



**ICARST 2017**

1<sup>st</sup> International Conference on Applications  
of Radiation Science and Technology

**ICARST**

**April 25-28, 2017**

# **Radiation-induced Oxidation, Cross-linking, and Grafting of UHMWPE**

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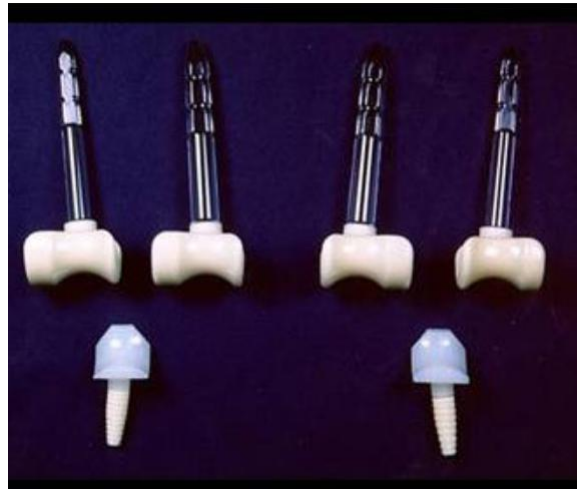
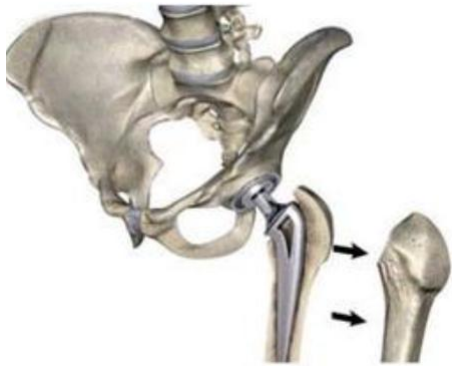
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**Shanghai Institute of Applied Physics,**

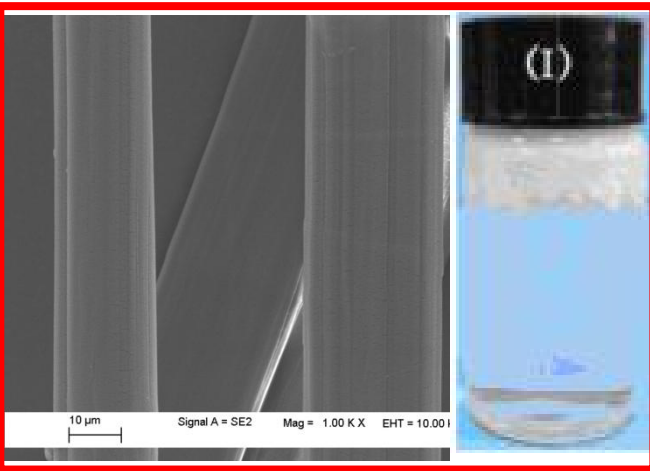
**Chinese Academy of Sciences, China**

# What is UHMWPE? $\text{-(CH}_2\text{-CH}_2\text{)}_n$

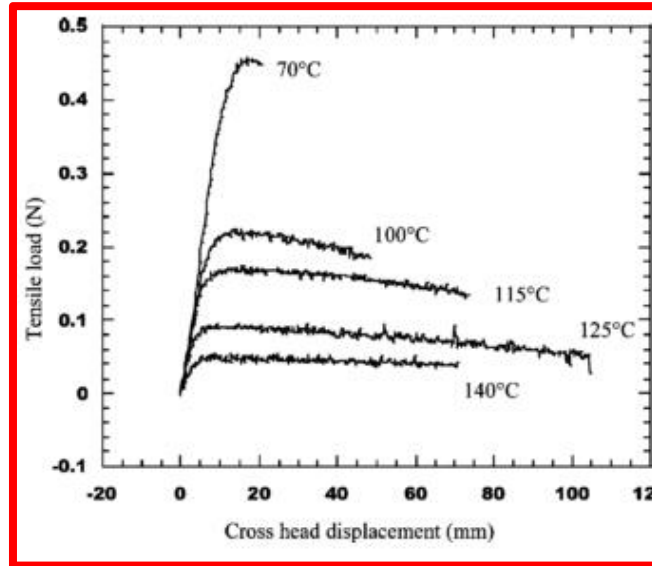
**UHMWPE (ultra-high molecular weight polyethylene)** has an average molecular weight larger of  $>1.5 \times 10^6$ , with high chemical resistance, excellent biocompatibility, mechanical properties and is widely used in medical devices, engineering and defense supplies.



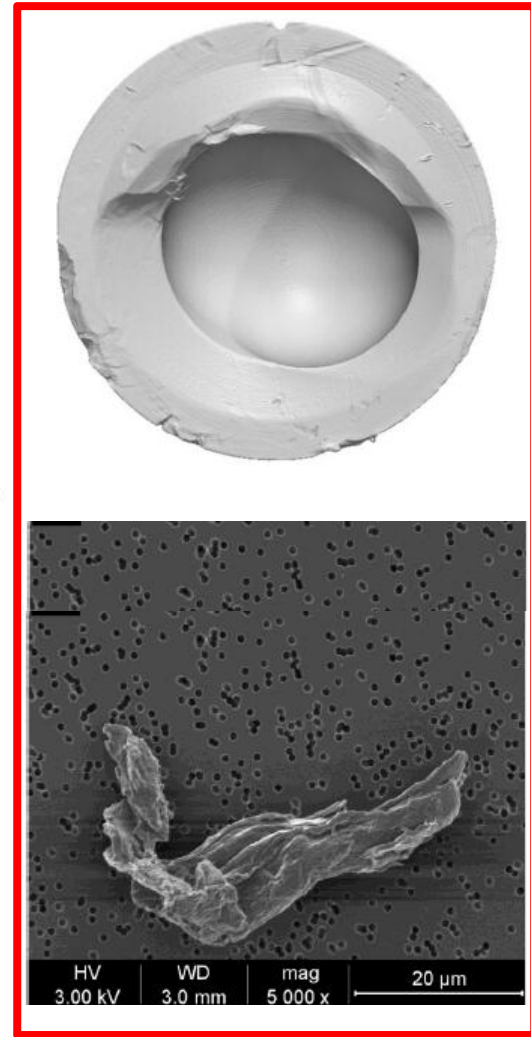
# Some drawbacks of UHMWPE



Low surface energy and poor compatibility, *Li et al. CST. 2015*



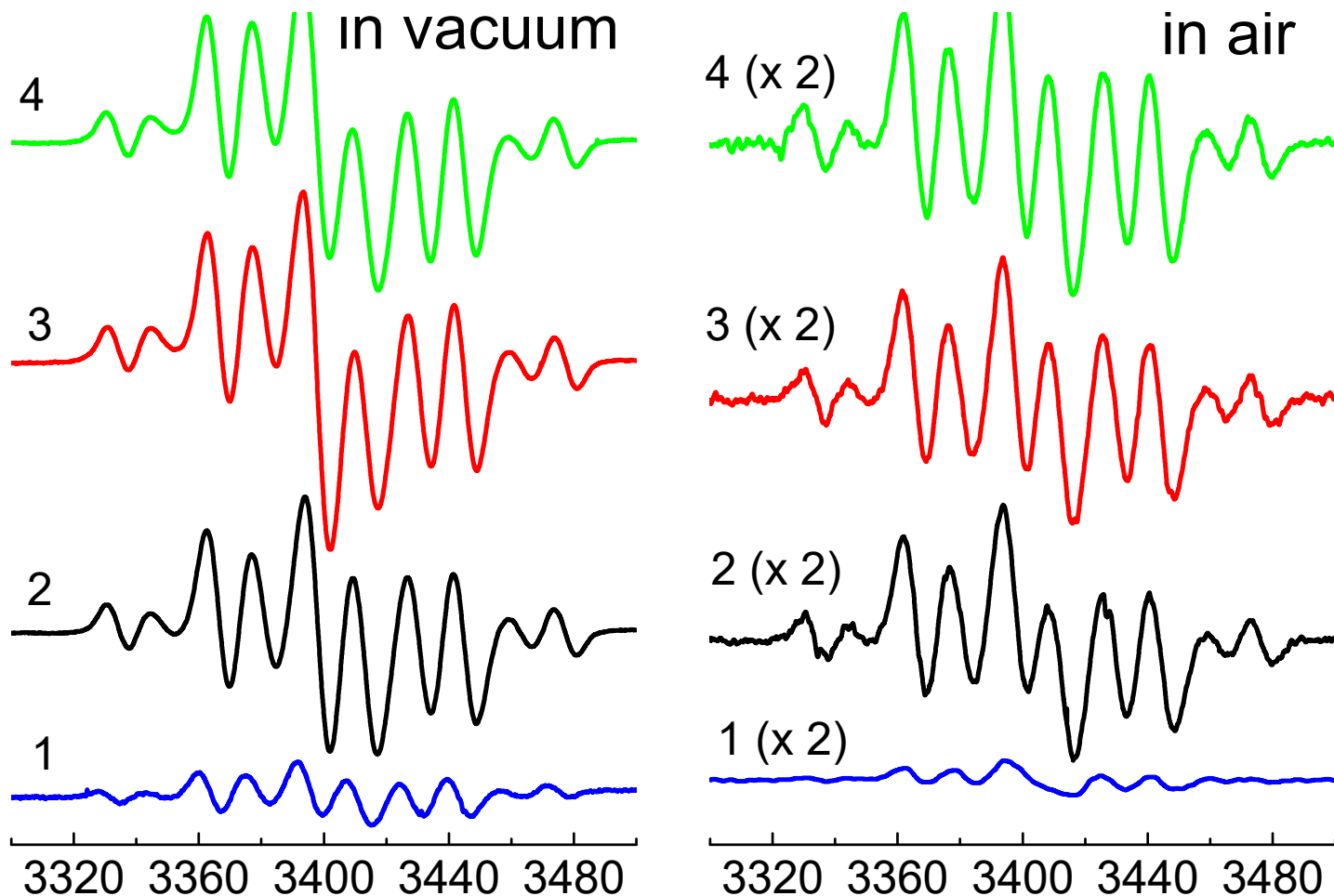
Poor thermal and creep resistance, *Kromm et al. polymer testing. 2003*



These drawbacks may be overcome by radiation technology.

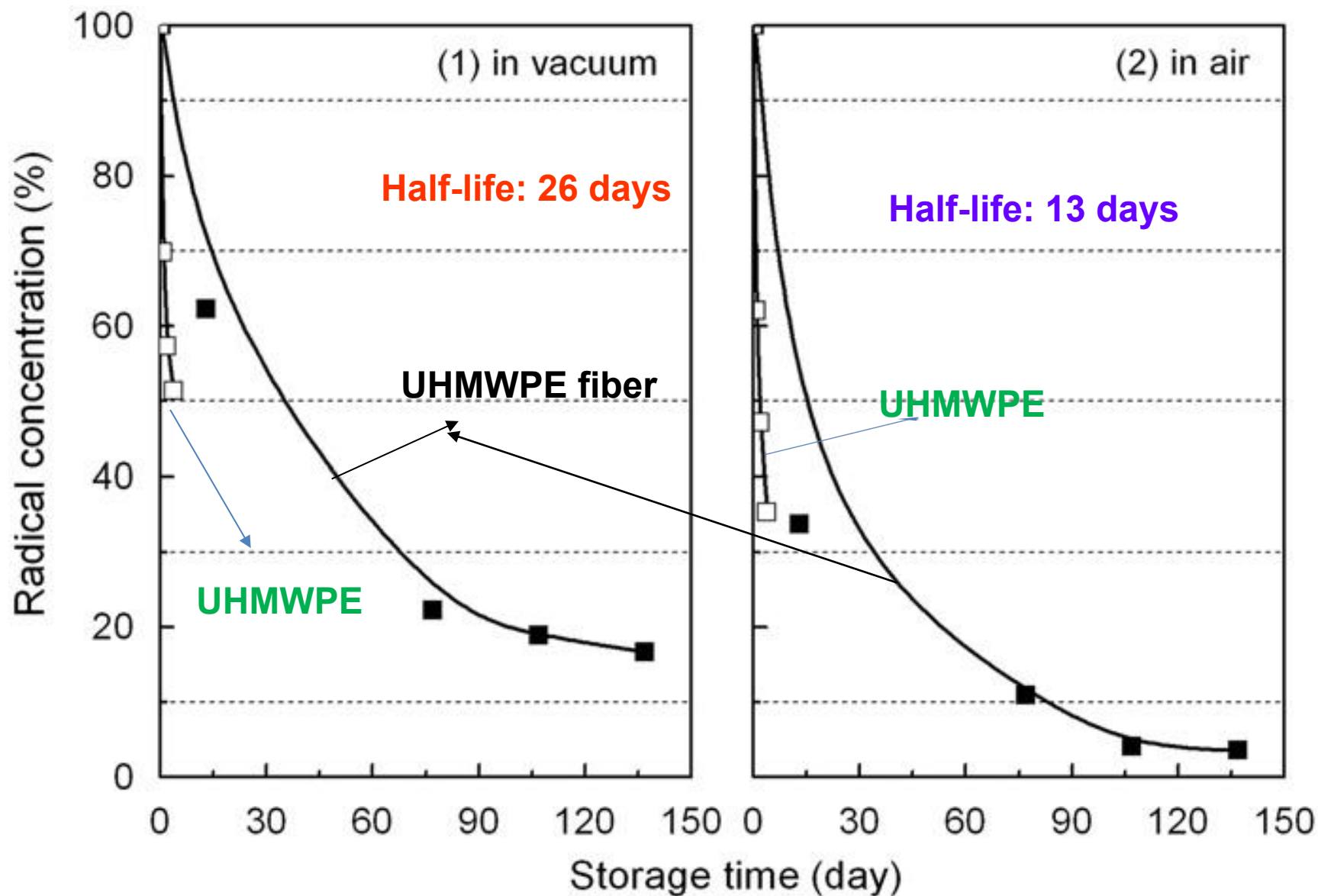
wear resistance should be improved, *Silvia et al. wear. 2014*

# Stable radical formation in UHMWPE fiber after irradiation



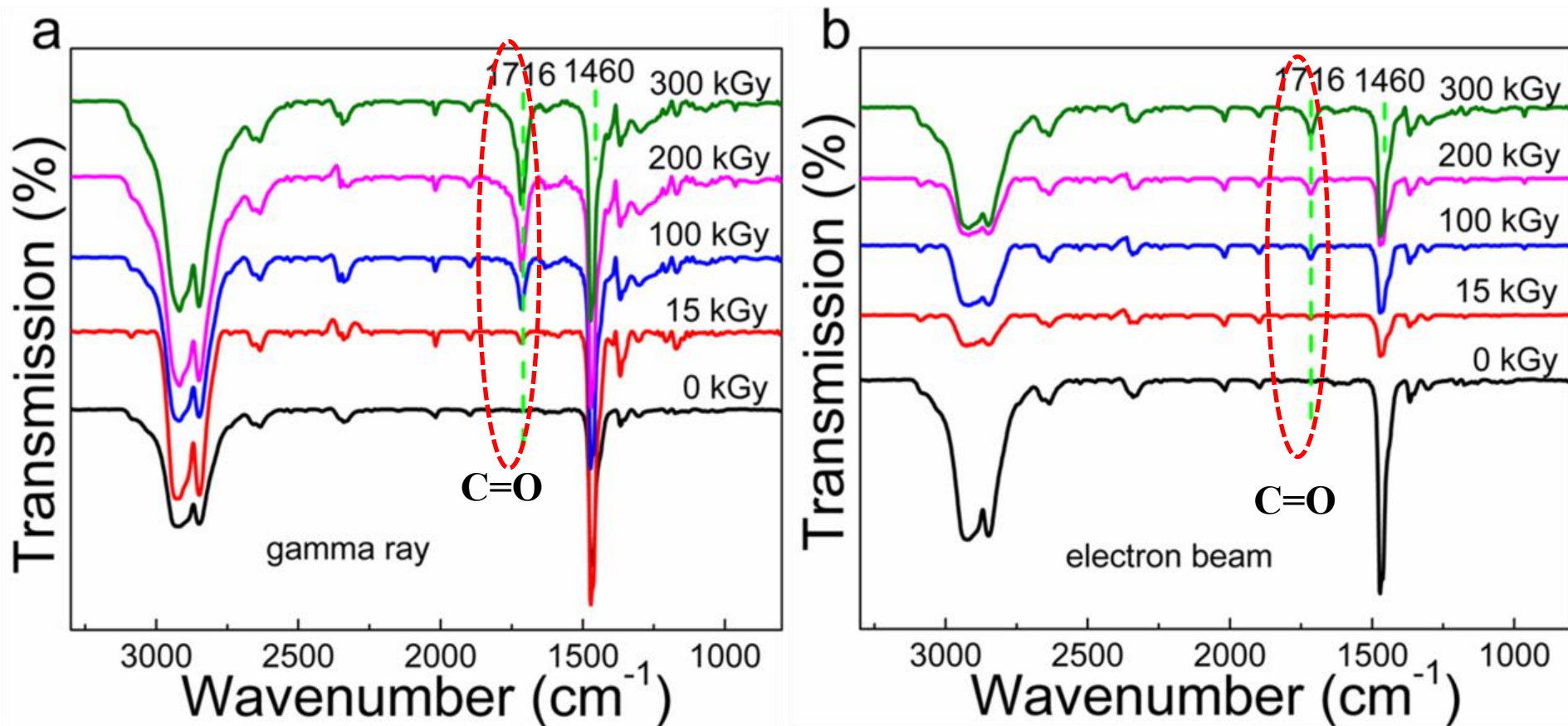
**ESR spectra of the UHMWPE fiber irradiated in vacuum and in air at room temperature with a dose rate of 0.73 Gy/s. 1: 10 kGy, 2: 60 kGy, 3: 130 kGy, 4: 200 kGy. ( $\times 2$ ) indicates the magnification of spectrum by a factor of two.**

# Long lifetime of free radicals in UHMWPE powder and fiber



Longer radical lifetime is easy for grafting polymerization.

## Radiation oxidation of UHMWPE powder in air

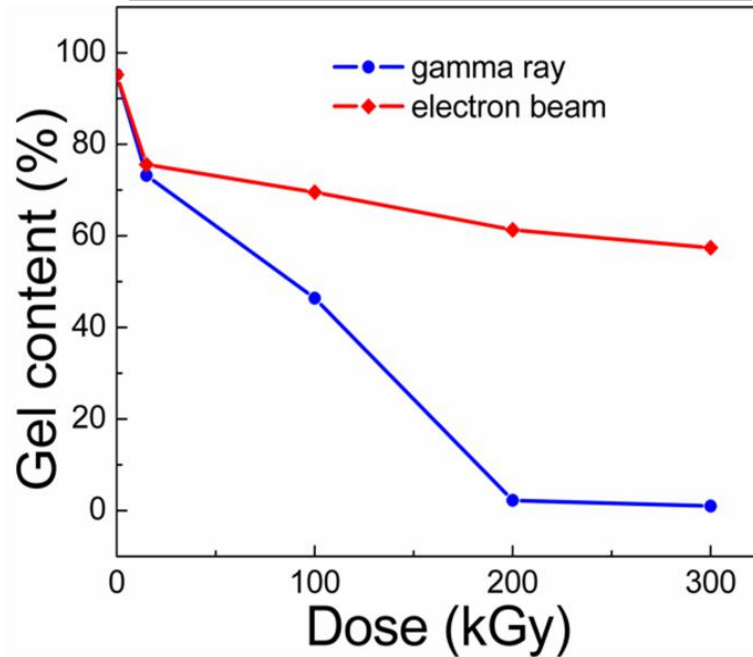


FT-IR curves UHMWPE powder irradiated by (a) gamma ray and (b) e-beams in air.

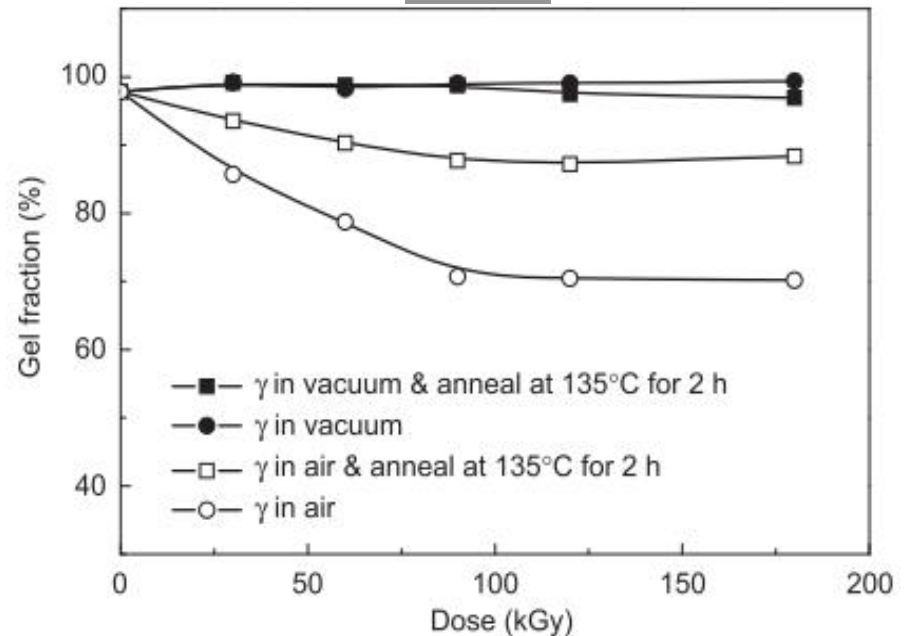
*For UHMWPE irradiated in air, the oxidation can't be avoided.*



powder irradiated in air



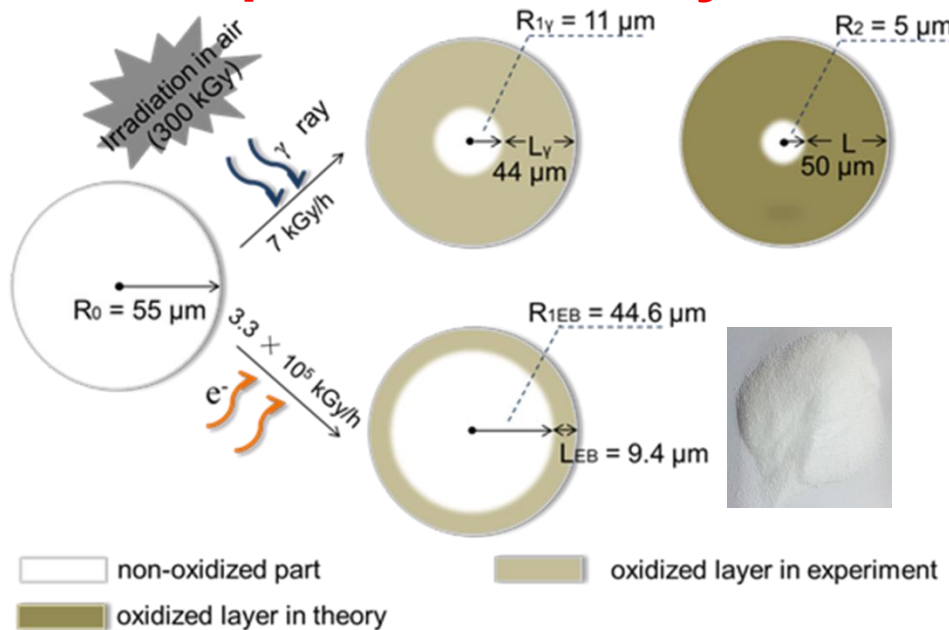
fiber



The oxidation level is dependent on the dose and the low dose rate.  $\gamma$  ray irradiation induced more oxidation than e-beam irradiation.

# Potential application: additive in nylon

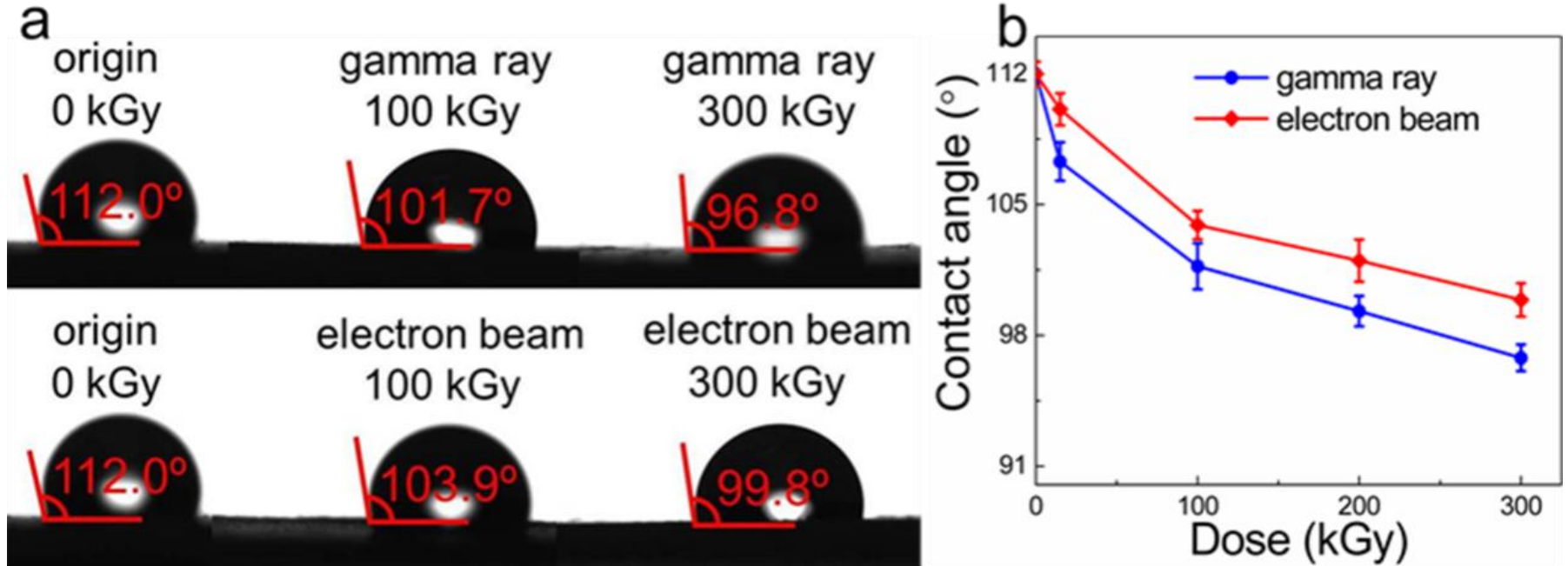
**powder 300 kGy**



**A large specific surface area leads to serious oxidation.**

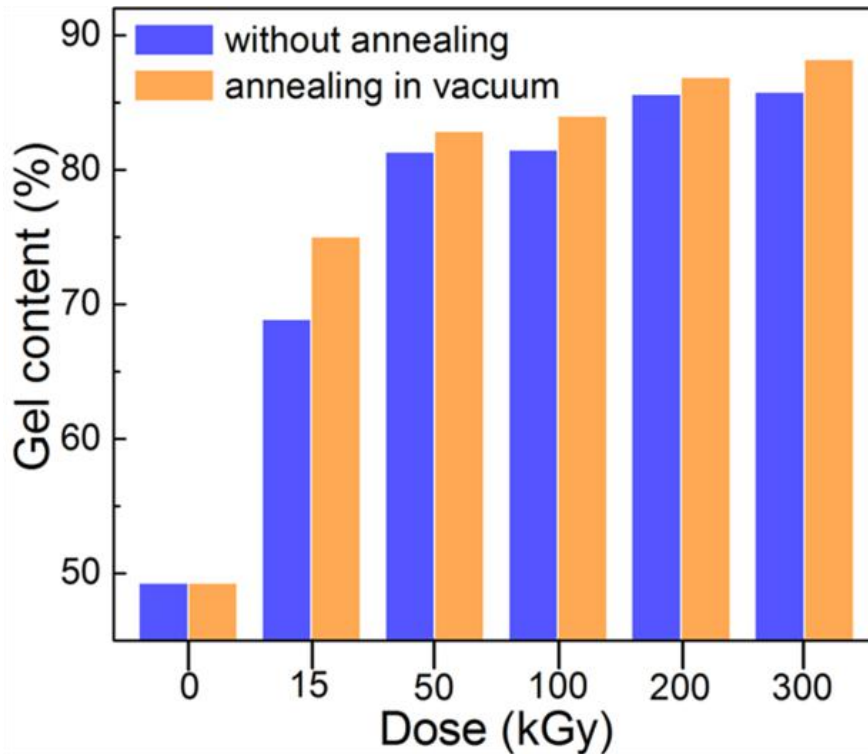


## *Radiation oxidation enhanced surface wettability of UHMWPE.*



**Static contact angle of UHMWPE powder after gamma ray and e-beams irradiation.**

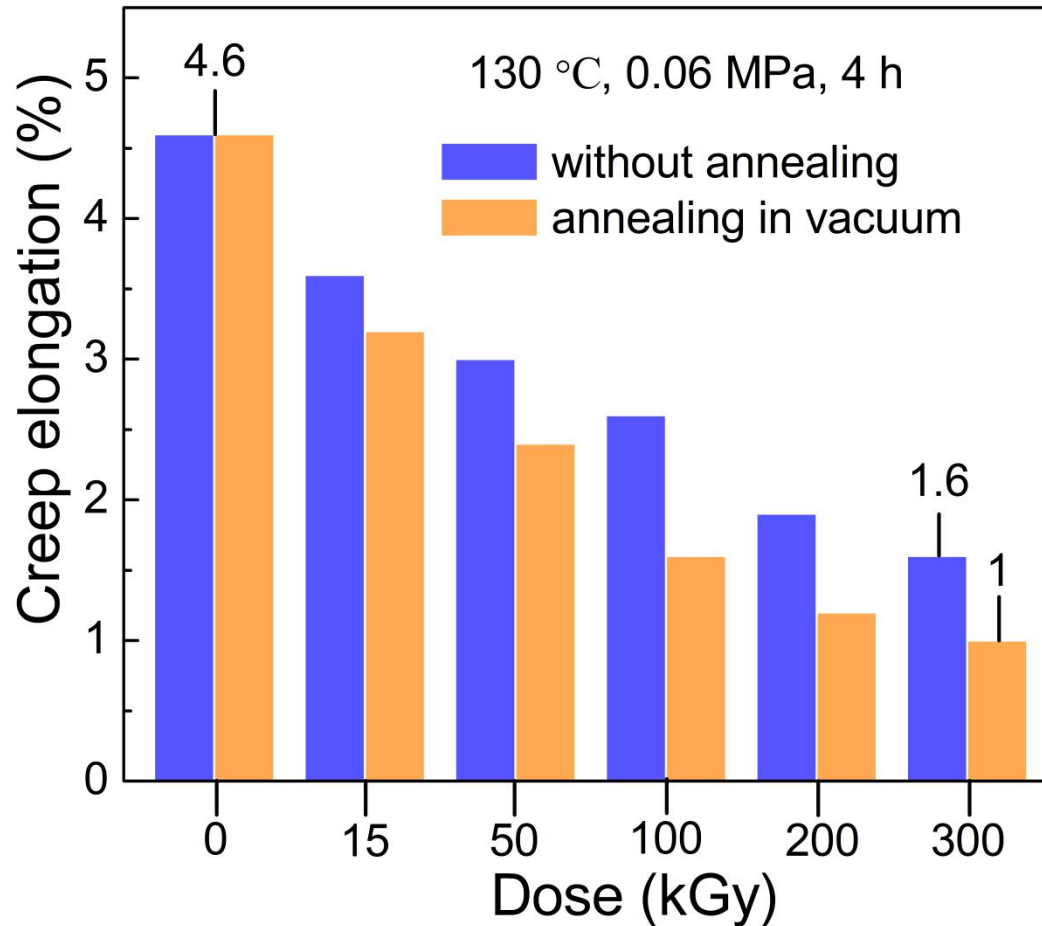
# Radiation cross-linking of UHMWPE sheet



**Gel content of UHMWPE sheet irradiated by gamma rays in air and with post-annealing.**

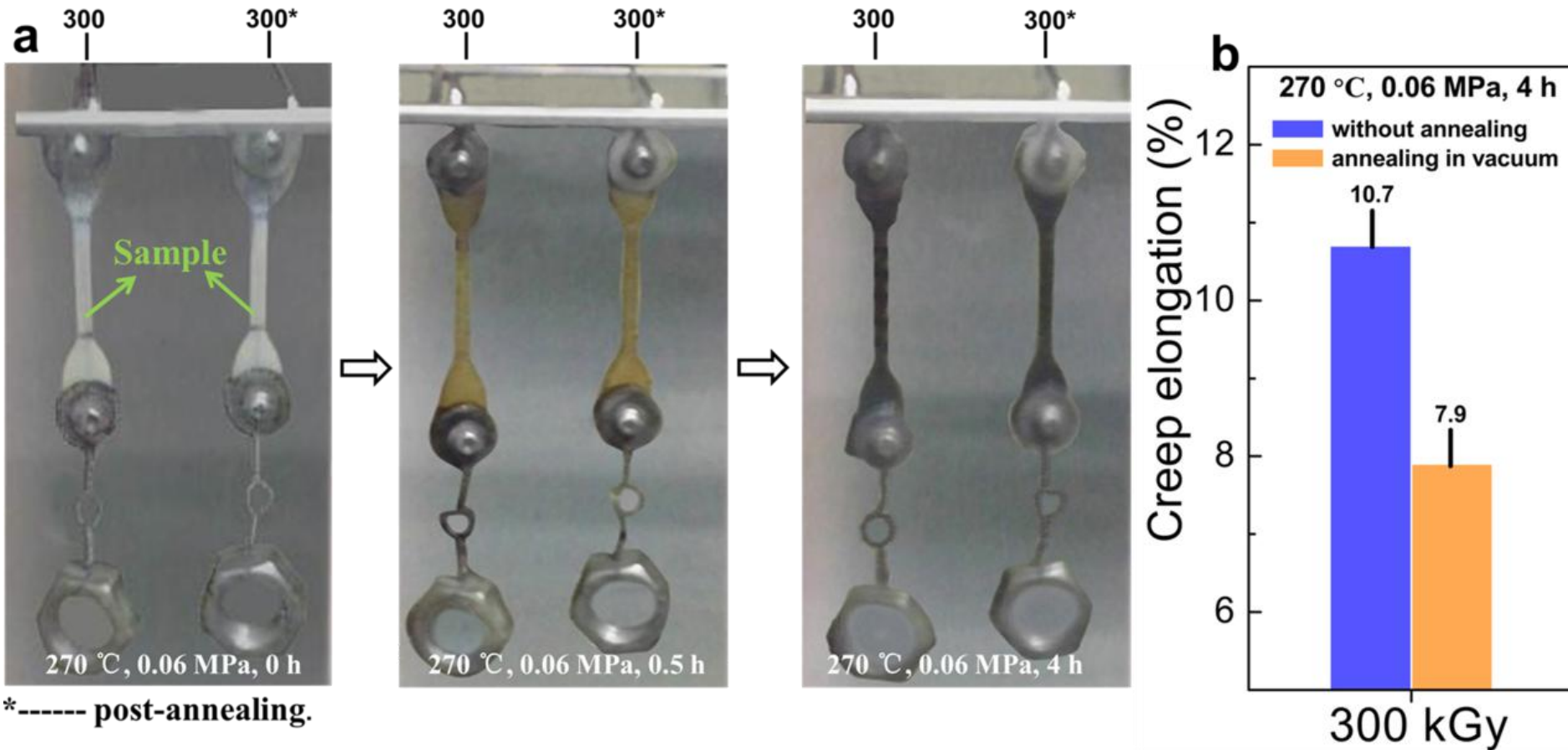
**For UHMWPE sheet irradiated in air, cross-linking is the dominant reaction during irradiation.**

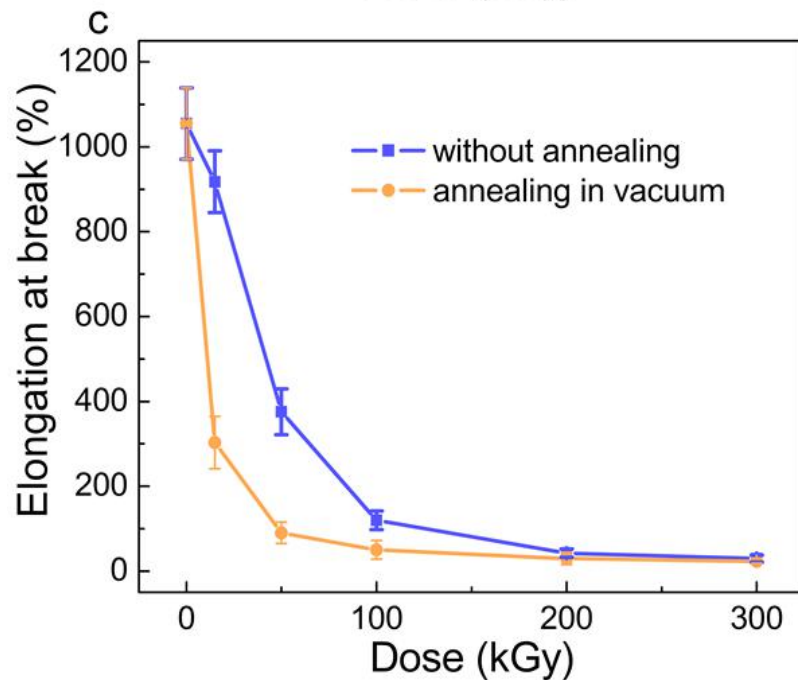
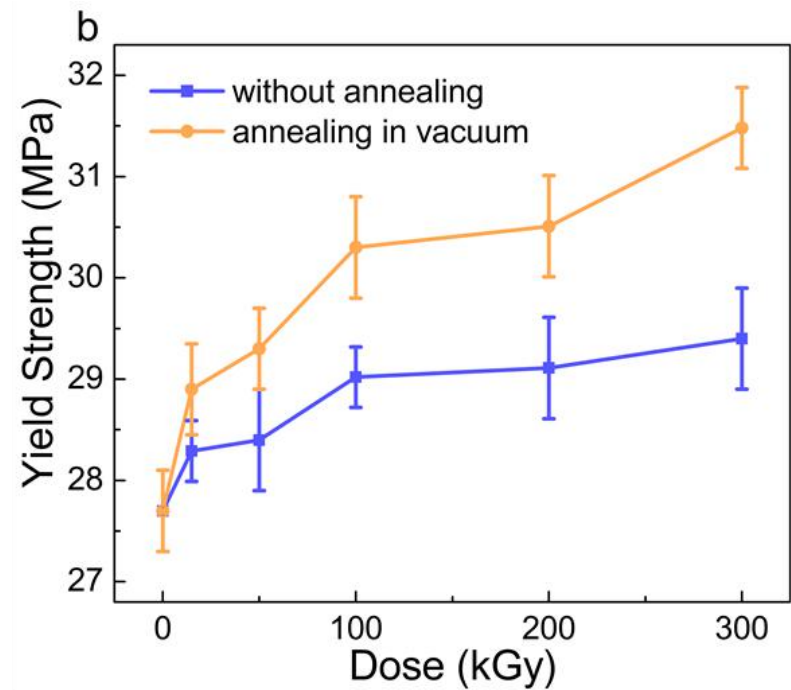
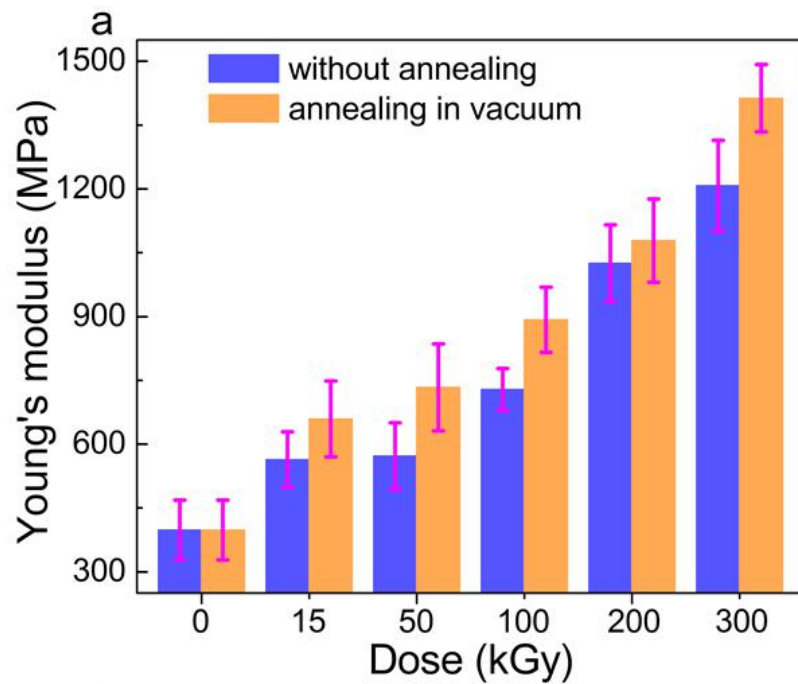
## Radiation cross-linking improves the creep-resistance of UHMWPE sheet.



Creep elongation of UHMWPE sheet after gamma ray irradiation in air.

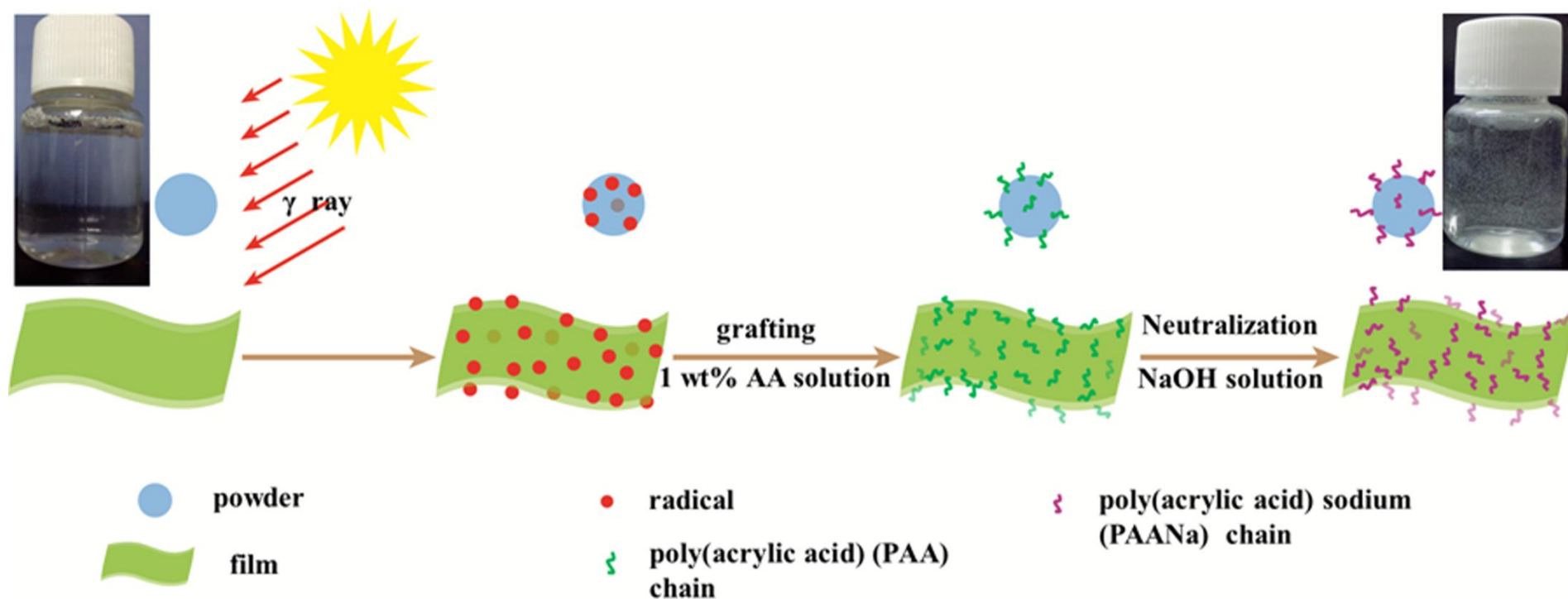
## Highly cross-linked UHMWPE sheet shows good creep-resistance.



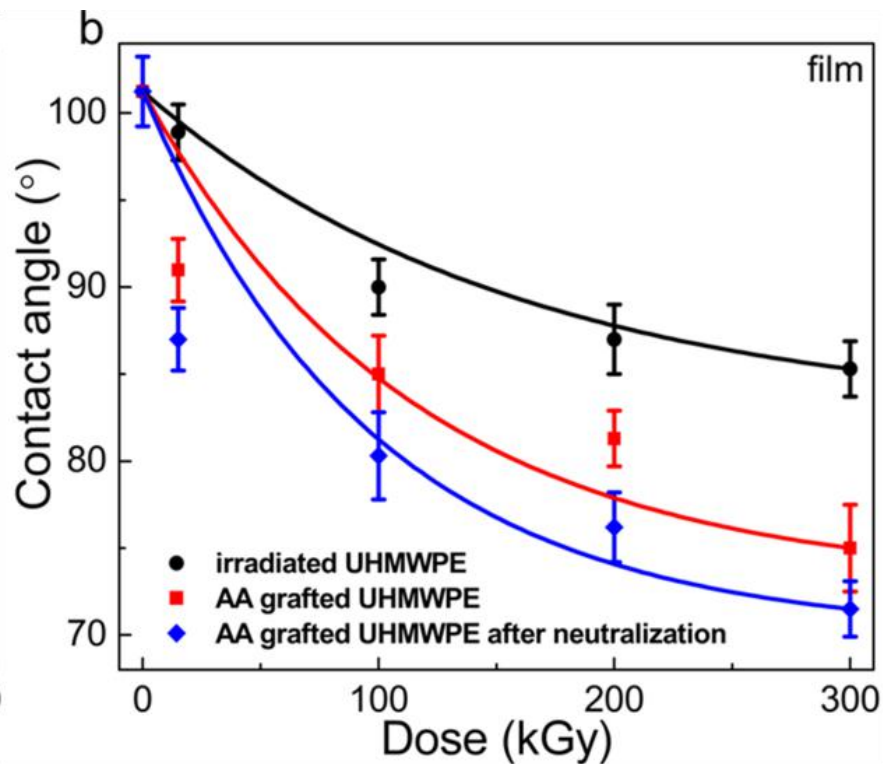
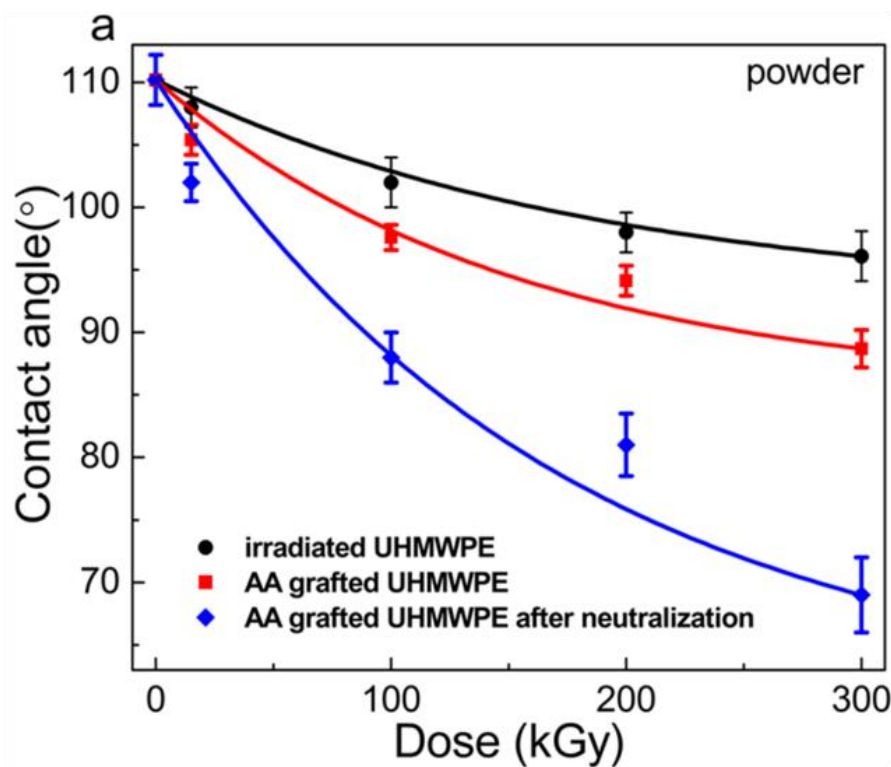


**Radiation cross-linking increases Young's modulus and Yield strength of UHMWPE sheet but decreases its ductility.**

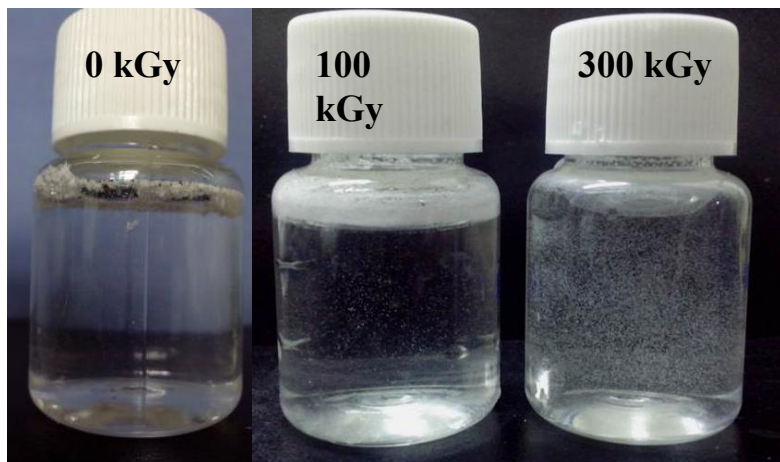
# Radiation grafting of a small amount of Acrylic acid (AA)





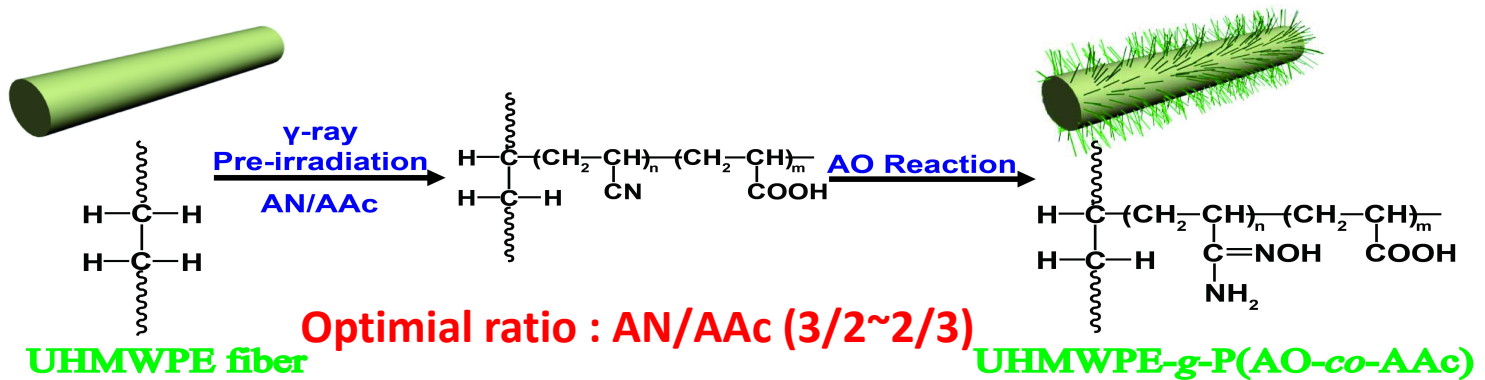


**Static contact angle of UHMWPE powder and film after gamma ray irradiation, grafting of AA and neutralization treatment.**



**Hydrophilic UHMWPE powder was prepared by radiation grafting of 5.7 wt% AA and neutralization treatment.**

# Radiation grafted (amidoximation) UHMWPE fiber for uranium adsorption from seawater

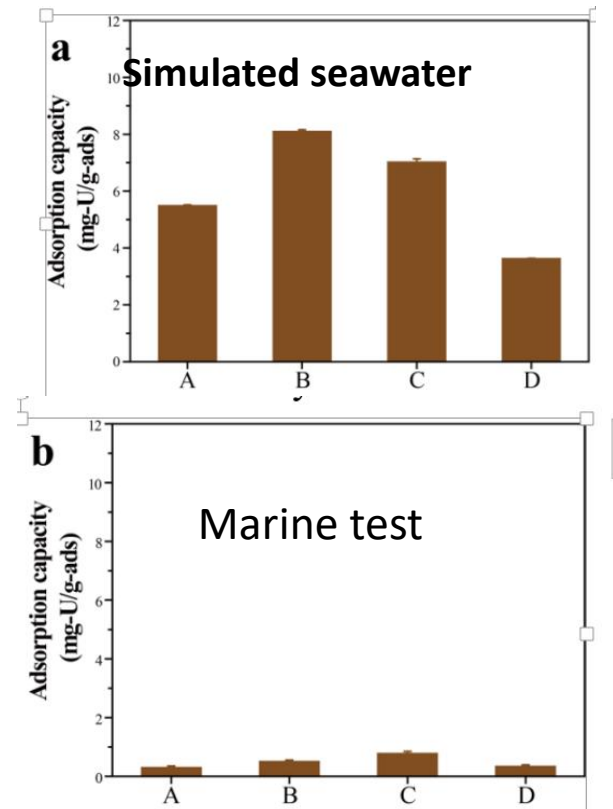


AN/Ac ratio: 4/1

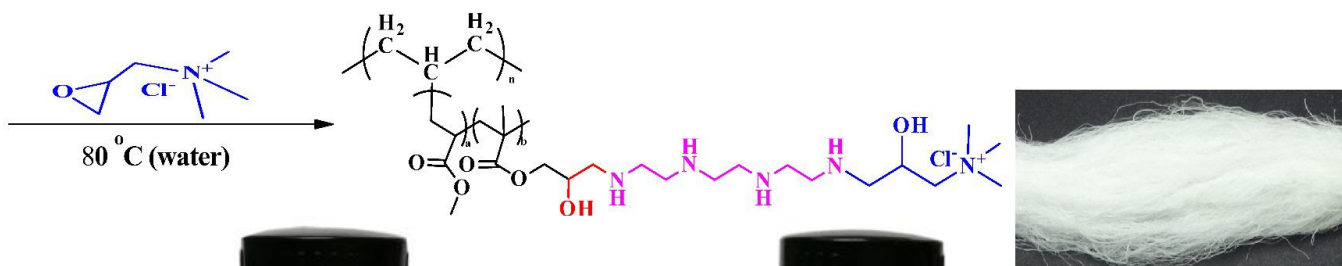
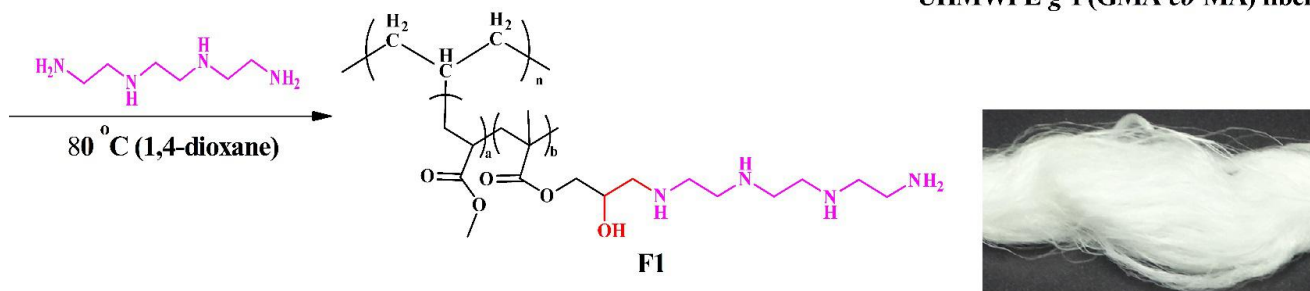
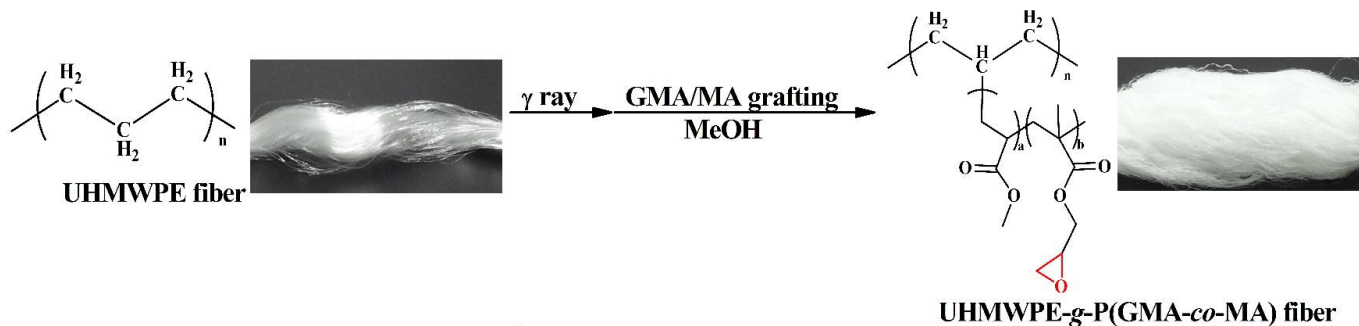
3:2

2:3

1:4



# UHMWPE fiber loaded with Pd



The fiber can be applied for catalytic reduction of Cr(VI) to Cr(III)

# **Conclusion**

**Radiation technology can be applied to modify surface , creep resistance and mechanical property of UHMWPE, and it has industrial application.**

# **Acknowledgement**

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THANK YOU FOR YOUR ATTENTION!

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