Ionising radiation influence on the physico-chemical and functional properties of the materials

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Radiation Chemistry – interaction of gamma photons, fast electrons, X-ray photons, charged particles with the valence spheres of the atoms (no radioactivity)

GAMMA: A colision of gamma photon with an atom causes ejection of an electron from the valence shell accompanied by emission of the photon with lower energy. Thus, both in the case of irradiation with electrons and with gamma photons, the processes in materials occur due to direct interaction with electrons.

The probability for interaction with atoms and molecules depend only on the electron density of the material.
However, the resistance to irradiation and the course of chemical processes depend on molecular structure and on supramolecular structure of the material (crystalline/amorphous properties)

PROCESSES - FREE RADICAL MECHANISM – THE SAME CONCERNS PROCESSES IN POLYMERS INITIALiZED BY CHEMICAL METHODS

POST RADIATION EFFECTS
The processes take place during irradiation and for some time after irradiation

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The objects subjected to radiation sterilization or decontamination

- **Medical Objects (Equipment, Transplants, Scaffolds)**
- **Medical (Pharmaceutical) Preparation**
- **Cultural Heritage**
- Foodstuffs
- agricultural usage (growth media)

Medical equipment and drug delivery systems predicted for radiation decontamination are often made or composed from polymers

Sterilization is ussually carried out with doses till 30 kGy.

In the case of new material for biomedical application, it is of high importance to consider the method of sterilization of the final product at the stage of the selection the material composition

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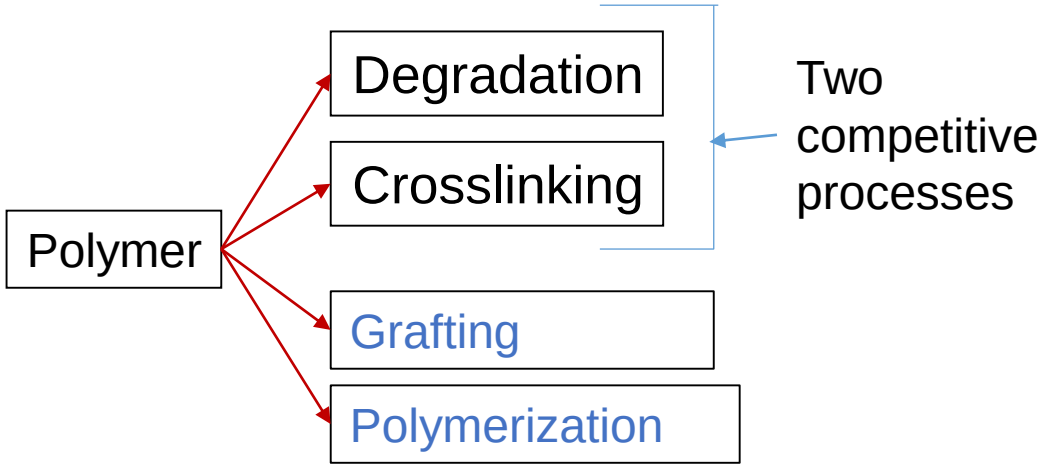
RADIATION EFFECTS IN POLYMERS



SPECIAL FEATURE OF RADIATION PROCESSESS

- Ability to limit or eliminate the chemical agents (initializing, crosslinking, etc) – clean proces
- No need for purification
- Do not need elevated temperature to initialize the processes („cold" processes)
- Easy to control

The methods for control the radiation processes

- Type of radiation (gamma, electron, X-ray, UV),
- environment (solid state or solution, type of solvent, concentration, gas atmosphere),
- composition
- dose and dose rate
- temperature

Protection effect (self- protection)
Some groups (i.e. aromatic rings) present in the polymers molecules act as scavengers of free radicals and restrict fre radical processes
.

✓ Antioxidants:
Compounds added to polymer composition for scavenging of free radicals.

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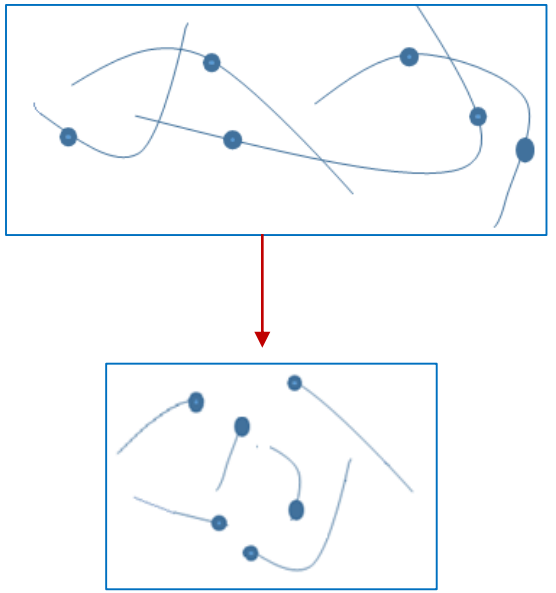
DEGRADATION OF POLYMERS

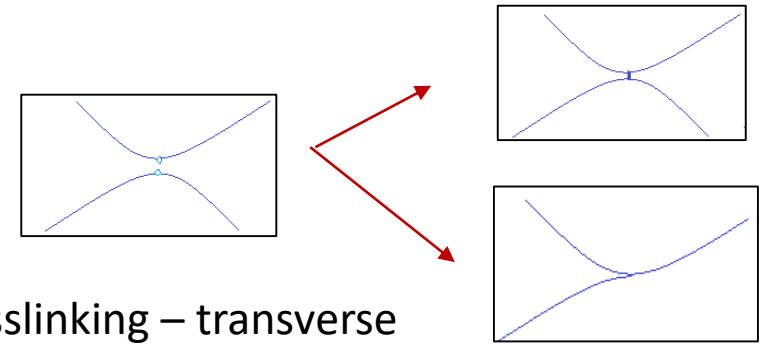
Scision of poymer chains:

- Scision of polymer chains and **oxidative degradation**
- Formation of the **functional groups (polar groups)** in result of the reactions taking place on the end of chain



Deterioration of physico-chemical properties

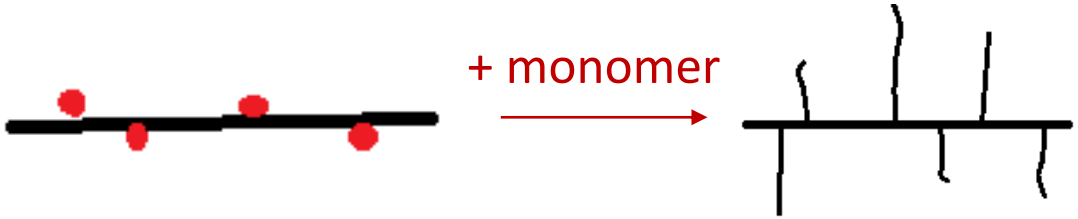
CROSSLINKING AND BRANCHING



Crosslinking – transverse linkages (crosslinks)

Improvement

GRAFTING



Modification of surface properties

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The strategies applied for elimination or reduction of the non-desirable degradation/ oxidative degradation

1. Irradiation at low temperature (i.e. liquid nitrogen) – reduces propagation of free radicals
2. Irradiation in the protective atmosphere (oxygen absence)
3. Modification of composition the base polymer (introduction of anti-oxidants and stabilizers)
4. Modification of composition of the base polymer: composition of aromatic-aliphatic groups, addition of crosslinkers that can enhance crolsslinking processes, or addition of appropriate monomers that can be grafted in result of radiation treatment
5. Irradiation in the short time with a use of high dose (restriction for difusion of oxygen, time of reaction)
6. *Irradiation in environment of solvent that terminates propagation of free radicals*

The effect of irradiation depends on density of the material and on it's form. Thin films and fibers are more exposed to action of oxygen than thick bulk polymer.

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EXAMPLES

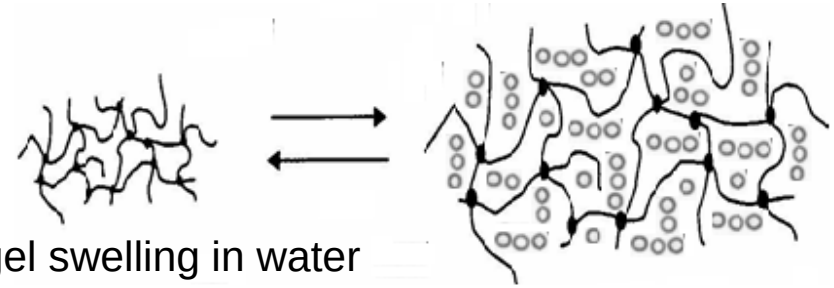
1. Ultra High Molecular Weight Polyethylene (UHMWPE) (Highly crosslinked PE)

Implants:
- Acetabulum of the hip-joint (acetabular cup)
- Knee

Exposure to high mechanical overload

UHMWPE - can be produced (crosslinked) by radiation technique **with a use of sterilization dose or higher**:
Problem: POST RADIATION EFFECT OF FREE RADICALS → **oxidative degradation**
Solution : - PE + antioxidant, irradiated. Highly effective scavenging of free radicals by antioxidant (α-tokoferol)

2. Manufacturing of sterile hydrogel wound dressing by irradiation



gel swelling in water

Composed from: synthetic water soluble polymers and/or natural polymers

Wound dressing, carriers for active compounds (medicines) in drug delivery systems, Hybrid organs (Encapsulation of living cel), Cements, Bedsore, etc

The example: composition **of PVP (+ agar and PEO)** in water,, placed in the form, then irradiated with a **sterilization dose** (photo by Kik-Gel, Poland)

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3. Irradiation of scaffolds for tissue engineering

Scaffold – biological material or
polymer + biological material

Radiation sterilizationon of the final scaffold enable to preserve it's functional properties and often is reported as the best method

RADIATION STERILIZATION AND CONSOLIDATION OF THE OTHER MICROBIOLOGICALLY INFECTED OBJECTS:

Cultural Heritage

Archives, historical manuscripts, wooden objects (icons, furniture), skin, biological objects (mummy, mammoth) etc. Very precious

Infected by: moulds, fungi, insects

Practice:

1. using of the minimal doses , only in the case of strongly destroyed objects
2. Consolidation: impregnation of the object with a solution of monomer that undergoes polymerization under irradiation

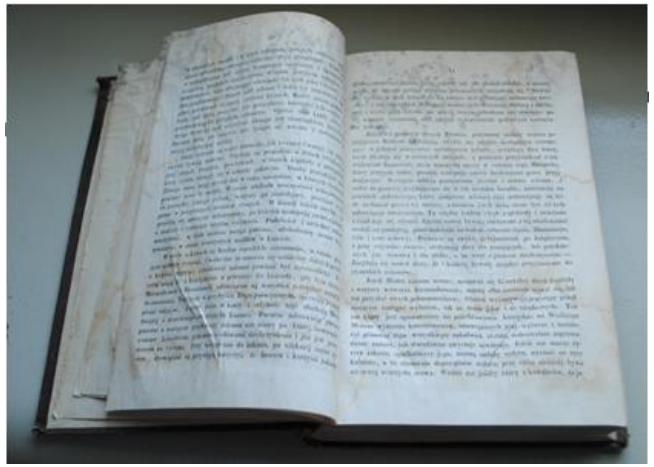

photo A. Kuberka, ALTO PROTECT, Poland

Food and Food Components

- Radiation decontamination of food (standard doses till 10 kGy (dry food))
- Modification of the food additives by: degradation, crosslinking

Lead to modification of functional properties of food hydrocolloids, or food itself

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SUMMARY AND CONCLUSION

- Ionising radiation induces desired and non-desired effects in material,
- Irradiation can be used also for targeted modification of the polymer properties,
- The effects of ionising radiation depend on the material composition and the conditions of radiation process,
- For a number of polymers irradiated with a use of sterilization dose in the range up to 30 kGy the radiation effects are low and can be neglected,
- The undesired changes in polymer induced by irradiation can be avoided by modification of the polymer composition and conditions of irradiation,
- These should be done for each individual composition experimentally,
- OPTIMALIZATION OF RADIATION STERILIZATION PROCESS IS ACHIEVED WHEN THE MATERIAL IMPROVES OR GET NEW FUNCTIONALITIES UNDER THE DOSE USED FOR STERILIZATION

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THANK YOU FOR YOUR ATTENTION

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