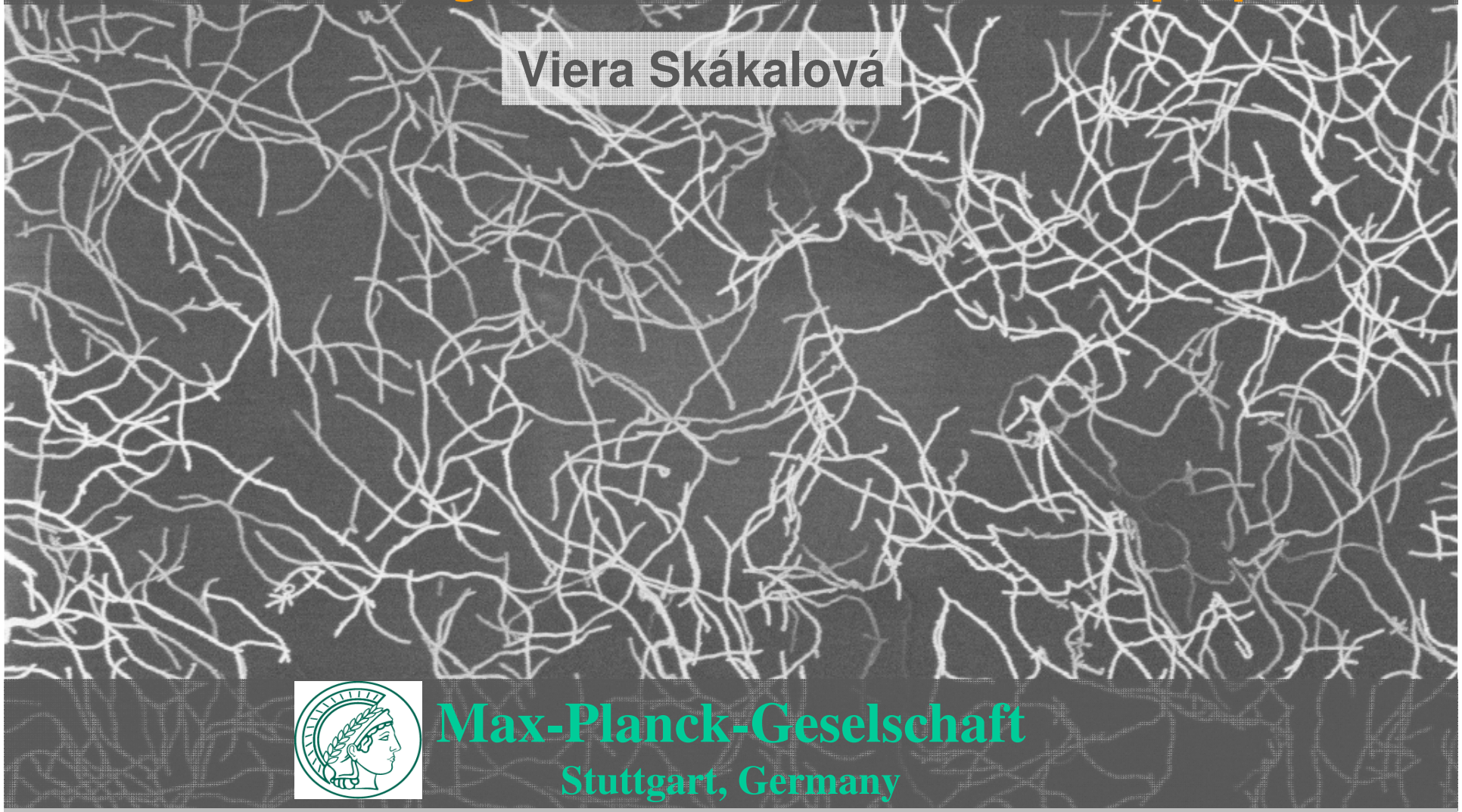
Ion-Irradiated Carbon Nanotube Networks:
Correlated changes in Conduction and other properties

Viera Skákalová



Max-Planck-Geselschaft
Stuttgart, Germany

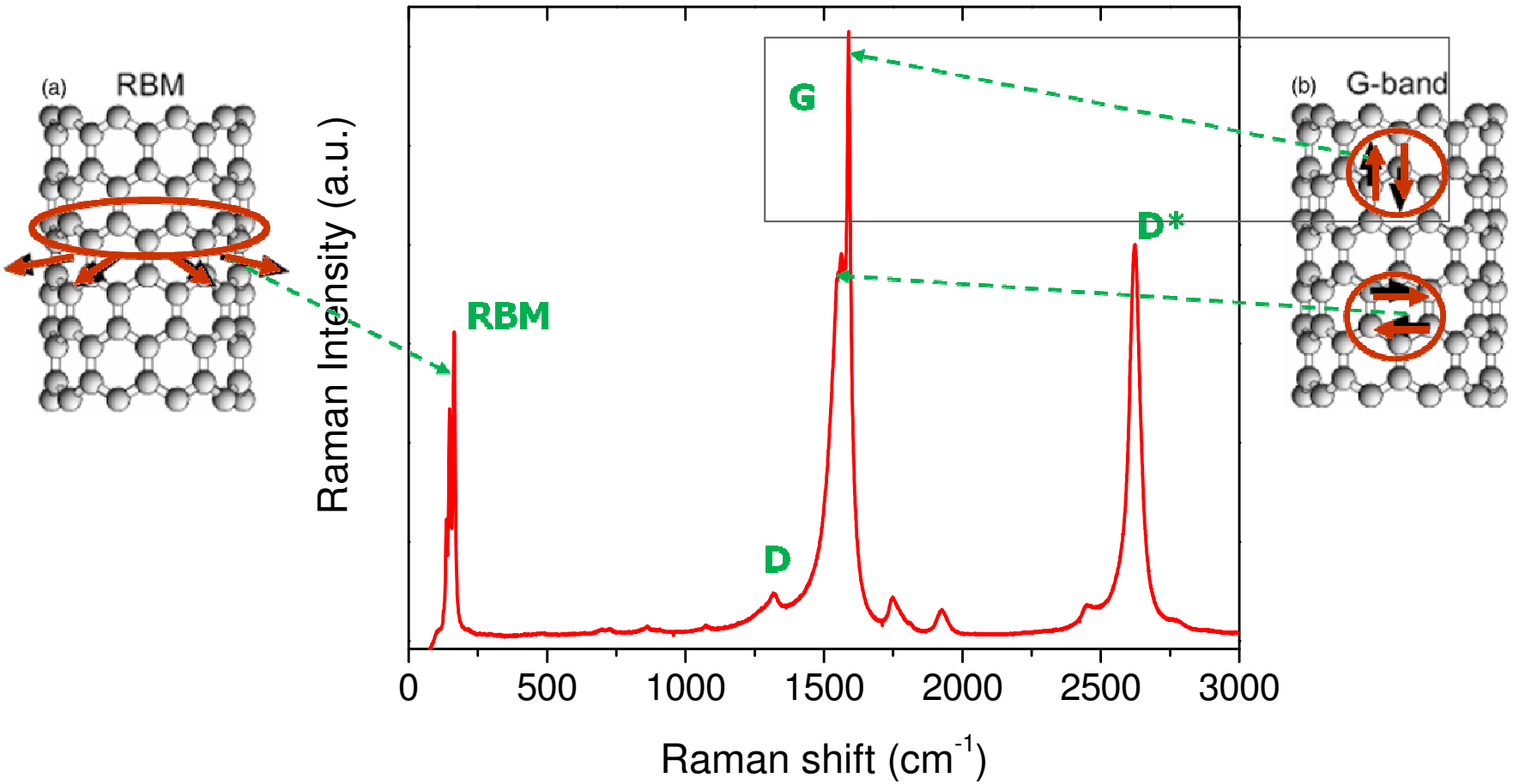
Danubia NanoTech, s.r.o.
Bratislava, Slovakia

Characterization:

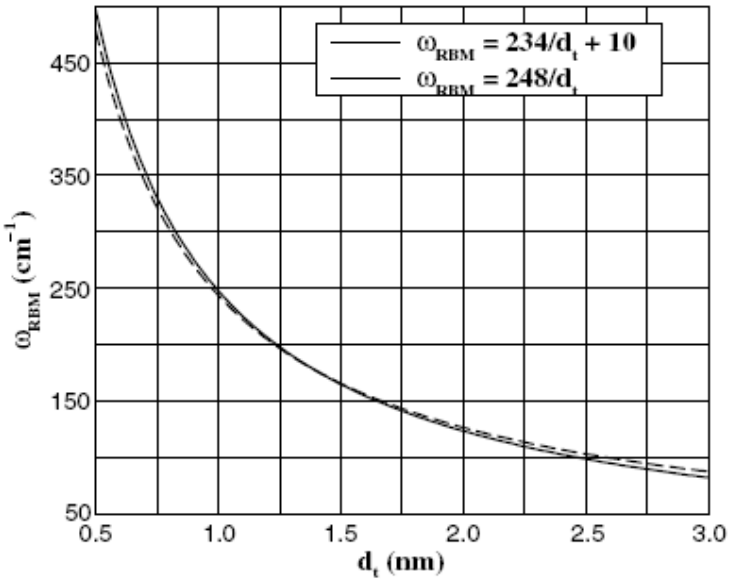
1. Raman spectroscopy
2. Optical spectroscopy (NIR,VIS)
3. Transmission electron microscopy (TEM, HRTEM)
4. Scanning electron microscopy (SEM)
5. Atomic force microscopy (AFM)

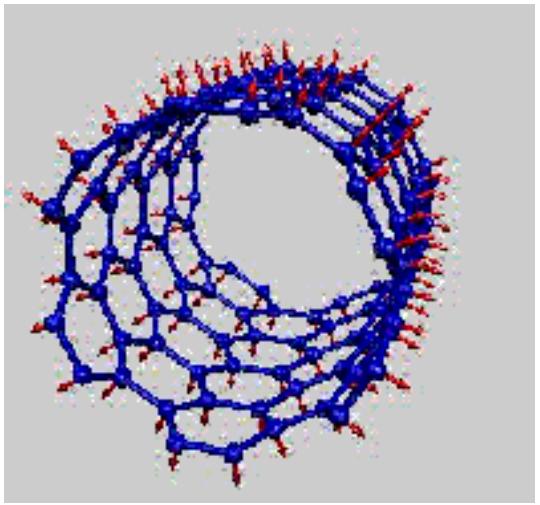
Raman specroscopy

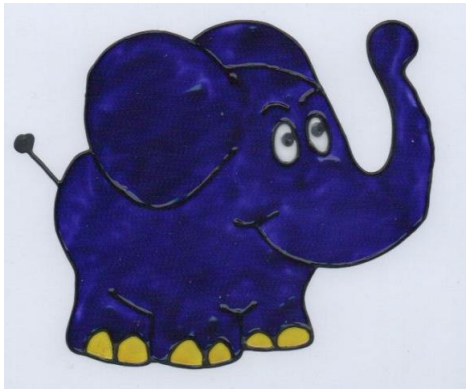
- inelastic photon scattering



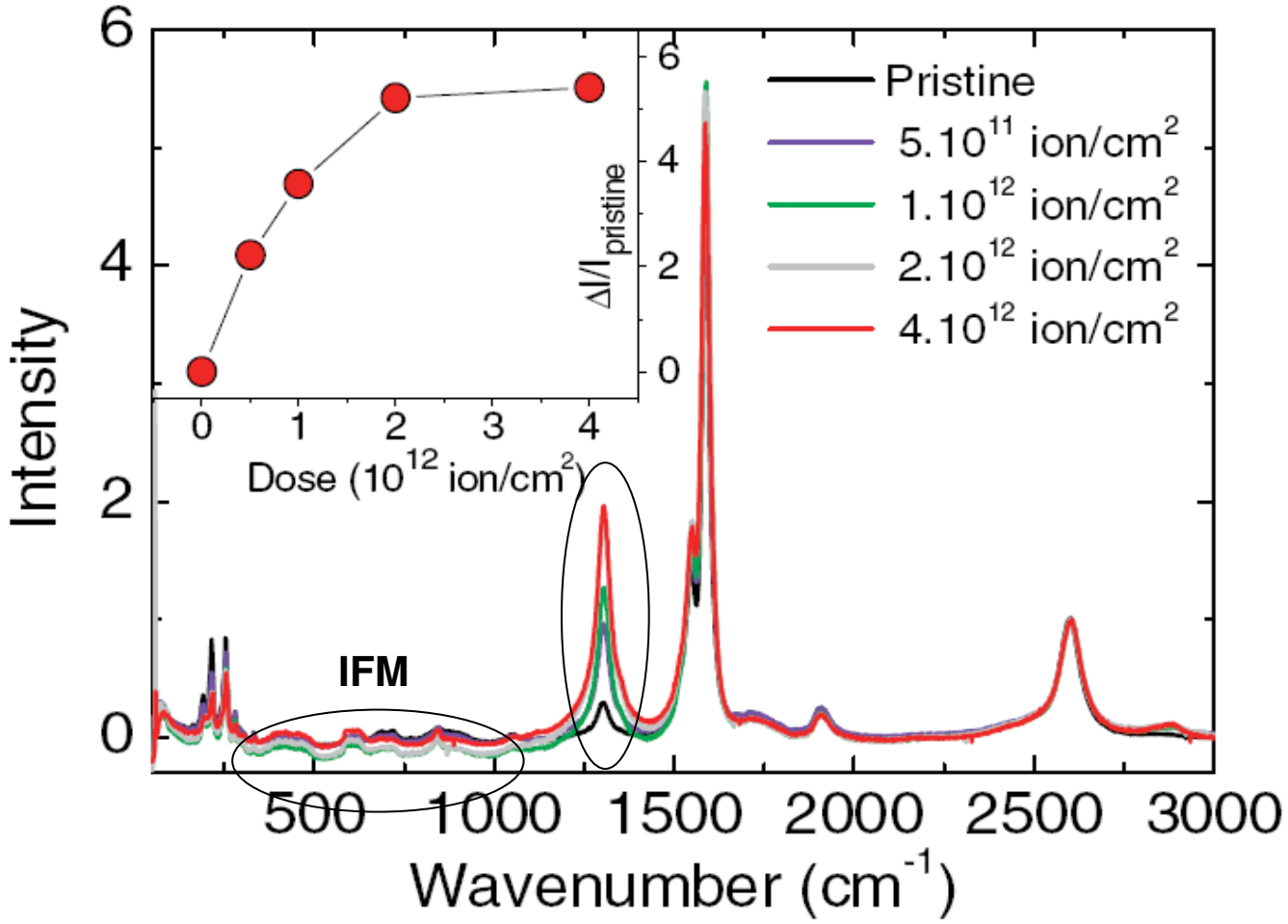
Radial Breathing Mode - RBM



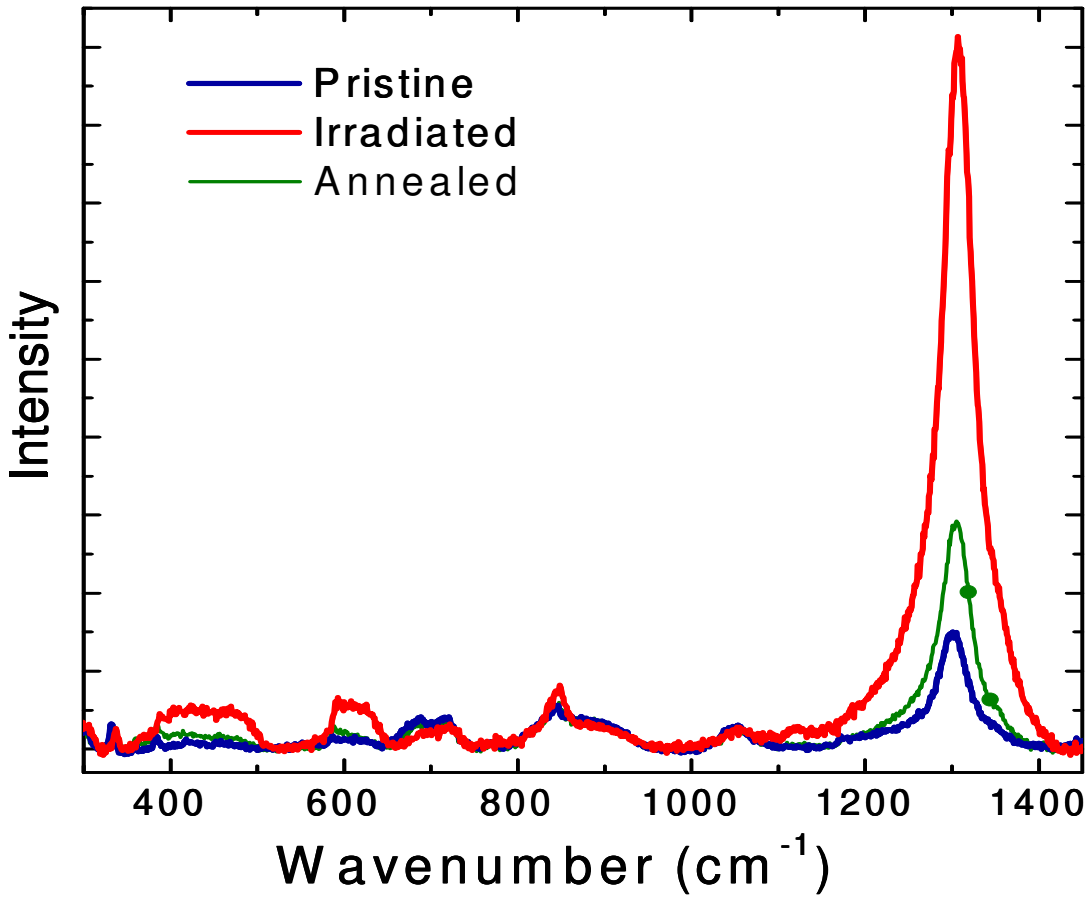




Raman spectra of pristine and Ar+ irradiated SWNTs
Inset: ΔI/I of the D-mode vs. Dose of Ar+ ions

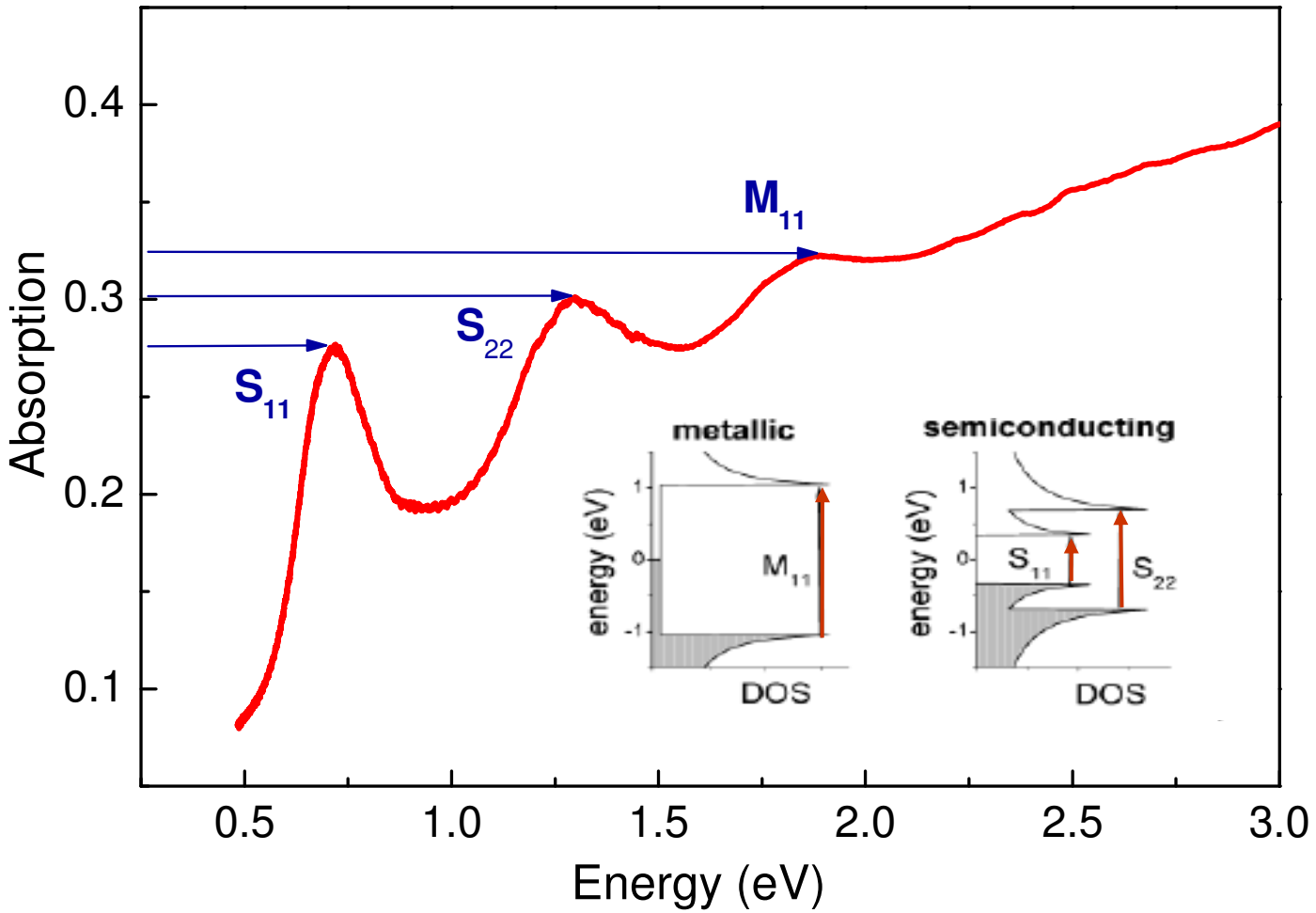


Effect of annealing

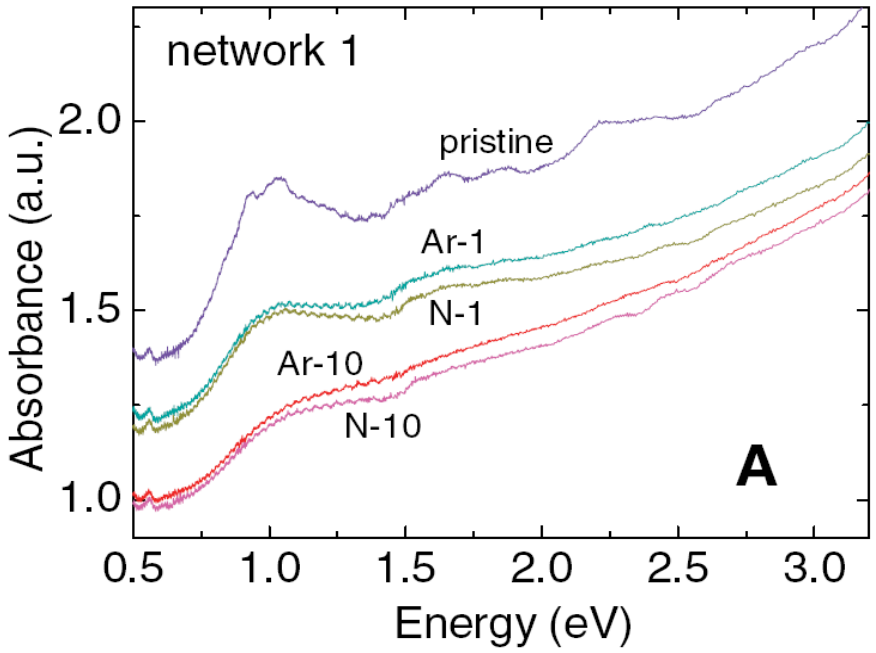


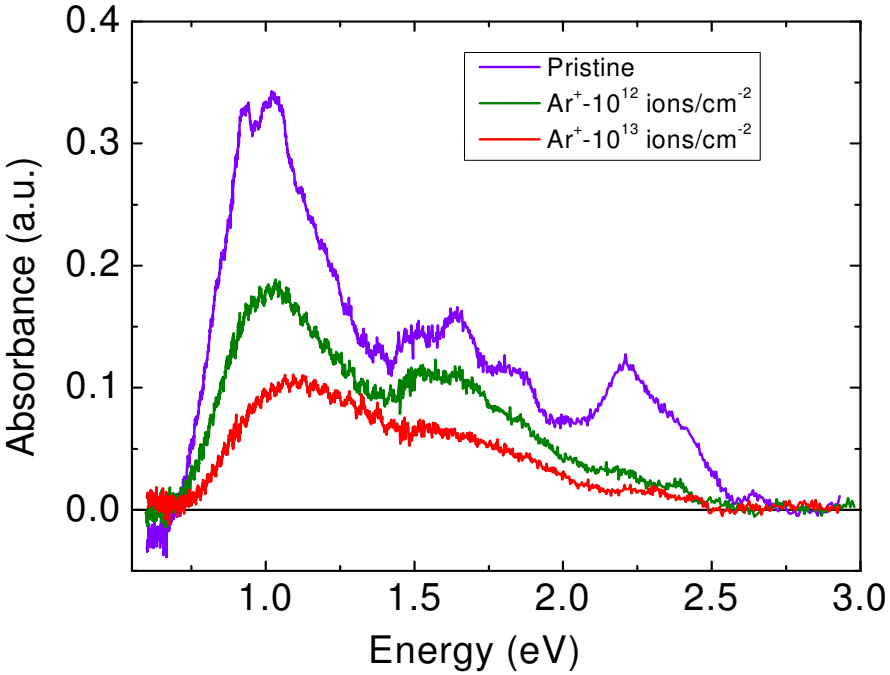
Viera Skákalová, Janina Maultzsch, Zoltán Osváth, László P. Biró, and Siegmar Roth,
Phys. Stat. Sol. (RRL) 1, No. 4, 138– 140 (2007)

Optical specroscopy

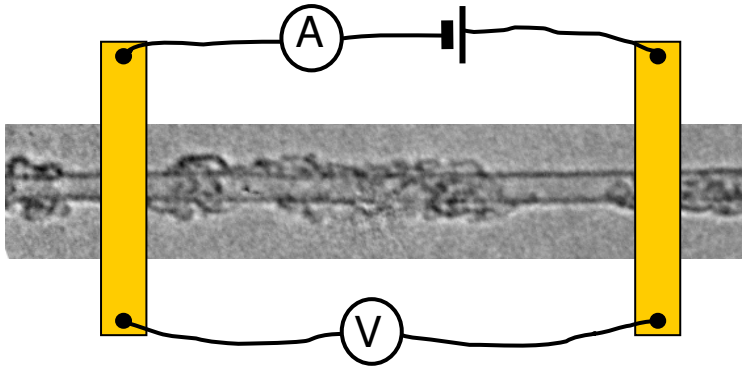


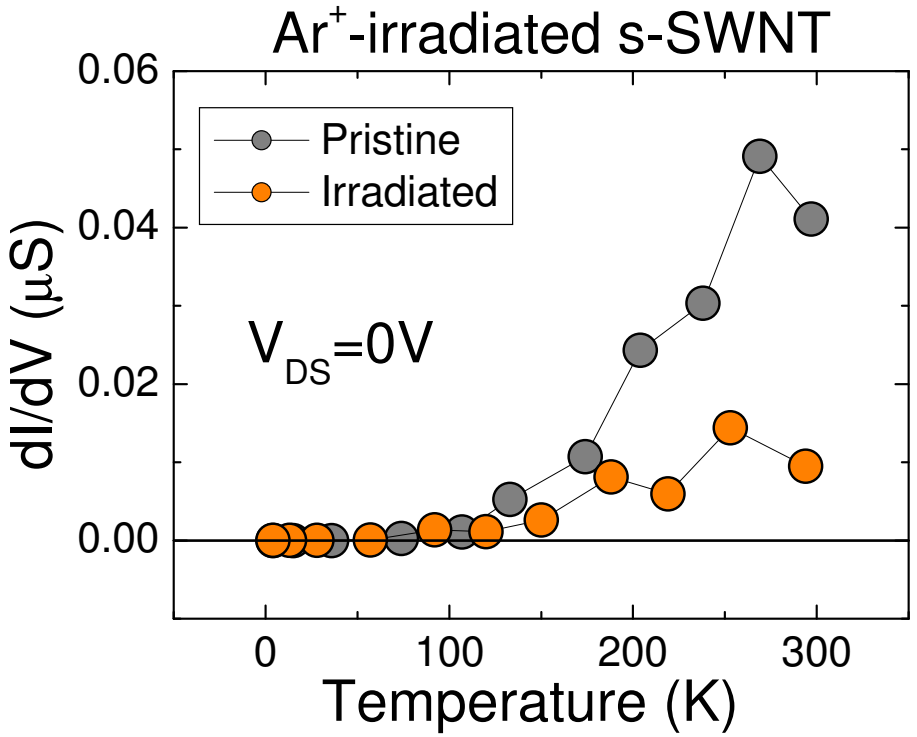
Optical absorption spectra of irradiated SWNT



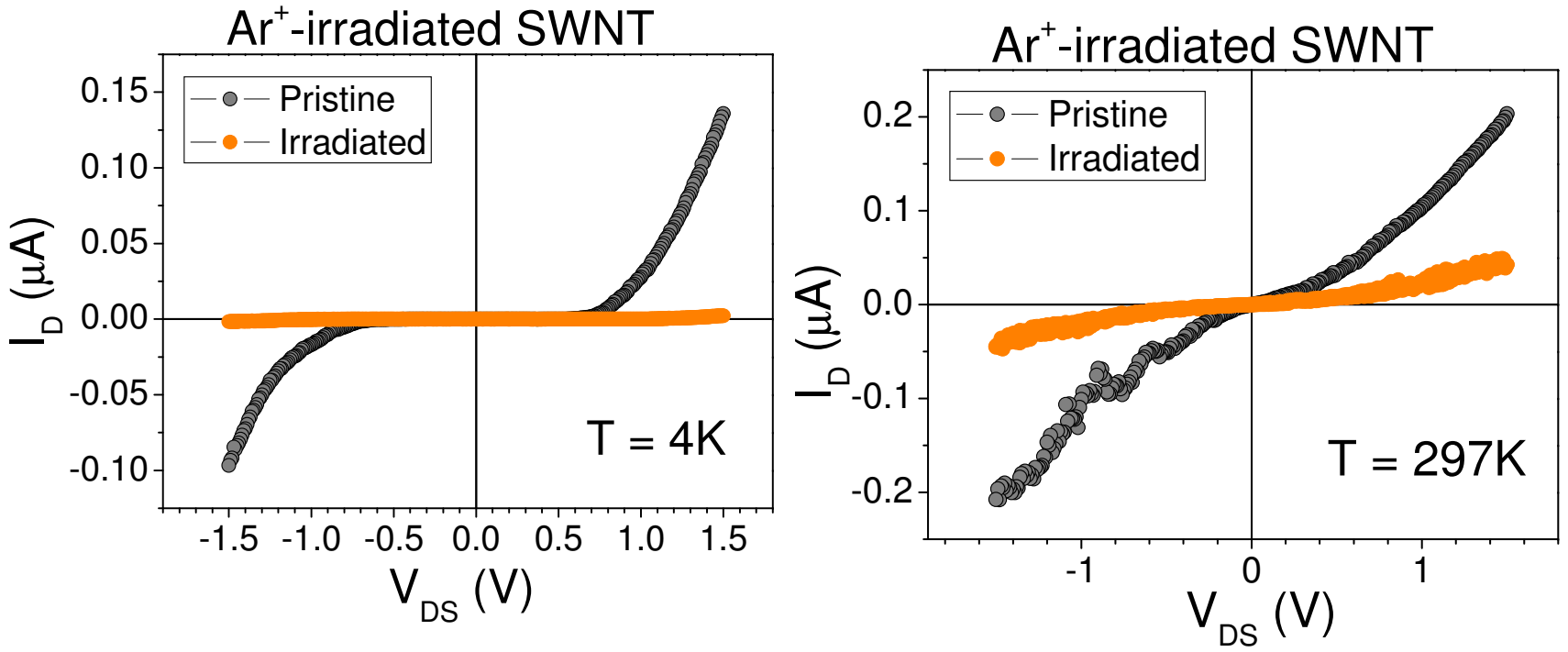


Electron transport in individual SWNT

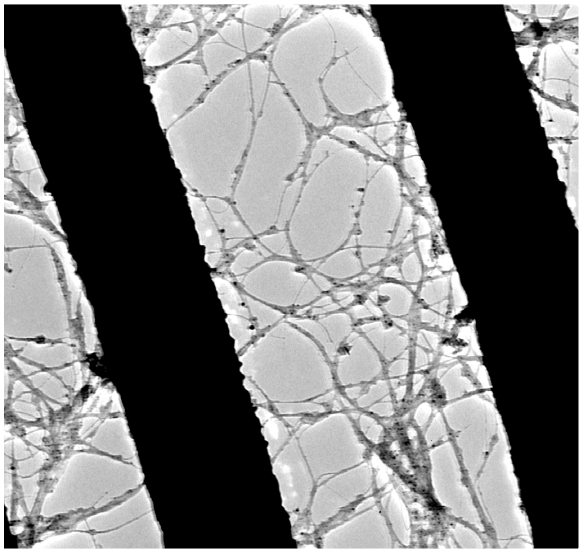


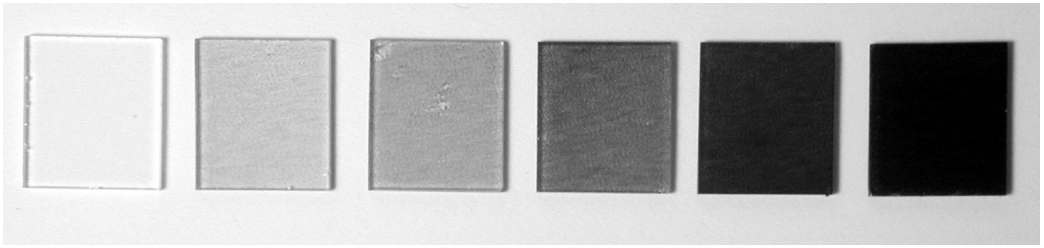


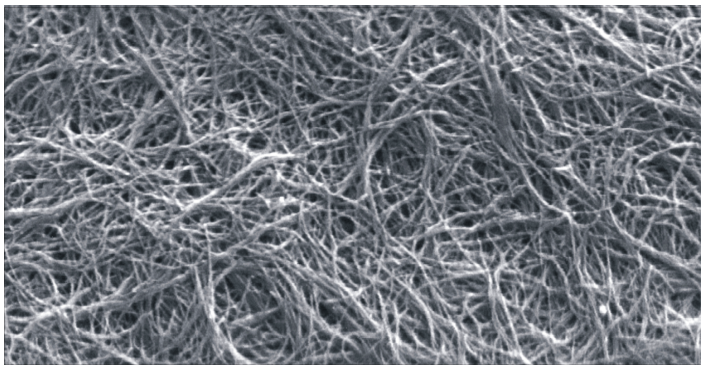
I-V plots before and after Ar^+-irradiation (5.10^{11} ion/cm^2):

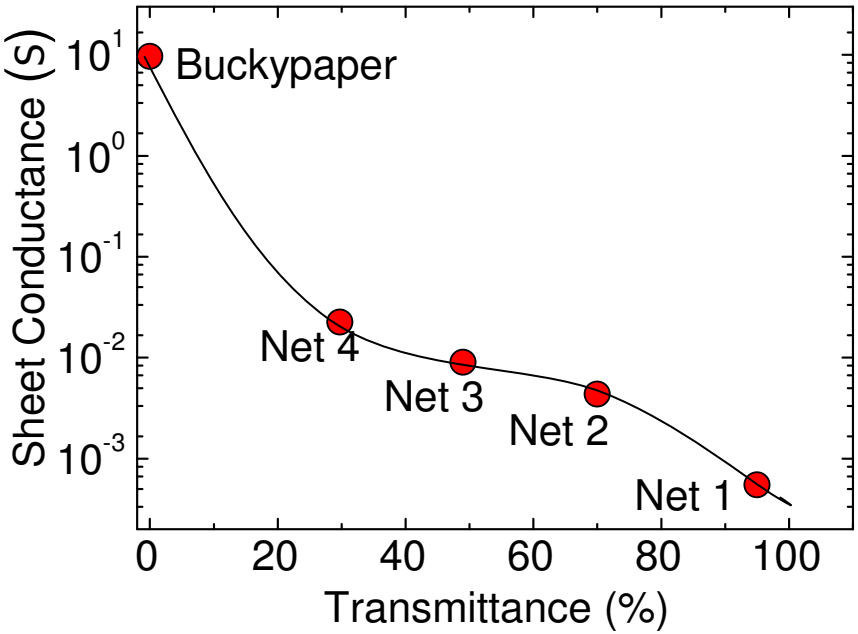


SWNT networks



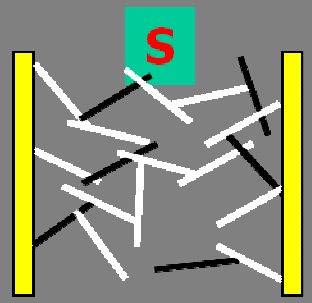




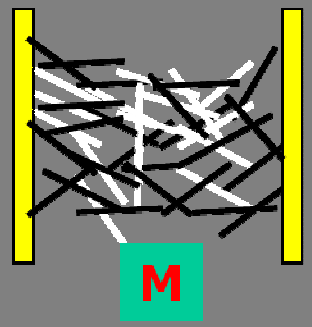


Electronic properties of SWNT networks

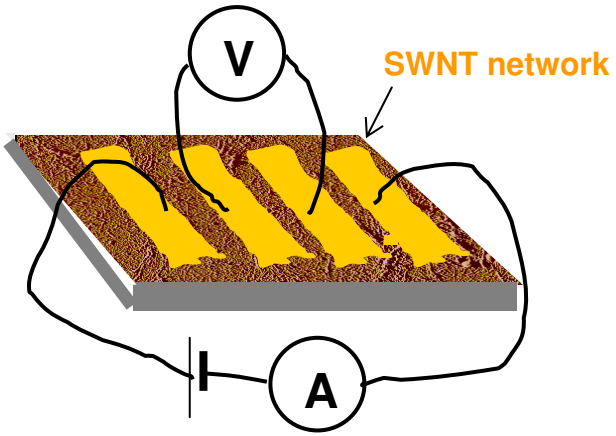
1. **Thin SWNT network:** semiconducting

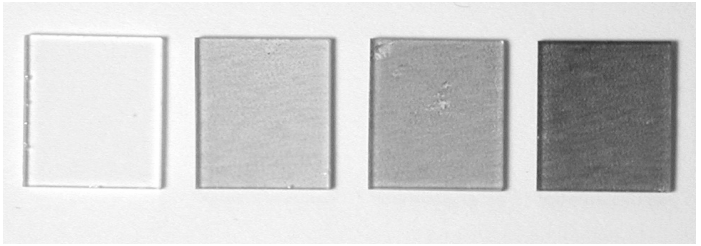


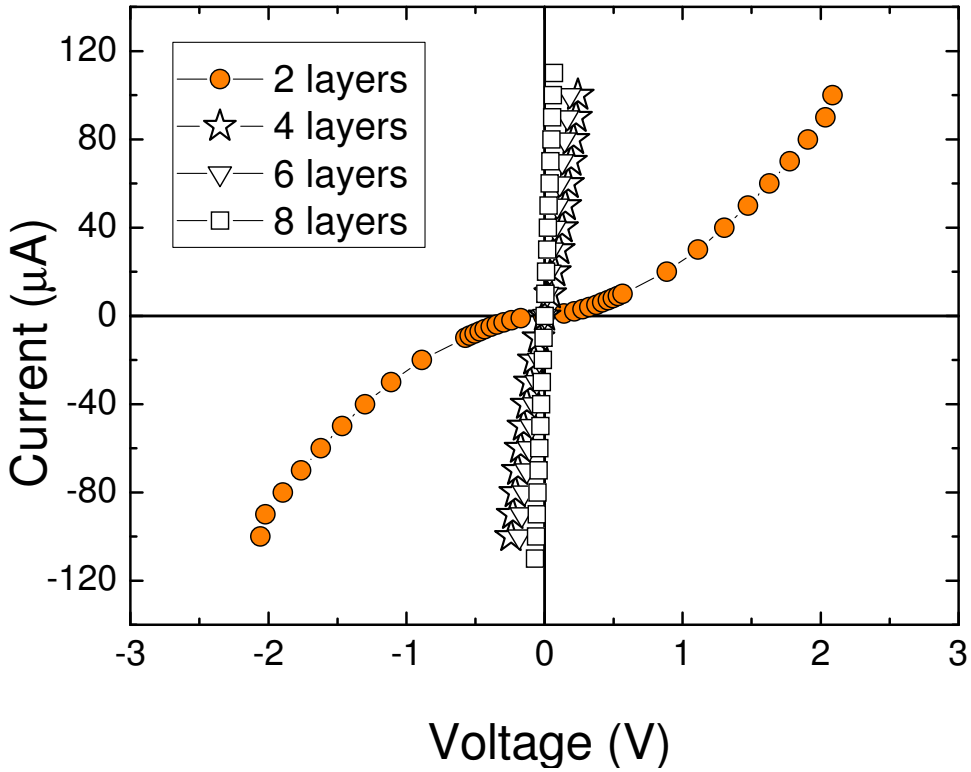
2. **Thick SWNT networks:** metallic



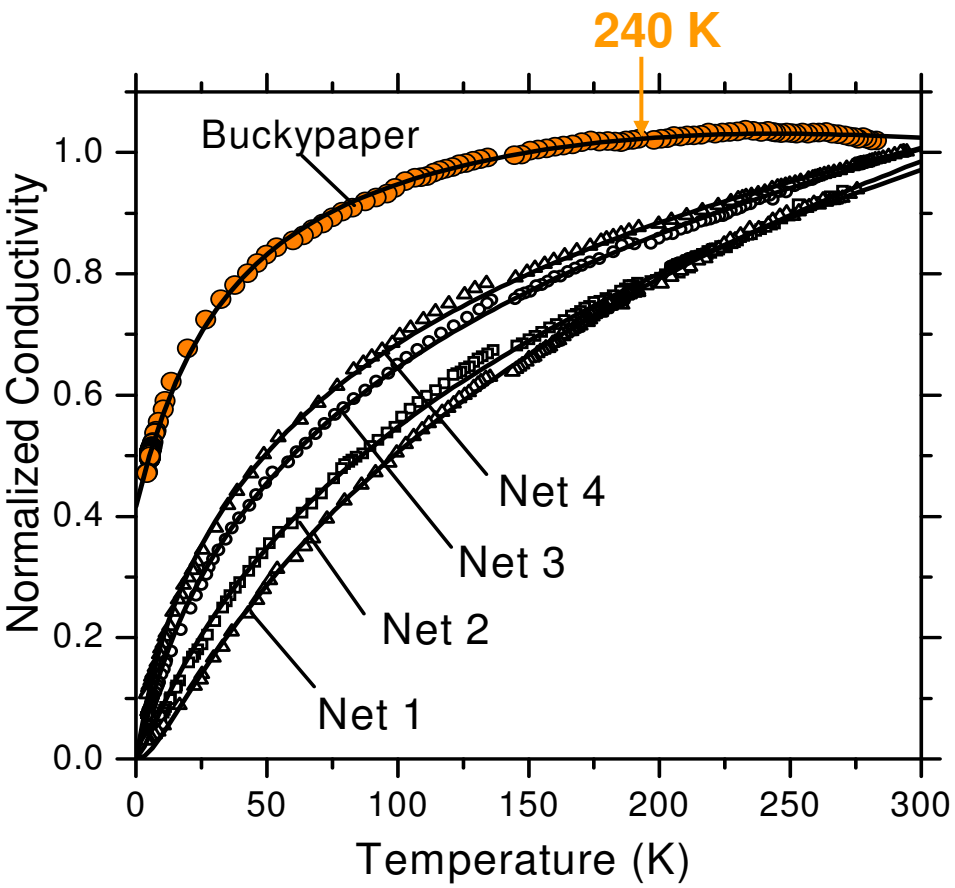
Thickness: current vs. bias voltage





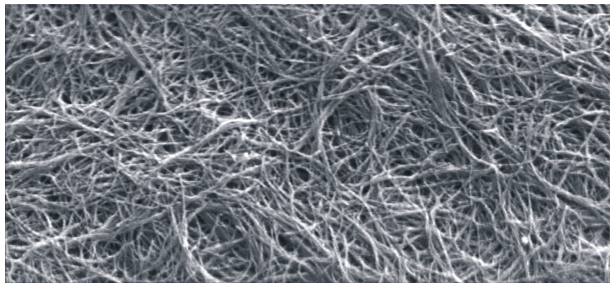


Thickness: Temperature dependences of conductivity G(T)

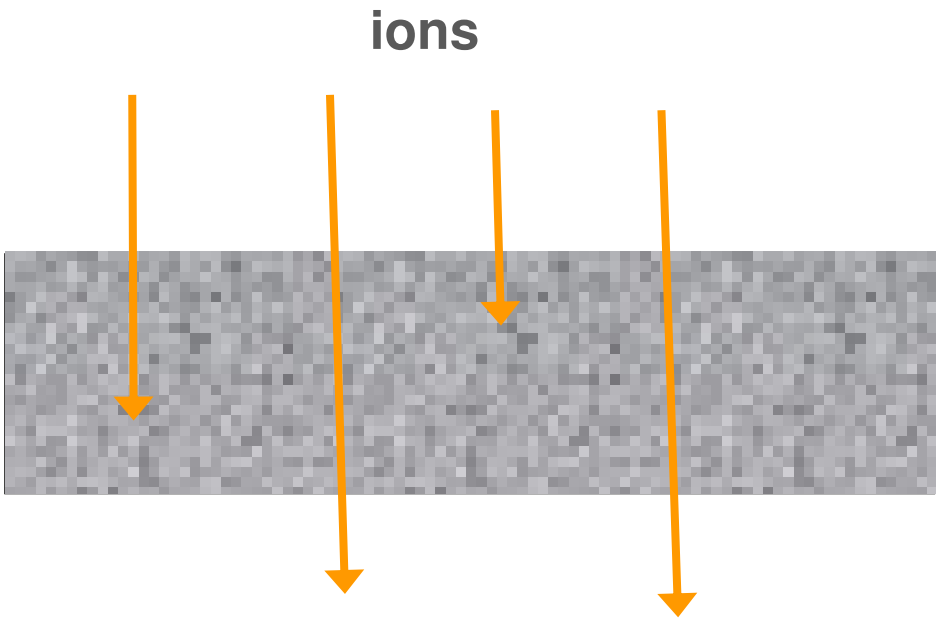


V. Skákalová, A. B. Kaiser, Y.-S. Woo, and S. Roth, PHYSICAL REVIEW B 74, 085403 (2006)

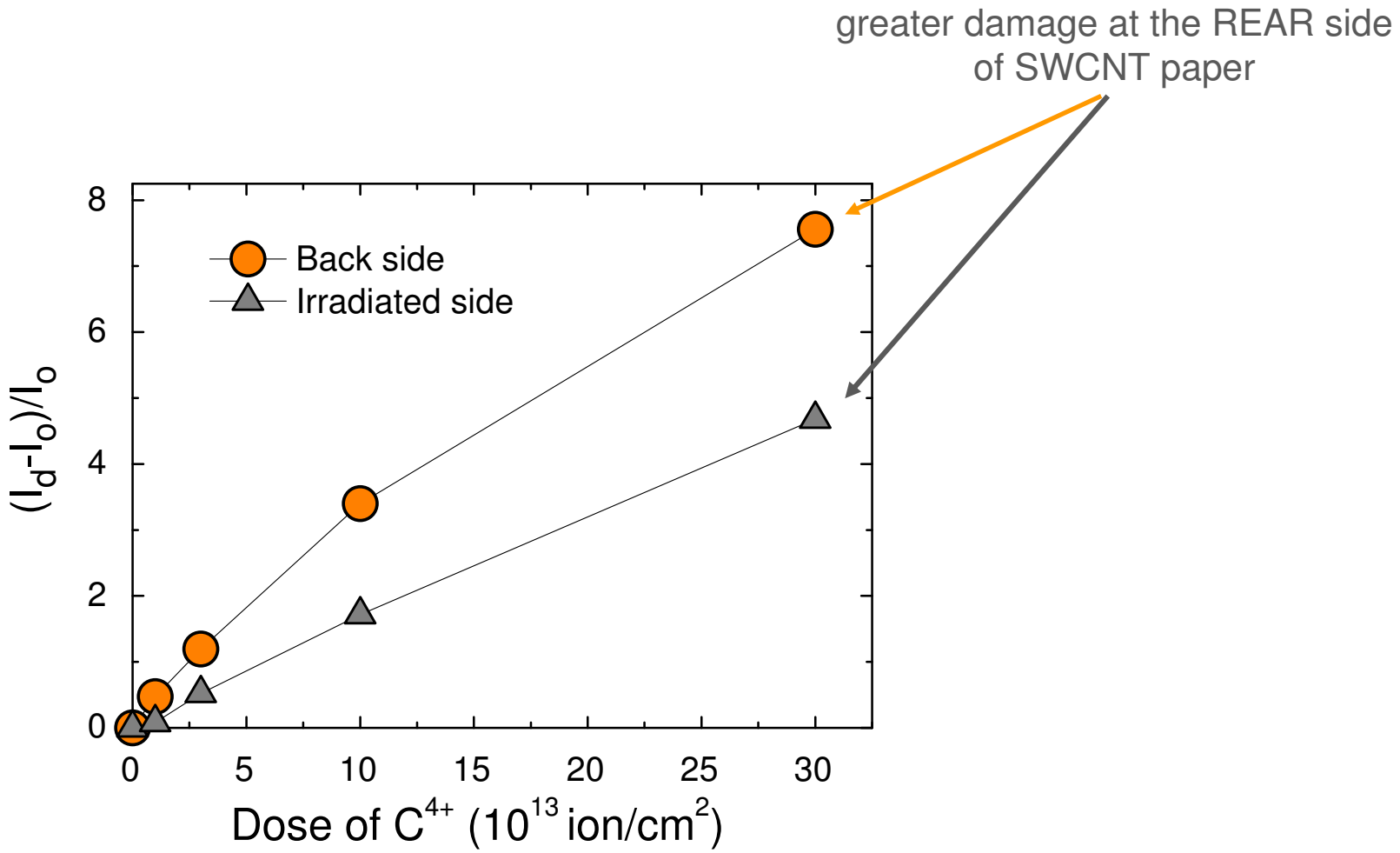
Effect of irradiation by 23 MeV C^{4+} ions



Penetration depth > Thickness **40 μm**

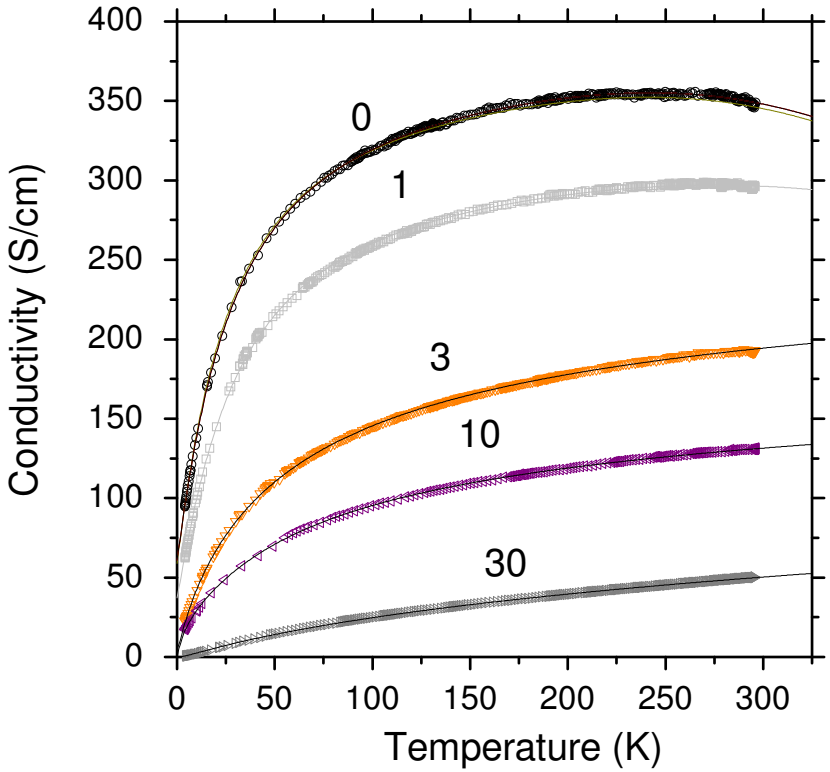


ΔI/I of the D-mode vs. Dose of C^{4+} ions



Skakalova, Kaiser, Detlaff, Arstila, Krashenninikov, Keinonen, Roth: Physica Status Solidi B, 245, (2008) 2280-2283

C^{4+}-irradiation of SWNT paper: T-dependent conductivity



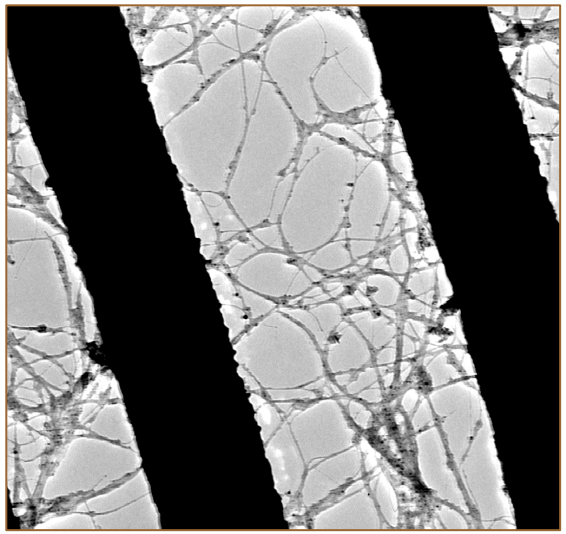
Pristine:

Quasi-1D metal

High dose :

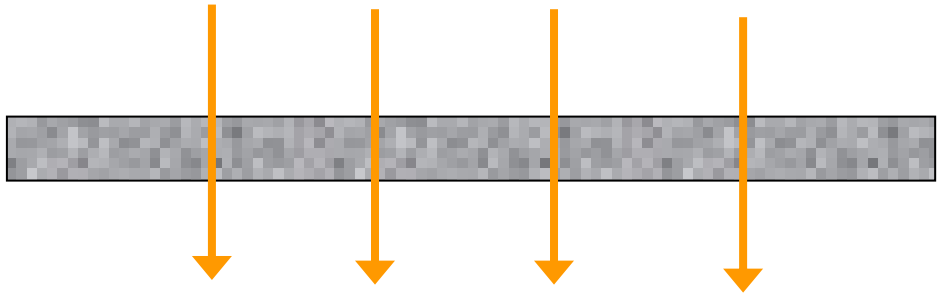
3D variable-range hopping

Thin SWNT networks irradiated by 30 keV Ar^+ ions

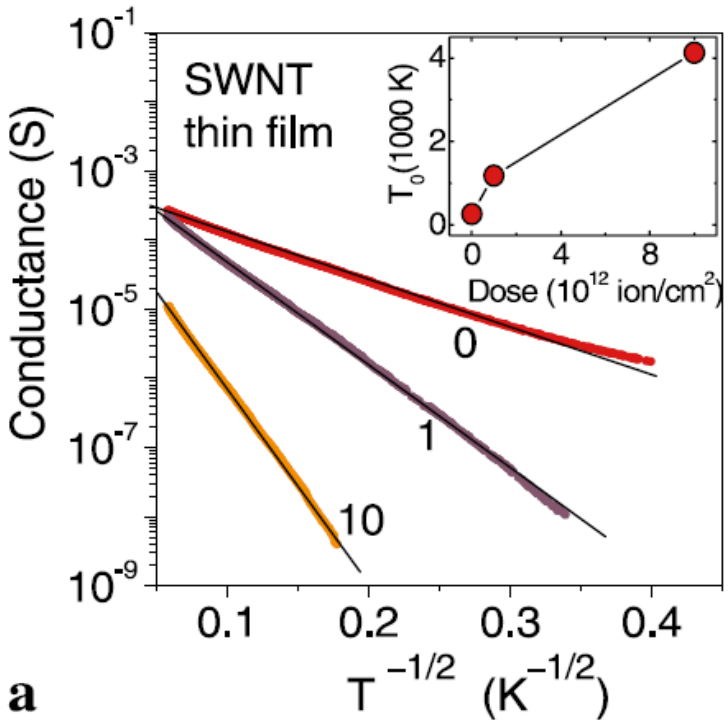


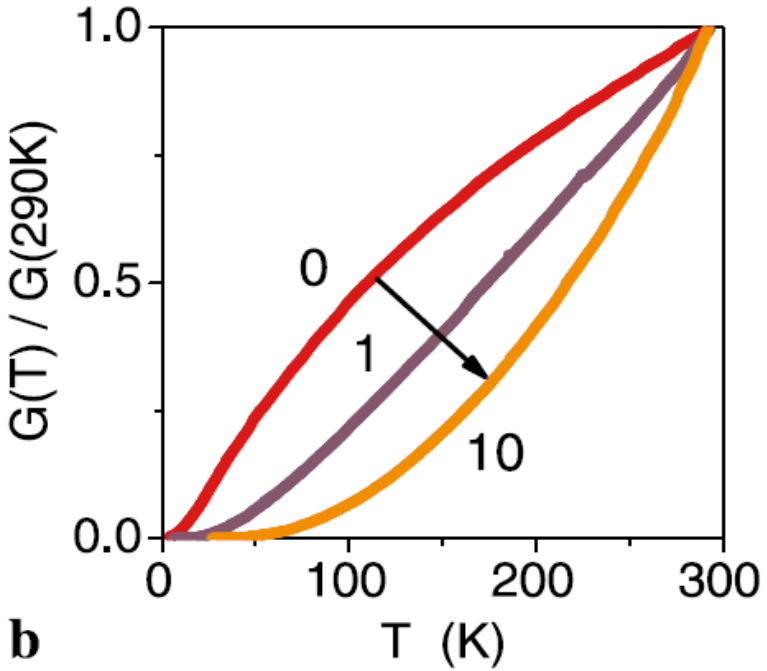
Penetration depth < Thickness **100 nm**

ions



Electrical conductance of Ar^+ irradiated thin SWNT networks

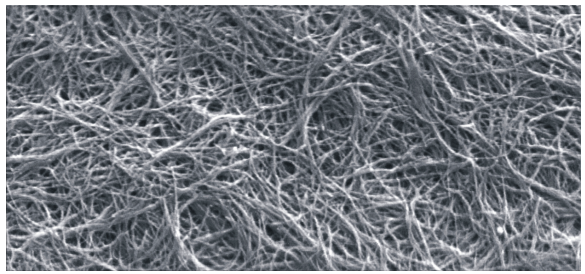




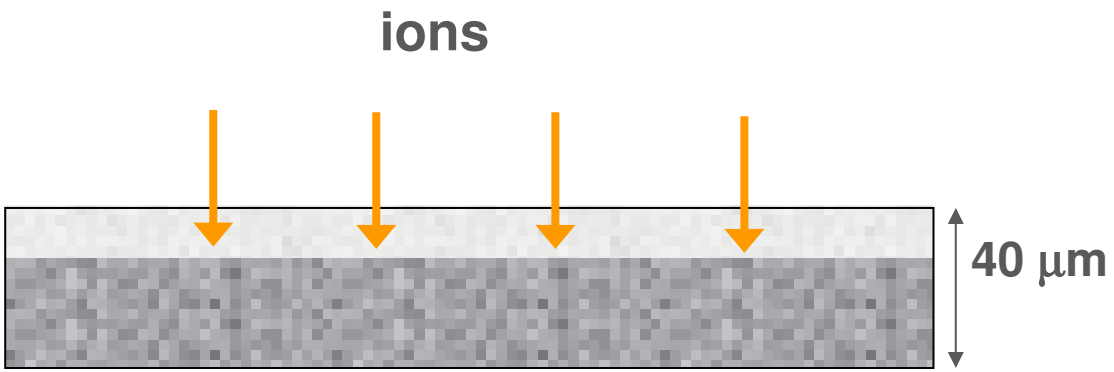
Variable-Range Hopping:

$$\sigma(T) = \sigma_0 \exp\left[-\left(\frac{T_0}{T}\right)^{1/(1+d)}\right]$$

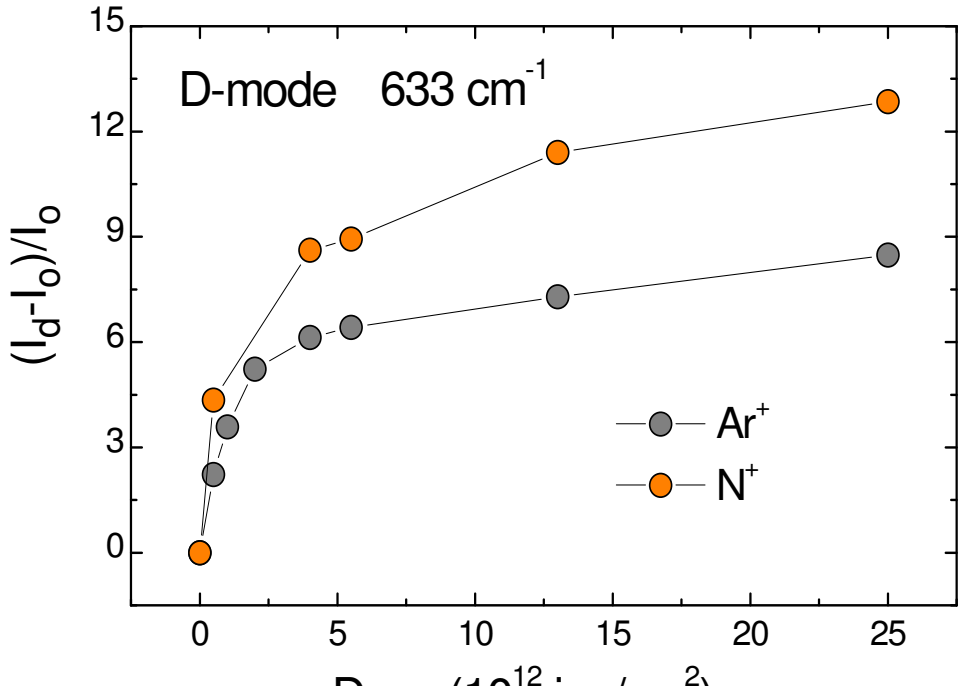
Thick SWNT networks irradiated by 30 keV Ar^+ ions



Penetration depth < Thickness **40 μm**



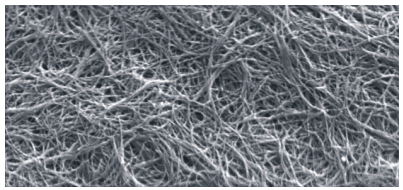
Raman spectra of irradiated thick SWNT papers by 30 keV ions

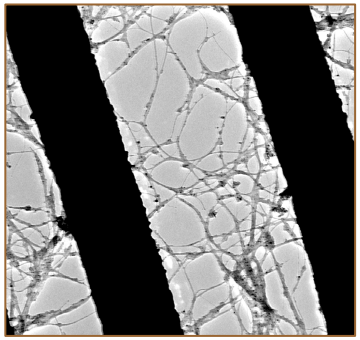


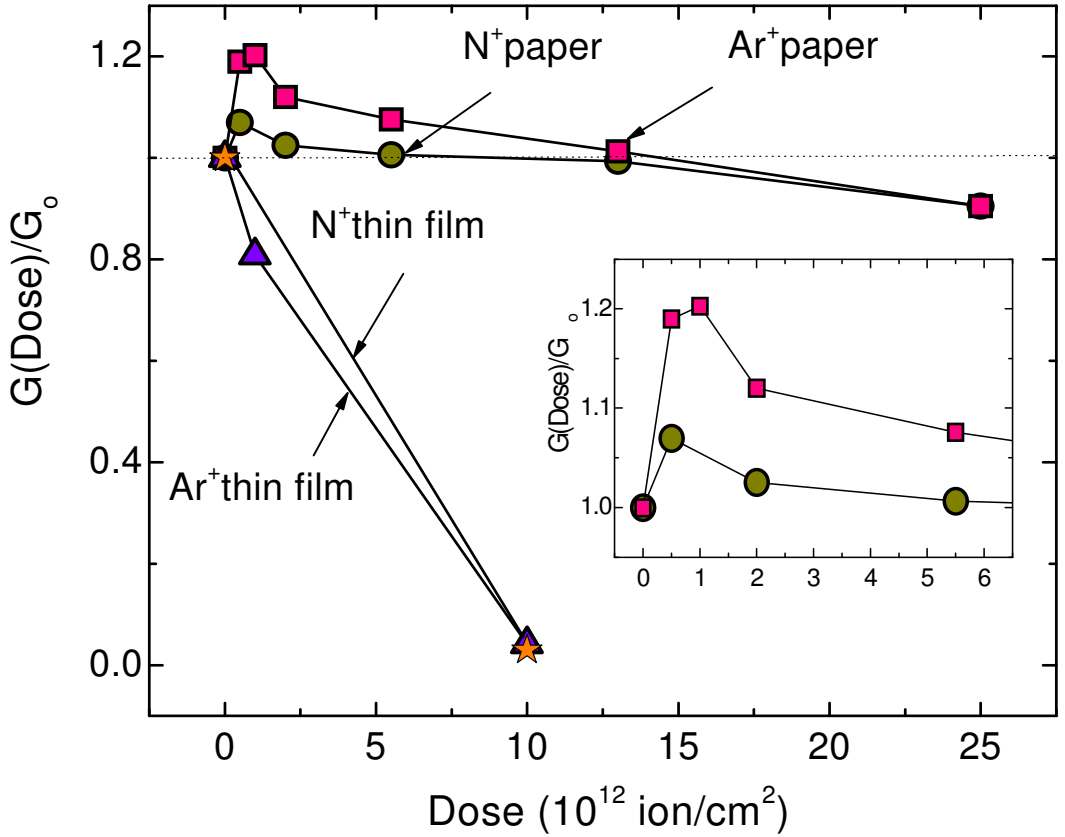
Penetration depth of the laser beam ~ 1μm > Penetration depth of the ions

Penetration depth of the Ar^+ ions < Penetration depth of the N^+ ions

Electrical conductance of irradiated thick SWNT papers

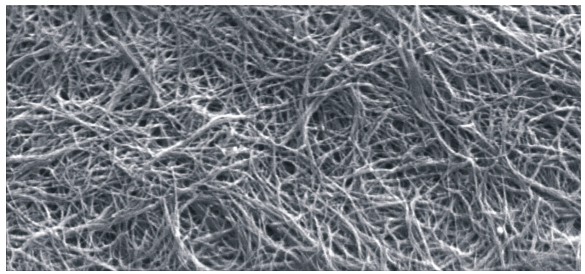


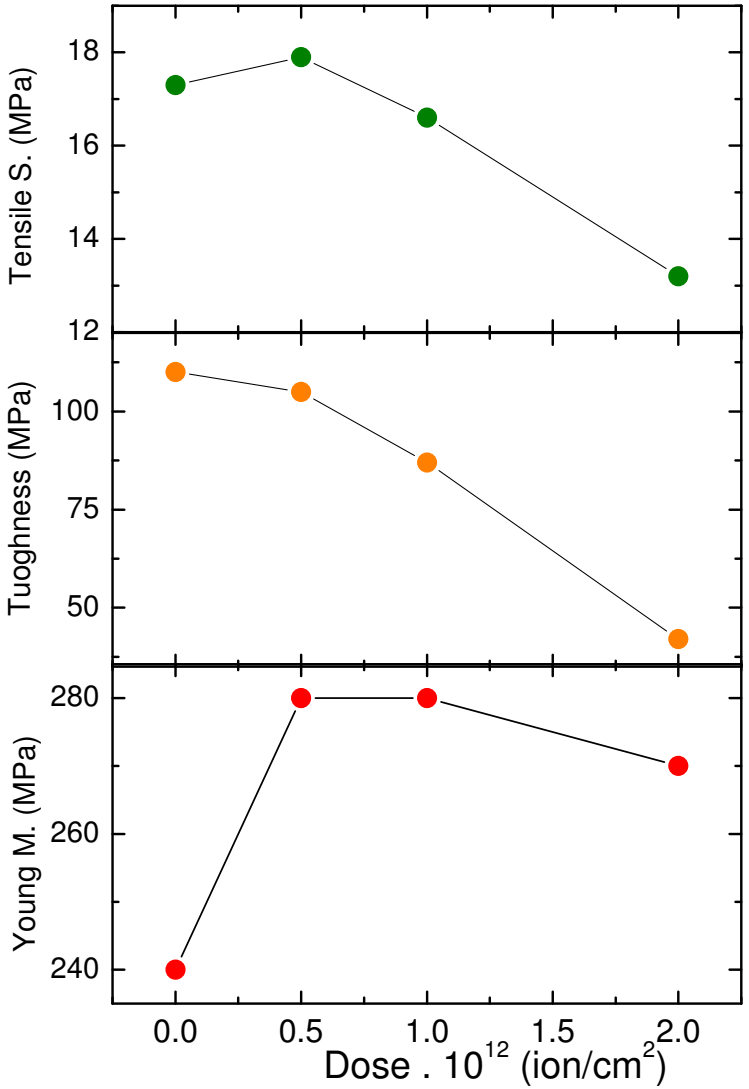




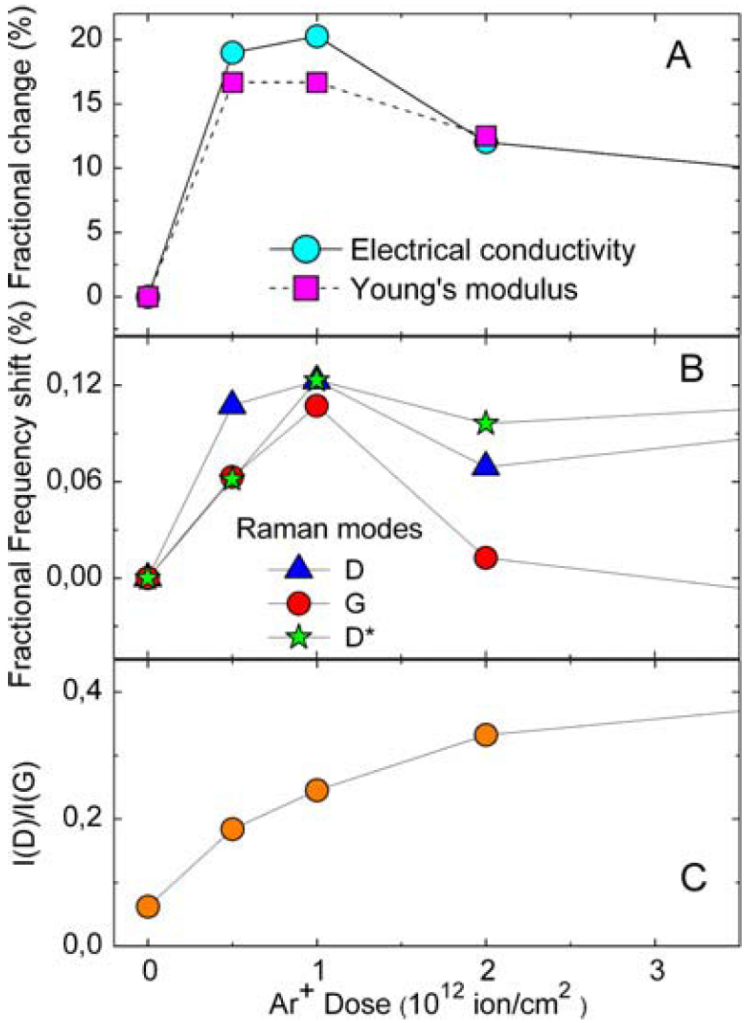
V. Skakalova, A.B. kaiser, Z. Osvath, G. Vertesy, L.P. Biro, S. Roth, Appl. Phys. A 90, 597–602 (2008)

Mechanical properties of irradiated thick SWNT papers





Correlation between Conductivity, Young's modulus and Raman mode shifts changes in modified carbon nanotube networks



V. Skákalová, A. B. Kaiser, and S. Roth: phys. stat. sol. (RRL) 2, No. 2, 62–64 (2008)

Summary

Raman spectra:

- D-mode increases and saturate with the increasing dose
- The new (forbidden) IFM modes as a consequence of broken symmetry

2. Optical spectra:

- The absorption peaks of Van Hove singularities decrease

3. Electrical conductivity:

- If the thickness of layers is smaller than the penetration depth of ions, the conductivity decreases with the dose of irradiation
- A maximum in the conductivity is observed at low ion energies. This is explained by thermal annealing of the sample.

The strong correlation between Conductivity, Young modulus and Raman frequencies shift showing a maximum