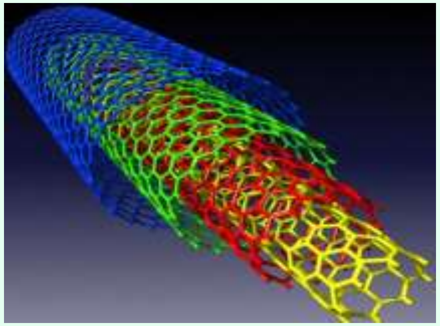
Single-walled CNT, chiral (n,m)



Double-walled CNT



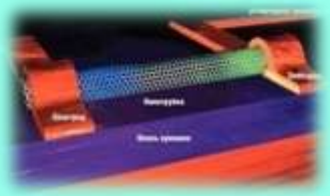
Multi-walled CNT

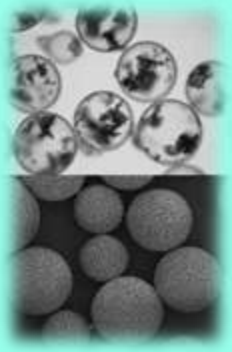


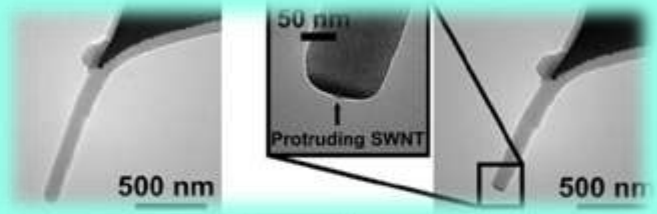
Carbon nanotubes: application field

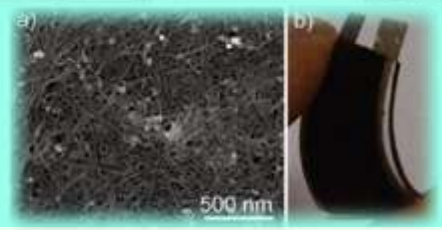
A P P L I C A T I O N

(carbon nanotubes)







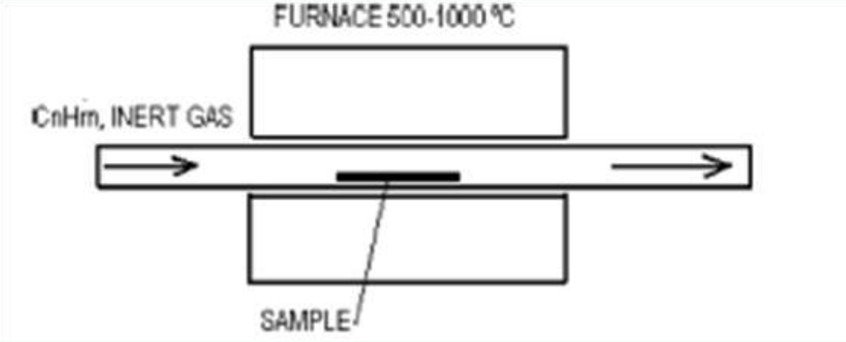


Increasing levels of system using and integration →

Materials	• Single-walled nanotube fibers	• Nanotube composites	• Integral thermal/shape control	• Smart "skin" materials	• Biomimetic material systems
Electronics/ computing	• Low-Power CNT electronic components	• Molecular computing/data storage	• Fault/radiation tolerant electronics	• Nano electronic "brain" for space exploration	• Biological computing
Sensors, Devices	• In-space nanoprobes	• Nano flight system components	• Quantum navigation sensors	• Integrated nanosensors	

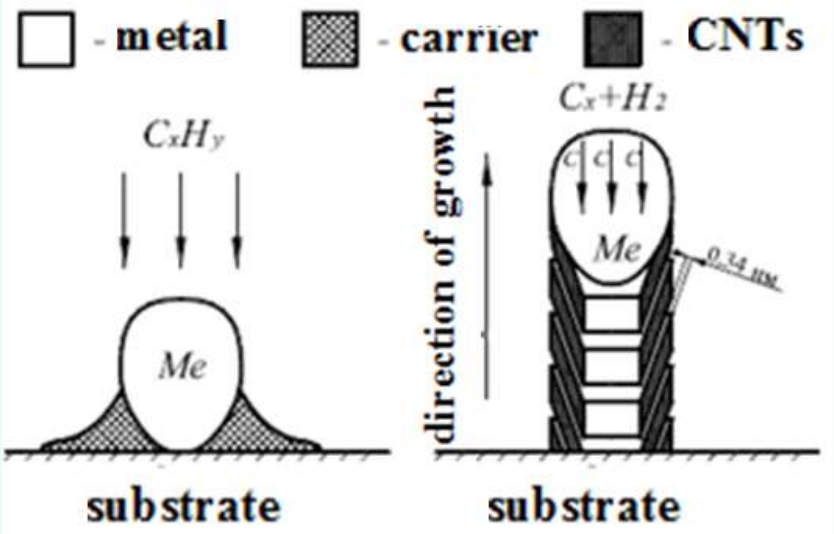
Features of synthesis of carbon nanotubes by Chemical Vapor Deposition

Scheme of CVD reactor



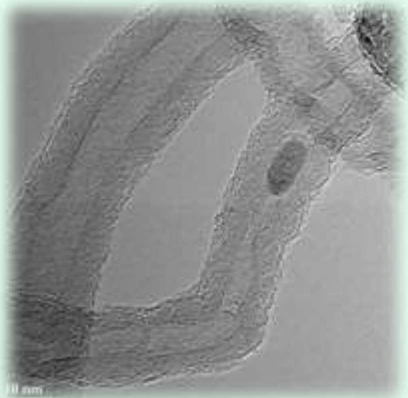
Pilot plant for synthesis of the CNTs

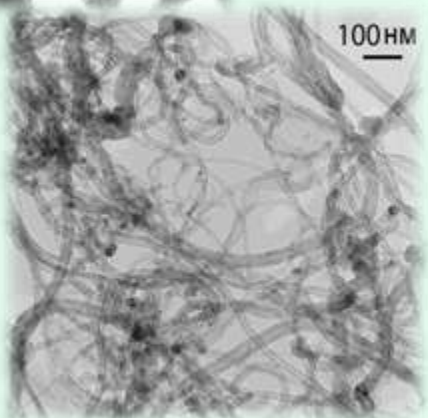
The model of catalytic growth of CNTs

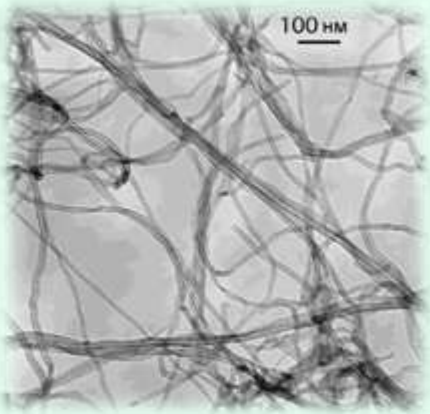


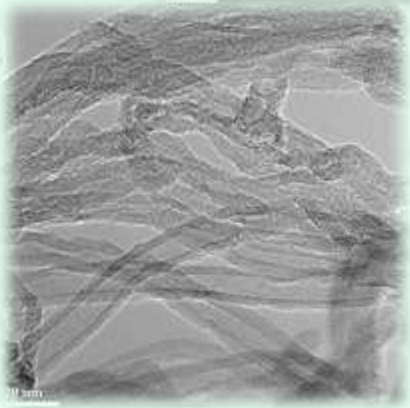
Features of synthesis of carbon nanotubes by Chemical Vapor Deposition

Synthesized products









Characteristics of synthesized CNTs by CVD method:

- Average diameter: 10 – 20 nm
- Specific surface: 200 – 500 m^2/g
- Bulk density: 15 – 40 g/dm^3
- The content of mineral admixtures: 6 – 20% (unpurified), < 1% (purified)

Characteristics of the synthesized carbon nanotubes by Chemical Vapor Deposition

Fig. 1. TEM images of the synthesized MCNTs

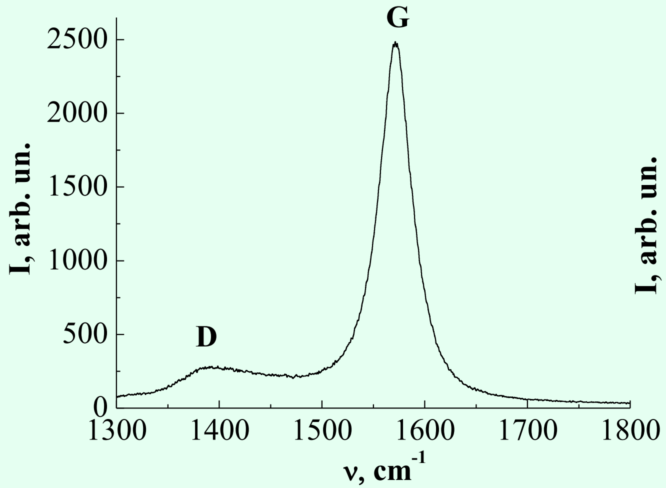


Fig. 2. Raman spectra of the synthesized MCNTs

Table 1. Results of mathematical processing of XPS spectra for samples of the synthesized MCNT

Sample	The quantitative ratio of carbon and oxygen in the samples (C: O)	Binding energy, eV		The concentration of functional groups on the C1s-spectrum, % (at.)
		C1s	O1s	
MCNTs	96 : 4	283,9	531,42	C-O – 58 C=O – 42

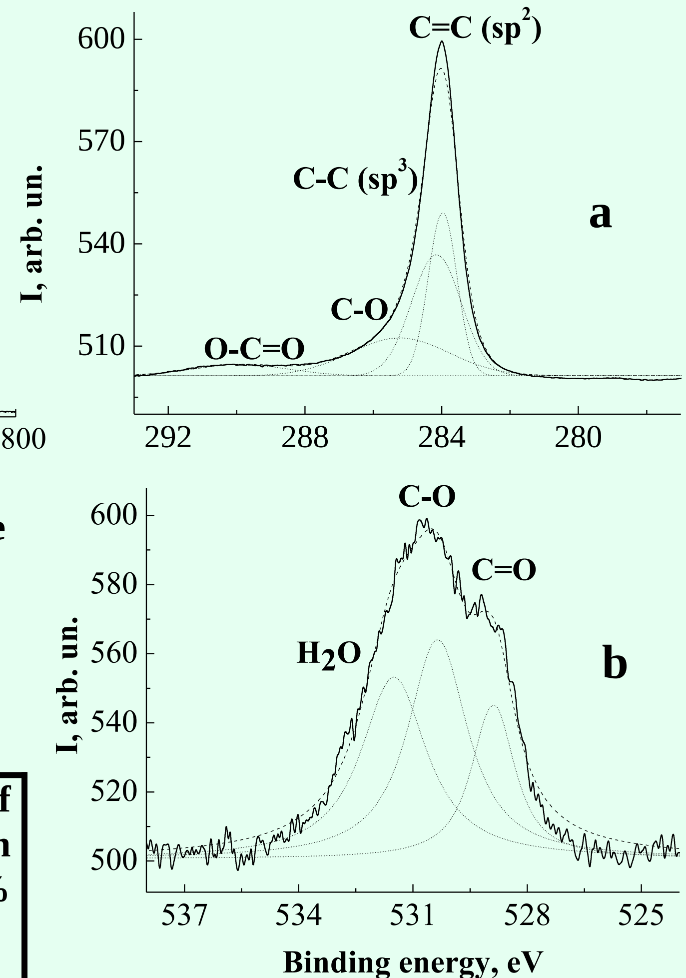


Fig. 3. XPS spectra of the synthesized MCNTs: C1s (a); O1s (b)

Composites based on CNTs and main problems in creating composite materials

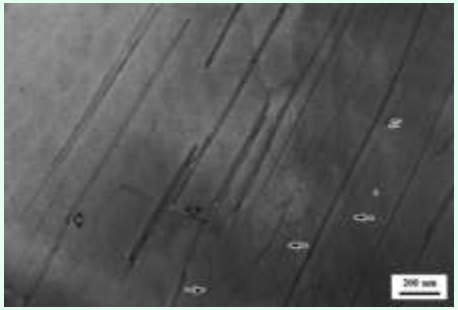


Fig. 4. Alignment of nanotubes in polymer matrix following cutting with microtome: arrows indicate buckled nanotubes

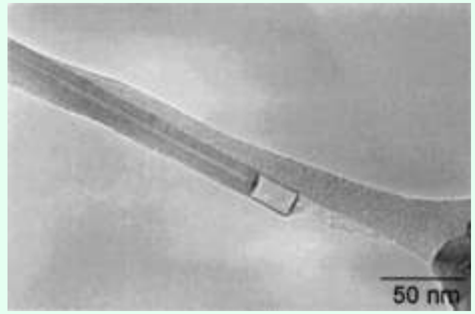


Fig. 5. Image of epoxy coated MWNT subject to tensile stress as result of electron irradiation: telescopic pull-out of outer tube layer has occurred

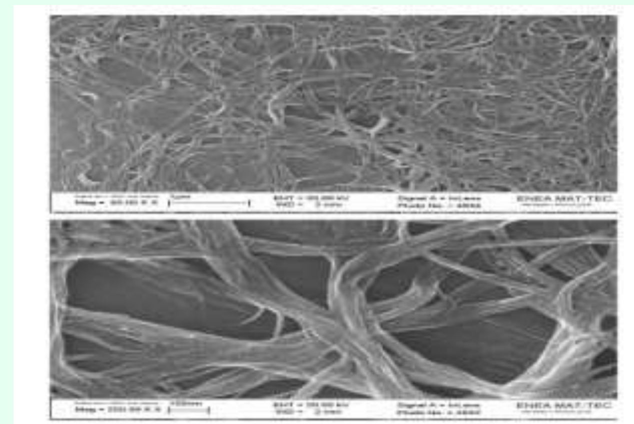


Fig. 8. Multiwalled (laminated) nanocomposites: blocks of carbon nanotubes had attached to the tape and placed in the folds of woven carbon composite to enhance the multiwalled material; carbon nanotubes are related to the carbon cloth

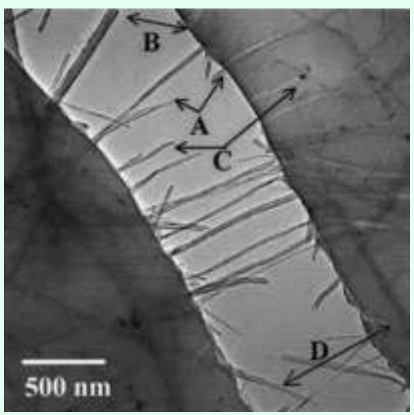


Fig. 6. TEM image of crack in MWNT/polystyrene thin film induced by thermal stresses

Fig. 7. Thin and flexible paper battery of cellulose-based implanted nanotubes as electrodes

Methods of homogenization

Ultrasonic treatment

Vortex treatment

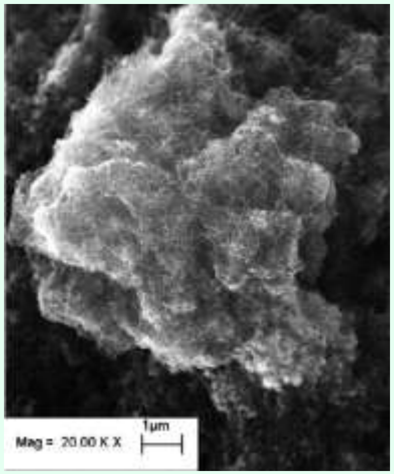
Cavitation treatment

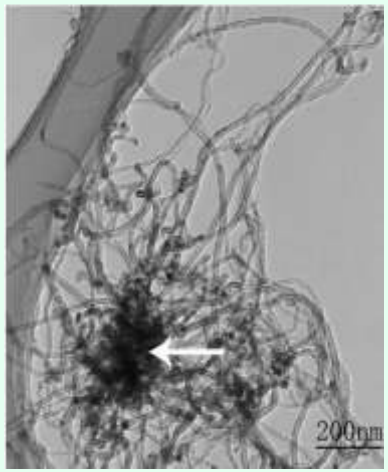
PROCESSES

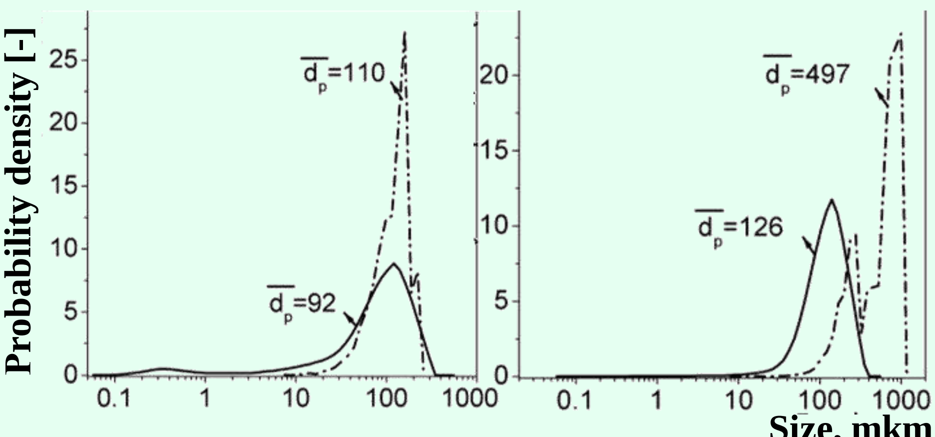
- ✓instantaneous mixing without separation
- ✓destruction of the aggregate state
- ✓activation of the chemical bonds
- ✓dispersion
- ✓depolymerisation
- ✓homogenization

Study of the characteristics of the synthesized agglomerates of CNTs

Agglomerates of CNTs are obtained by CCVD







a b

Fig. 9. Comparison of particle sizes are determined by laser scanning method and statistical processing mikro-photos (─ laser scanning, - • - statistics mikrophotos): original catalytic particles (a); agglomerates of MCNTs (b)

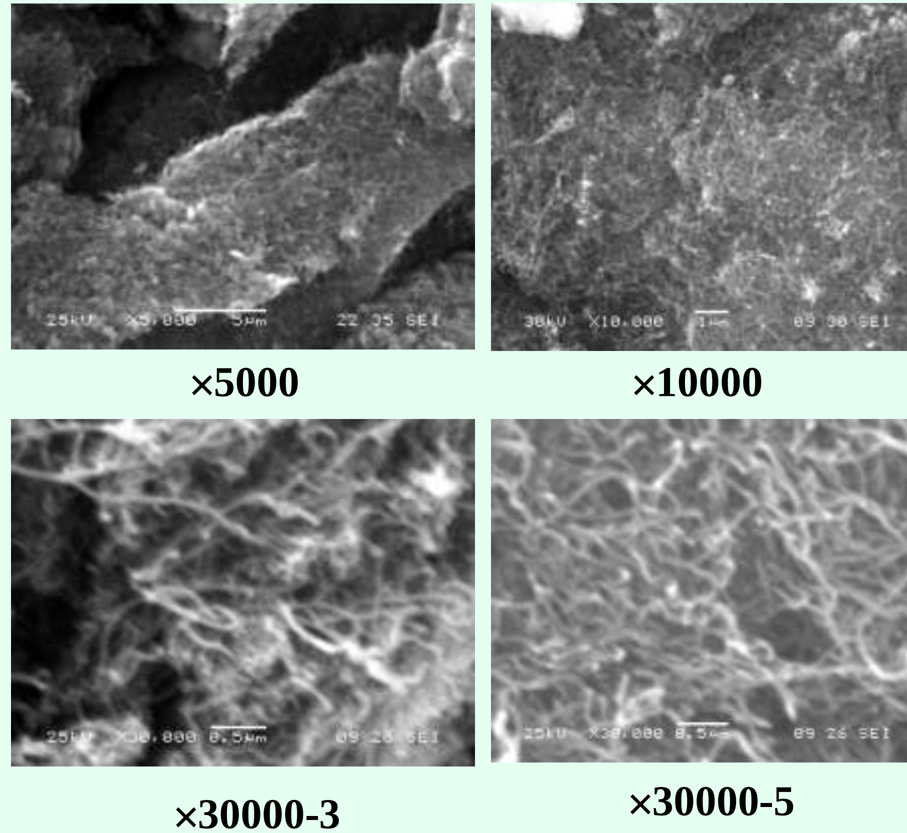
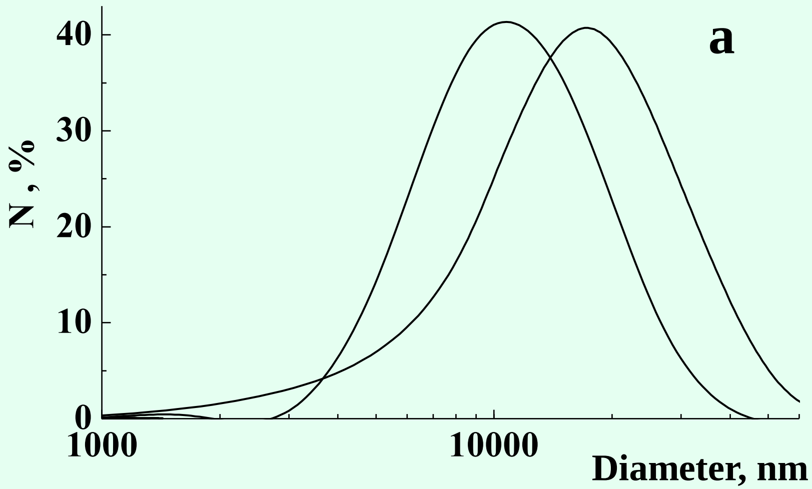


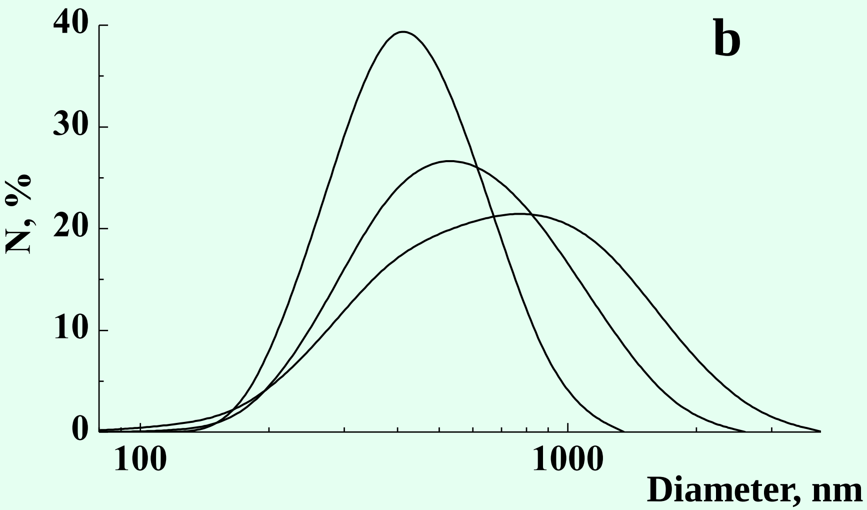
Fig. 10. SEM MCNTs agglomerates are obtained from propanol and purified aqueous solution of HCl - HF

Deagglomeration of the carbon nanotubes in aqueous solutions of different actuators

Water systems	Type of treatment	Time of treatment, min	Distribution of CNTs-size	The stability of dispersions
$C_6H_{12}O_6$/CNTs	ultrasound	10-20	1-100 micron	non
H_2O/CNTs	cavitational	2-4	1 – 100 nm	non
C_2H_5OH/CNTs	rotary homogenizer	2-5	450 nm	non
Water-soluble polymer and ionic surfactant system/CNTs	rotary homogenizer	2-5	150 – 400 nm	half year

Stability of deagglomerated CNT suspensions in aqueous solutions





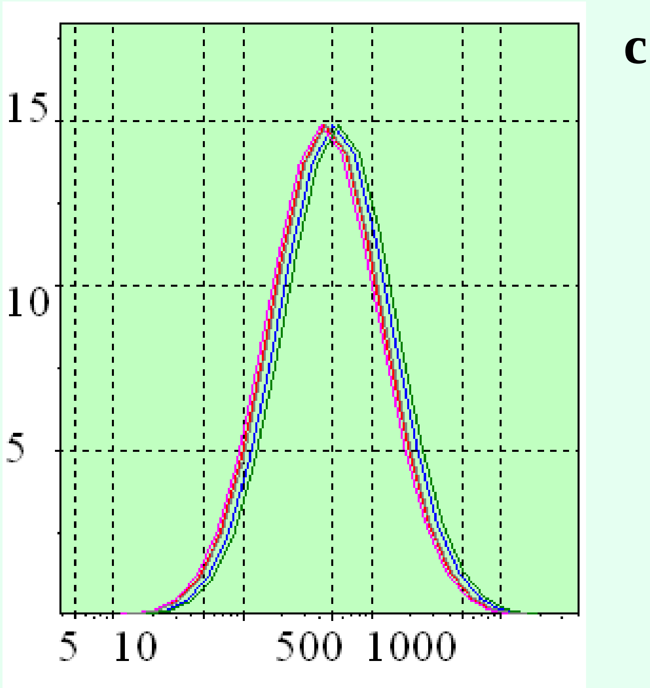
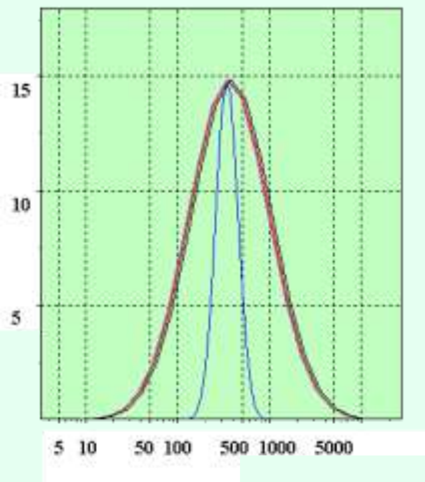
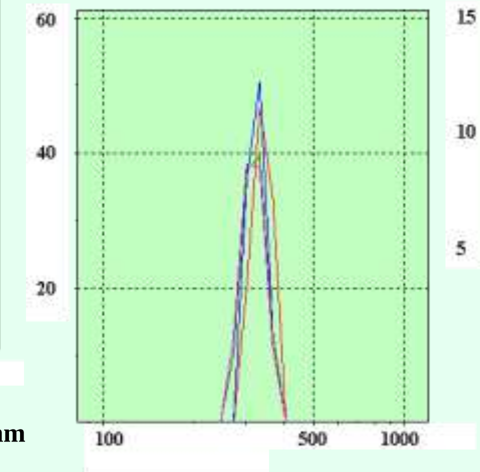


Fig. 11. The distribution of the CNT agglomerates by size: after ultrasound treatment in 3% aqueous solution of glucose with 0.067 wt%. CNTs (a); after cavitation processing system with 0.05 wt%. CNTs (b); after processing with rotating homogenizer in ethanol 0.05 wt% CNTs (c)

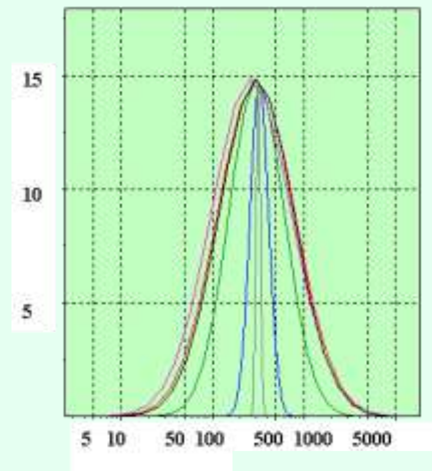
Stability of the CNT/water-soluble polymer/ionic surfactant system



a

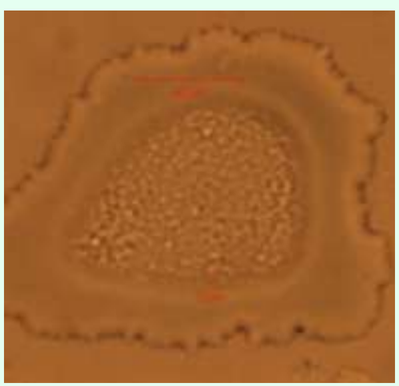


b

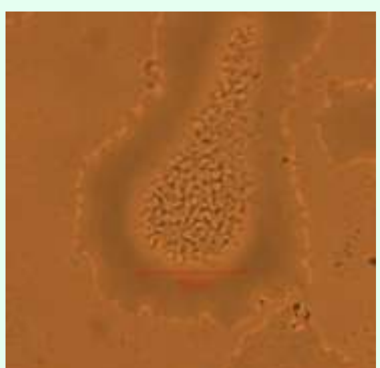


c

Fig. 12. The size distribution plots of the CNTs agglomerates after the treatment in rotation homogenized of the CNT/water soluble polymer/ionic surfactant system: monodisperse distribution of sizes from 220 to 450 nm with an average size of 360 nm (a); solution diluted in 5 times, a stable suspension of nanoparticles with an average size of 300 nm (b); in polymodal approximation there of the smaller fraction of size about 150 nm (c)



a



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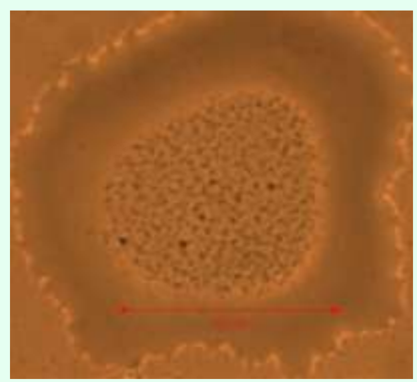

c

Fig. 13. CNT/water-soluble polymer/ionic surfactant mixture films, deposit on the glass surface, correspondingly to the Fig. 9.

Conclusions:

- **Deagglomeration of the carbon nanotube bundles were performed in an aqueous solutions of different chemical composition using ultrasound, cavitation and rotating homogenizing treatment.**

- **Degree of dispersion performed through cavitation is strongly depends on the concentration of the CNTs in water. Preparation of the unsaturated solutions (> 3 wt. % CNTs) helps to the formation of the homogeneous mixture, in which the particles are uniform and with size of 10–200 nm. The organic additive ($C_6H_{12}O_6$) increases the efficiency of the dispersion during the ultrasound treatment. Processing with an universal homogenizer of the CNT/water-soluble polymer/ionic surfactant system results in the stable solution with a particle size of from 150 to 400 nm.**

- **Obtained results are helps to: explain behavior of the CNTs agglomerates during the homogenizing procedure; underline the factors which are helps to homogenize CNTs in the aqueous solutions. Utilizing of the CNT/water-soluble polymer/ionic surfactant mixture coupled with homogenizer machine shows the best results in terms of the solution stability, particles size and their distribution. Developed pathway is the open road for CNT/polymer composites preparation.**

Thank you
for your attention!