MWNT´s acting like free radical scavengers in gamma irradiated UHMWPE/multiwall carbon nanotubes nanocomposites

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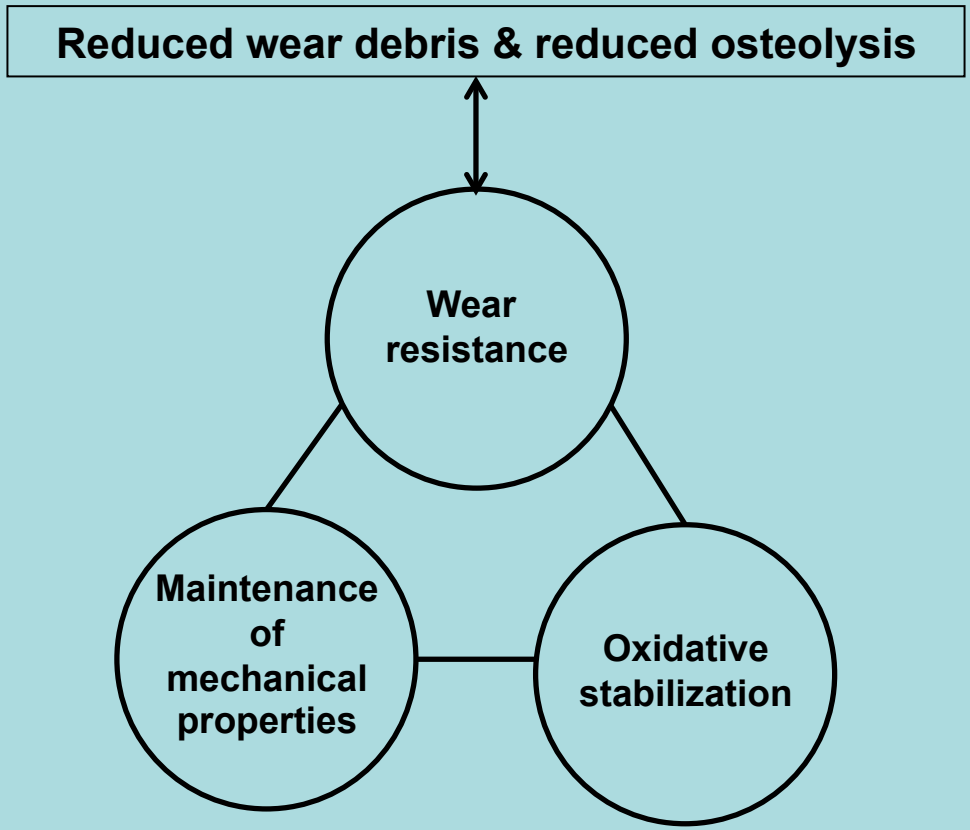
The paradigm of UHMWPE : wear, oxidation and mechanical properties



Enrique Gómez-Barrena et al. Acta Orthopaedica 2008;79(6):832

HIGHLY CROSS-LINKED UHMWPE

First generation: Highly crosslinked UHMWPEs and thermal stabilized

Remelting : Oxidative resistance ✓

Susceptible to fatigue cracking X

Annealing: Mechanical properties ✓

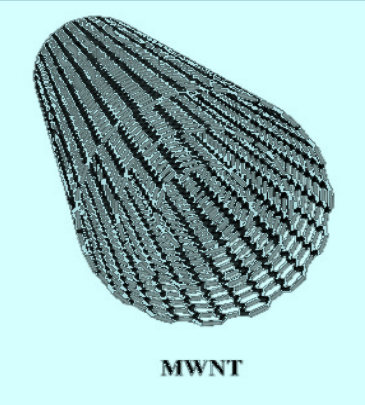
Susceptible to *in vivo* oxidation X

Second generation:

Sequential irradiation and annealing process:

Addition of vitamin E:

ALTERNATIVE: UHMWPE/MWCNTs COMPOSITES



E= 1054- 1200GPa

σ*= 150 GPa

TOPICS:

Improvement of mechanical properties

Thermal stability

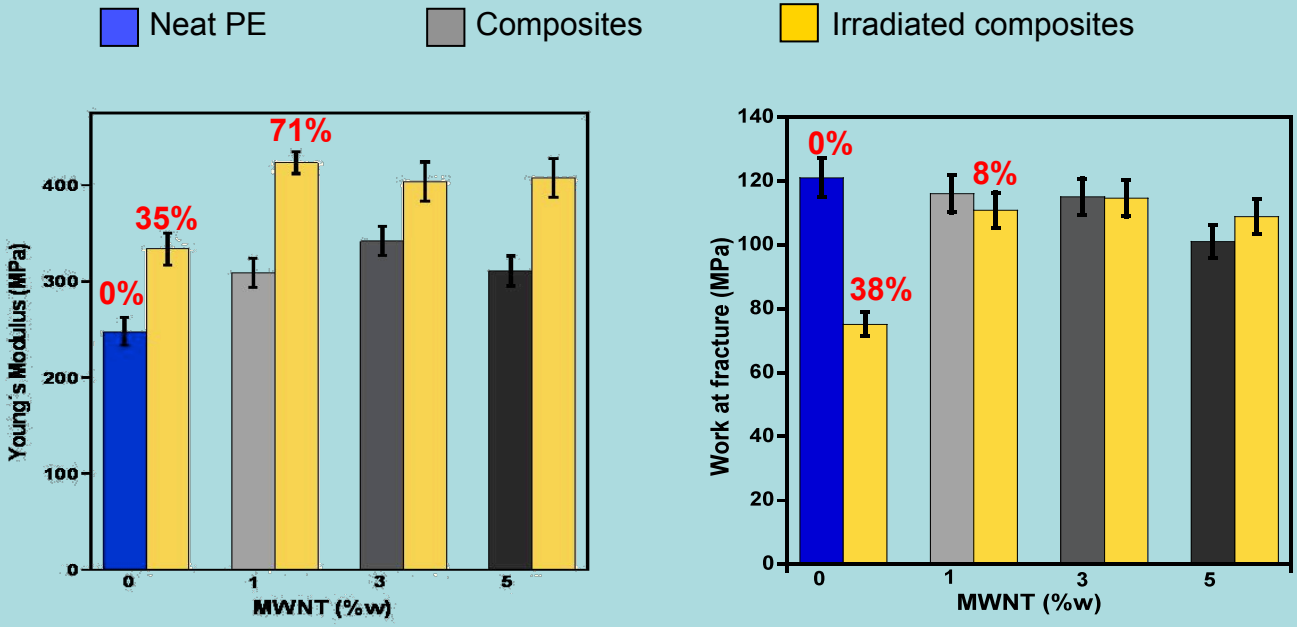
Previous results

Biocompatibility

Free radical scavengers??

PREVIOUS RESULTS

- *Mechanical properties*



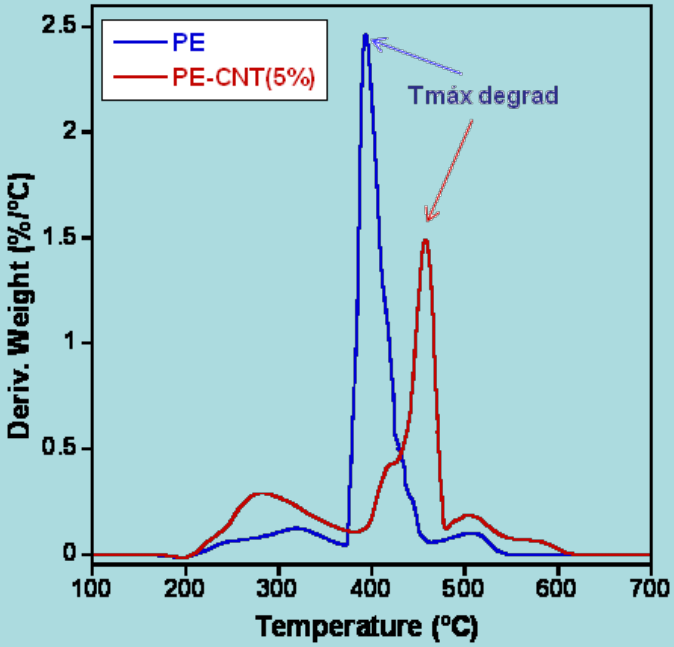
MWCNTs ⟶ reinforcement of UHMWPE

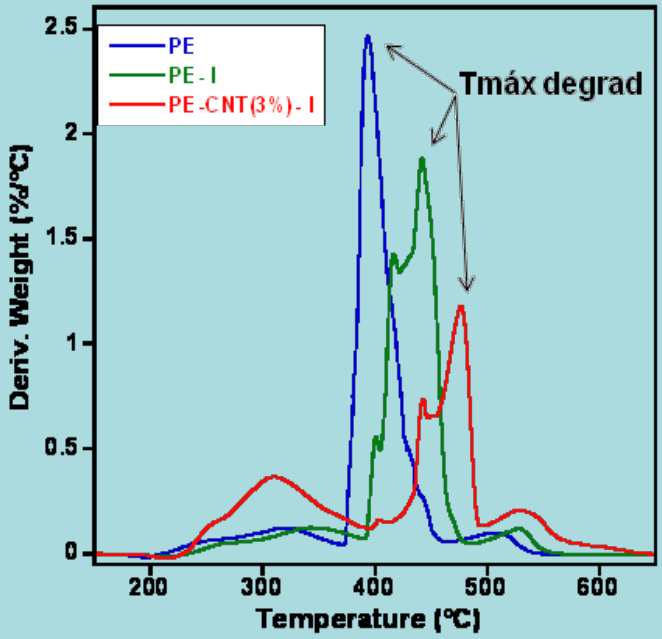
MWCNTs ⟶ prevent the loss of toughness due to the irradiation

M.J. Martínez et al. Comp. Sci. and Tech. 2011;71:282

PREVIOUS RESULTS

- *Thermal stability*





MWCNTs increase the temperature of maximum rate of thermal degradation of UHMWPE

OBJETIVES

MWCNTs ⟶ Free radical scavenger ??

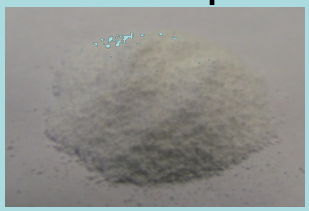
* *Ability of MWCNTs to act as free radical scavengers*

* *To prove the oxidative stability of UHMWPE with the incorporation of MWCNTs*

* *Effects of MWCNTs on the crosslinking density of UHMWPE*

RAW MATERIALS

- UHMWPE powder



- Multiwall nanotubes (MWNTs)

SYNTHESIS OF THE COMPOSITES

A) Mixing process

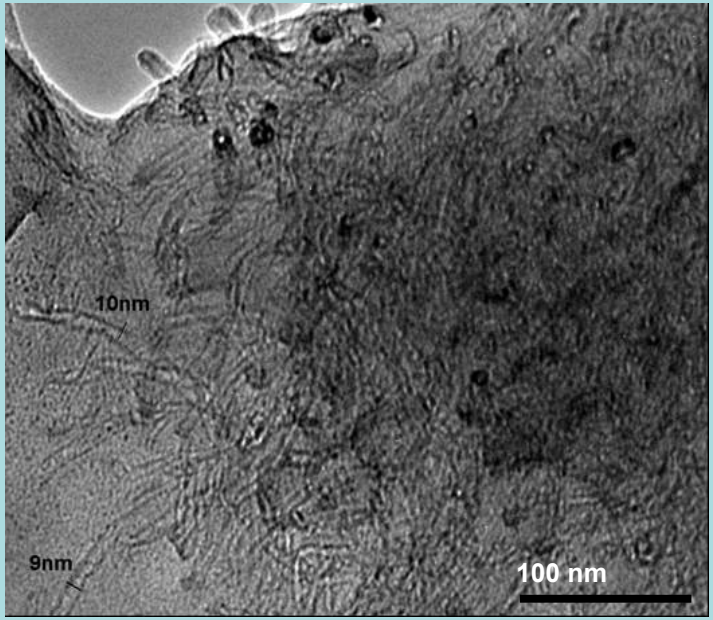
Ball mill (2 h 400 rpm) ⟶ Composites (0.1; 0.5; 1; 3 and 5%wt MWCNT)

B) Thermo-compressed process

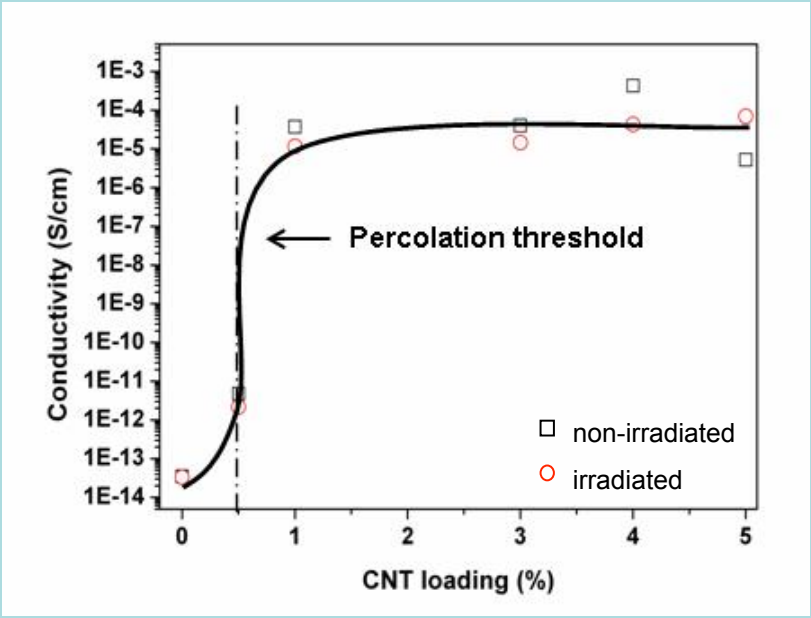
T = 175ºC
5 min of preheating
p = 10 MPa
t = 15 minutes
Cooling in air under pressure

DISPERSION

- *TEM*

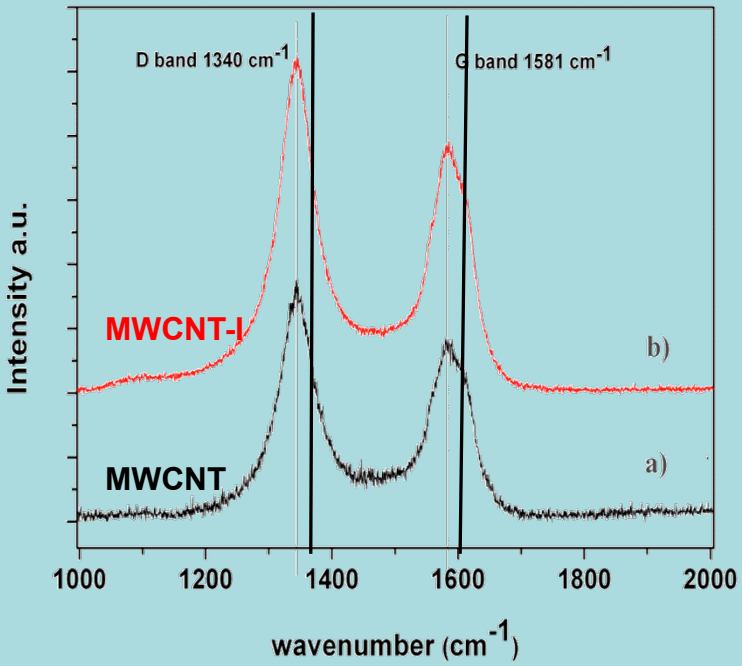


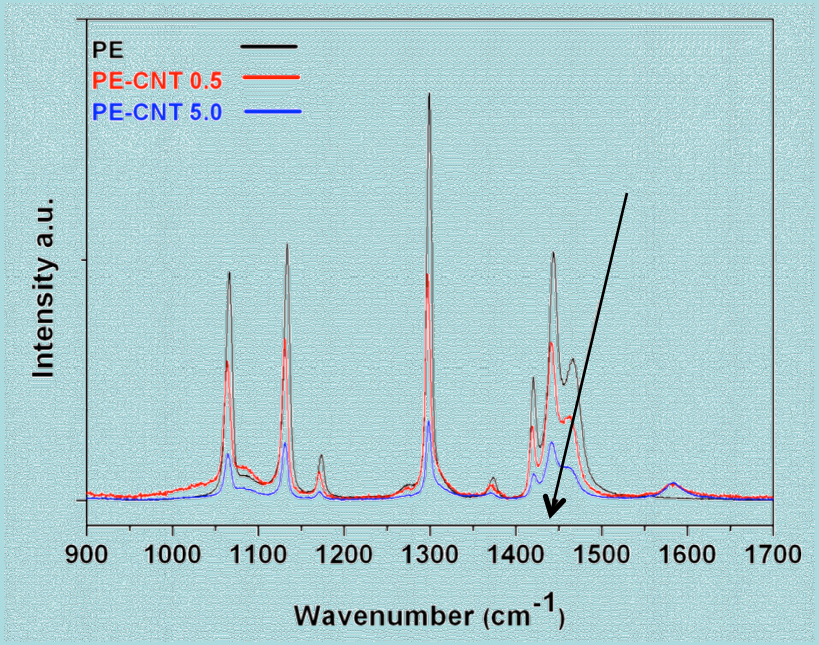
- *Conductivity*



Low percolation threshold (~ 0.5wt%) → GOOD DISPERSION

RAMAN





Irradiation increases G/D ratio

↓

Higher graphitization

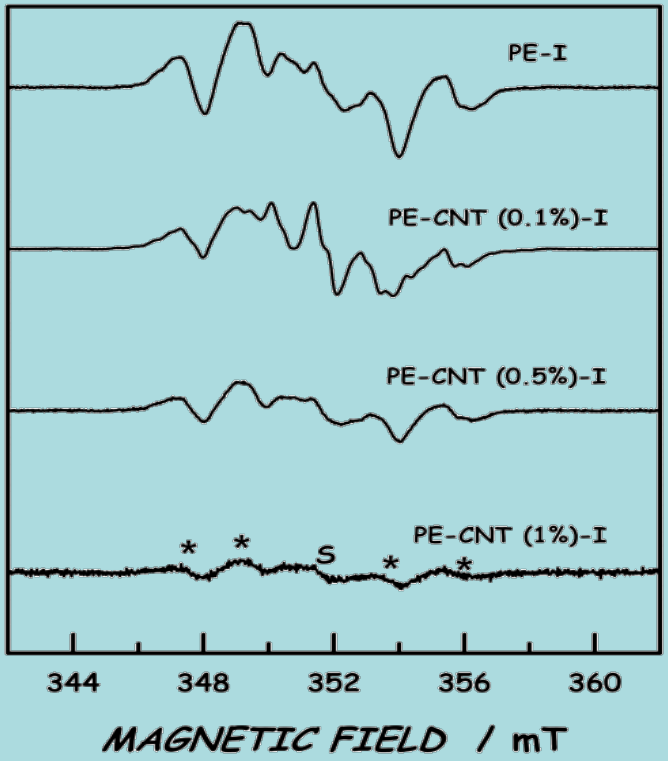
MWCNTs reduce the polymer modes

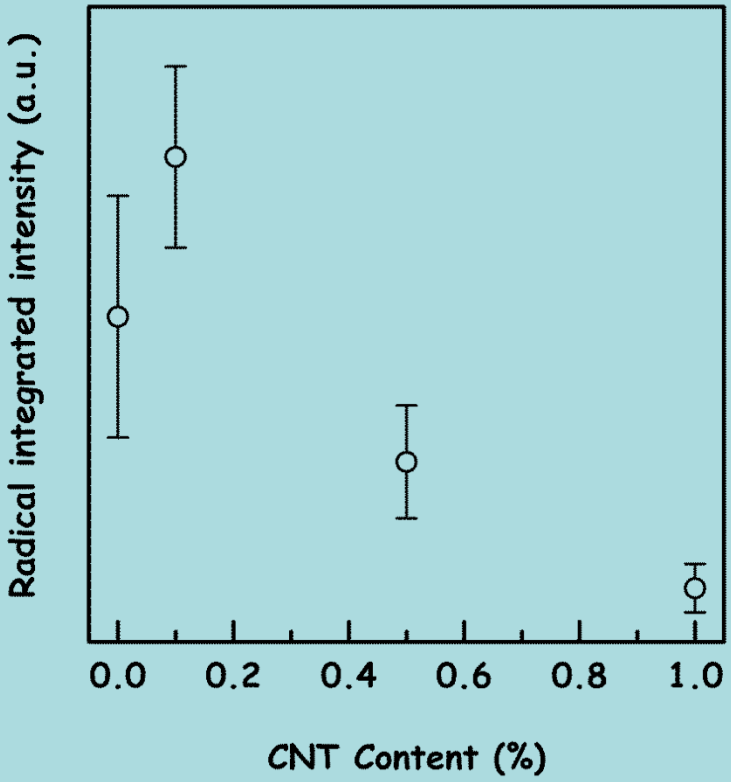
↓

Effective interaction

FREE RADICAL SCAVENGER

- *ESR*





As the MWCNTs concentration increases,

the total free radical concentration formed by irradiation decrease

OXIDATIVE STABILITY

- *FTIR*

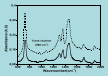
Material	% OI Increase
PE-I	66
PE-CNT(0.5%)-I	5

Aging: 36 h 120ºC

The results corfirm the antioxidant activity of the MWCNTs in preventing the oxidation of UHMWPE

TRANS-VINYLEN INDEX

- *FTIR*



PEI

PE-CNT(1%)-I

ITV = A (965 cm $^{-1}$)/A (1360 cm $^{-1}$)

Material	TVI
PE-I	0.04 ± 0.002
PE-CNT(1%)-I	0.05 ± 0.004

The MWCNTs do not affect to the trans-vinylene index of UHMWPE after irradiation

CROSSLINKING DENSITY

- ***Swelling measurements***

Material	Swell Ratio	Extract [%]	Gel content [%]	Crosslinked Density [mol/dm^3]
PE-I	4.6 ± 0.3	15.5 ± 0.3	84.5 ± 0.3	**0.08 ± 0.01**
(PE-CNT(3%))-I	5.1 ± 0.5	14.9 ± 0.5	85.1 ± 0.5	**0.07 ± 0.01**

Explanation: **Changes produced in the CNT structure by irradiation process can involve the CNT interacting simultaneosly with different polymer chains providing a network additional to the crosslinking.**

CNTs contribute positively to the crosslinking density during the irradiation

SUMMARY

- Electrical conductivity of nanocomposites shows a low percolation threshold (0.5%wt) ⟶ Good dispersion of MWCNTs throughout the polymeric matrix.

- The amount of radicals introduced by the gamma-irradiation in UHMWPE decrease as the CNT concentration increase

  ↪ the MWCNTs behave as free radical scavenger.

- The presence of the CNTs increases the oxidative stability of the irradiated UHMWPE after aging.

- The incorporation of MWCNTs does not affect to the crosslink density of UHMWPE during gamma irradiation.

  ↪ Good wear resistance

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THANK YOU FOR YOUR ATTENTION!!

ANY QUESTION??