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Joint ICTP-IAEA Workshop on Radiation Resistant Polymers

14 - 18 March 2011

SELF-HEALING IN POLYMERS

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SELF-HEALING IN POLYMERS

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Lecture given at the ICTP/IAEA Workshop on “Radiation Resistant Polymers”, 14-18 March 2011, Trieste, Italy

- SH comes from the nature, ability to heal is a chracteristic of living organisms. A damage triggers an automatic healing response.
- Materials that can recover mechanical properties following failure offer “increased safety and service life”.
- Relevant to materials that are used without or with only limited access by men, e.g. Medical applications, civil, aerospace, automotive and power engineering.

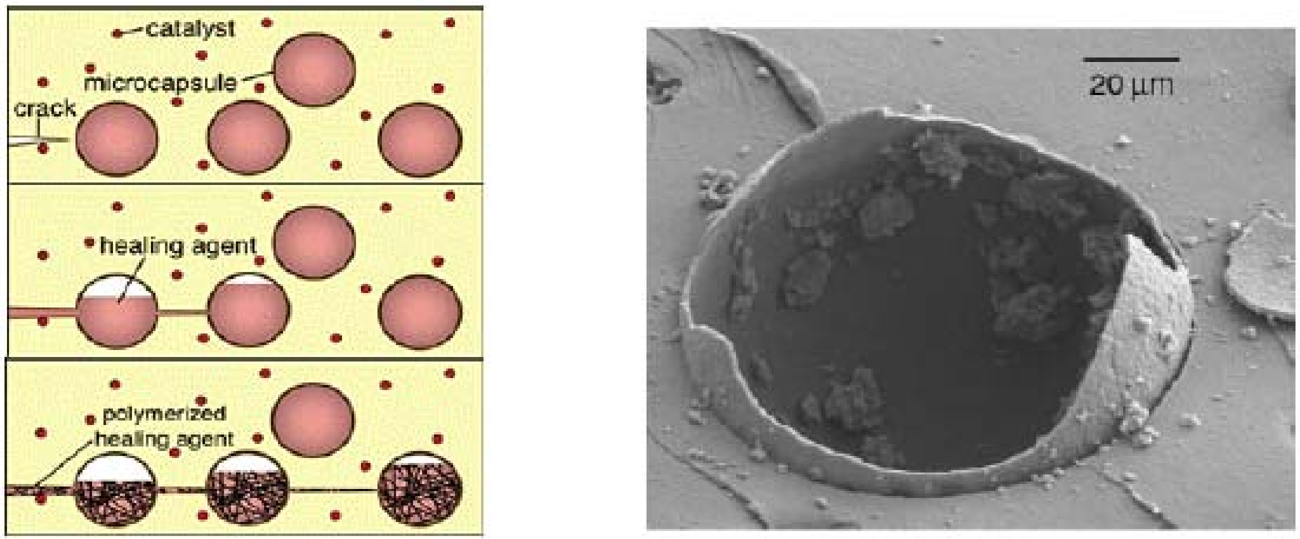
Self-healing Coatings in Practice - Examples

- Nissan X-Trail (2005; „Scratch Guard")
- Nissan Infiniti (2008; „Scratch Shield")
- Toyota Lexus (2010)
- Iveco/PPG (driving cab of an innovative concept truck 2010)
- Fiat/PPG (practice test with different test cars 2010/2011)

Healing of Scratches?

- Polymer networks are made to self-heal by either adding microcapsules filled with uncured resin or by introducing reversible bonds.
- The resin held within the matrix is released upon crack formation and hardens to heal the crack.
- The other mechanism of healing relies on the reversibility of bonds found designed into polymer networks.
- SH polymeric materials are therefore multifunctional composite systems.

SH by MICROCAPSULE APPROACH



(a) (b)

Figure 1: (a) Basic method of the microcapsule approach, (b) ESEM image showing ruptured microcapsule [White et al, 2001]

Prerequisite for a self-healing of a (mechanical damage) is the generation of a mobile phase which can close this crack

www.MaterialsViews.com

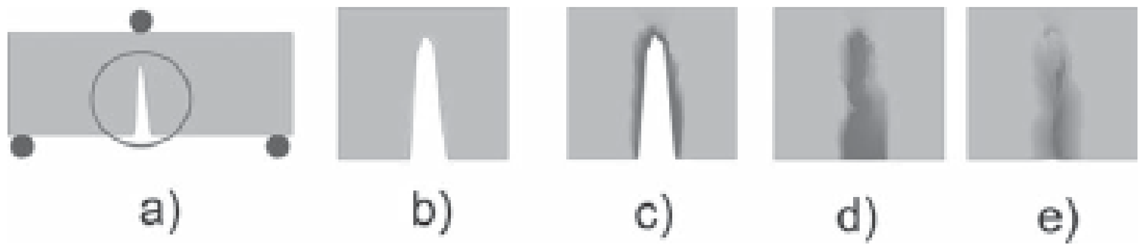


Figure 1. Common basic principle of self-healing materials. a) The mechanical load induces a crack; b) detailed view of the crack; c) a "mobile phase" is induced; d) closure of the crack by the "mobile phase"; e) immobilisation after healing.

SH by REVERSIBILITY OF BONDS

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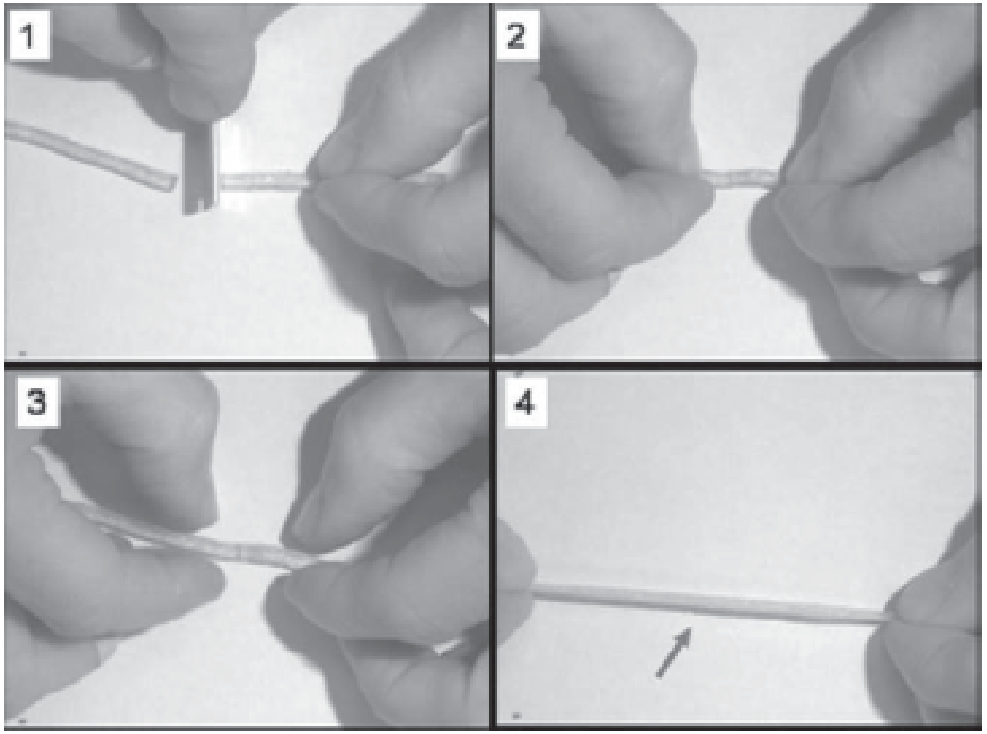
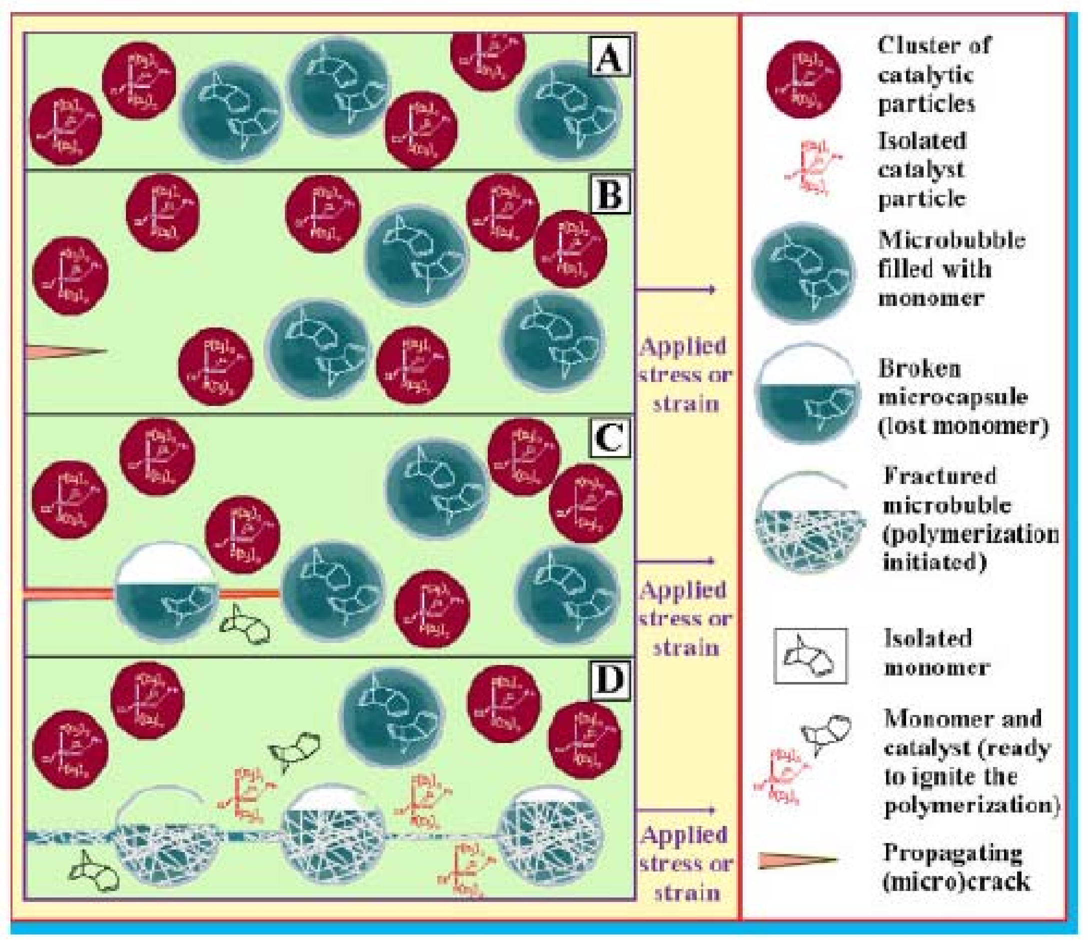
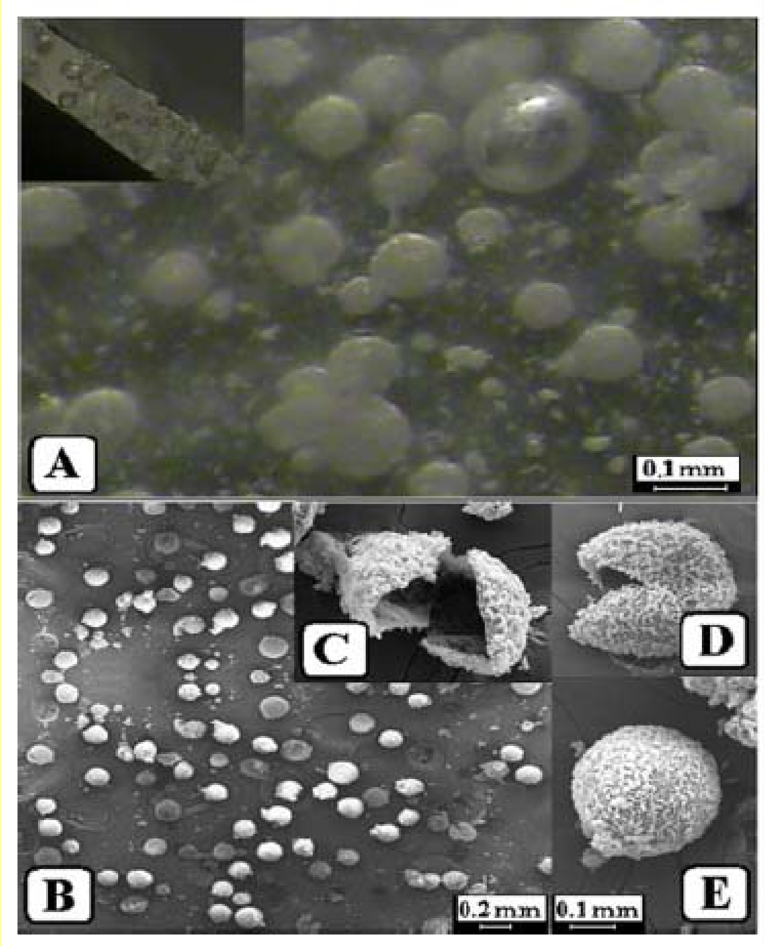


Figure 3. Self-healing properties of a supramolecular polymer by Leibler and coworkers. Reproduced with permission.[61] Copyright 2008, Ludwik Leibler, CNRS.



M.Chipara et al. PAT, 20(2009)427-431


A
0,1 mm
B
C
D
E
0.2 mm
0.1 mm

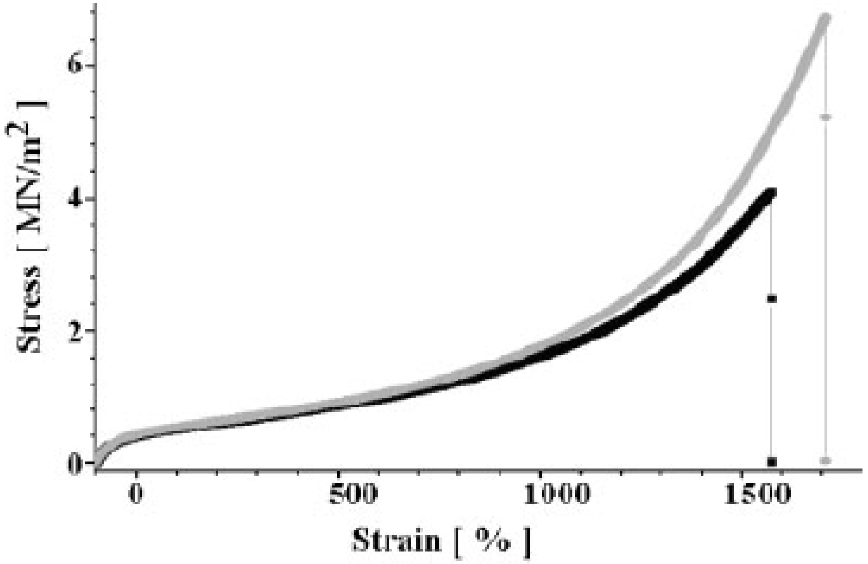
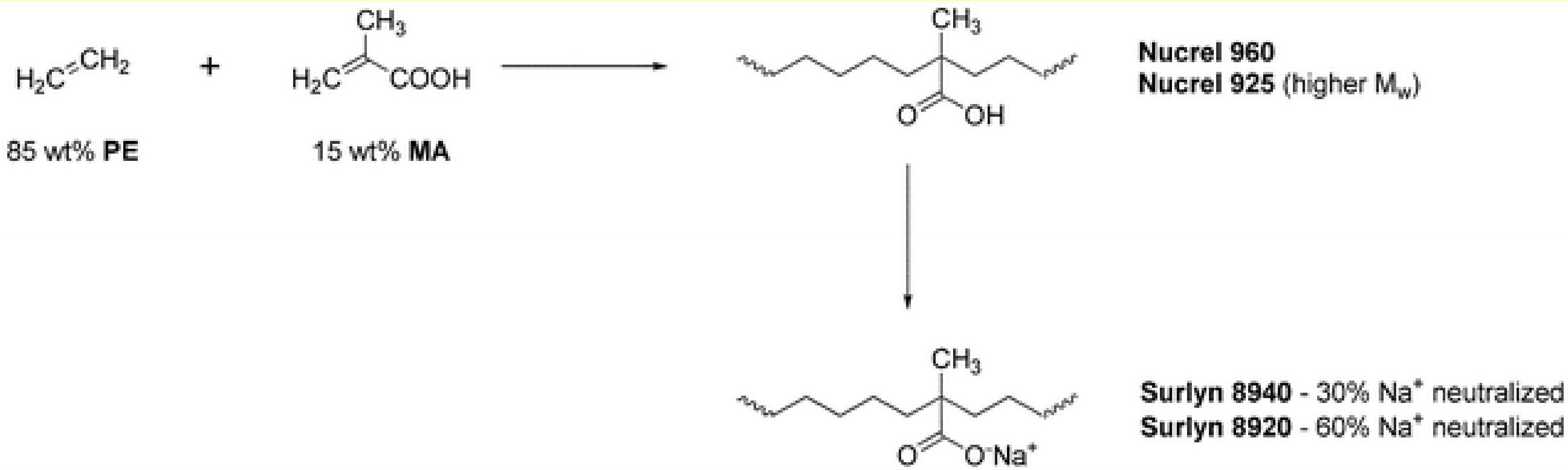
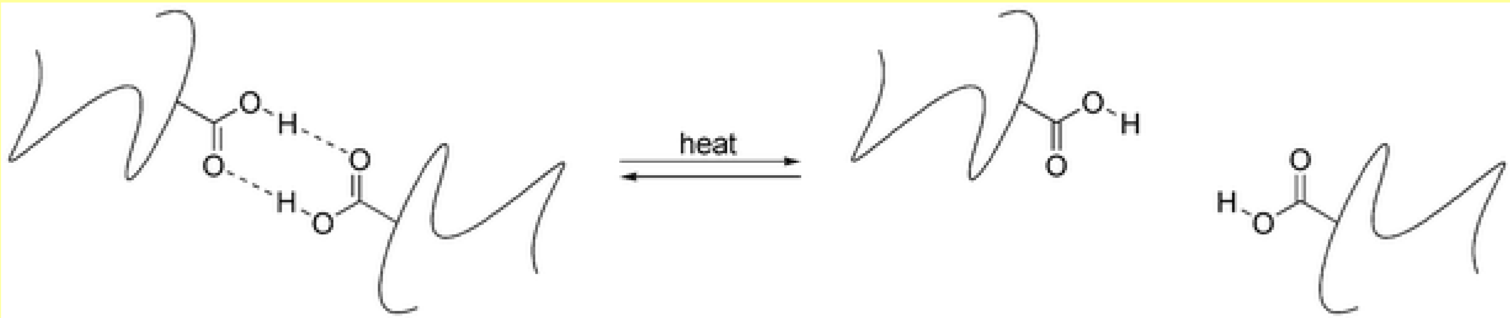


Figure 5. Stress–strain dependences for polystyrene-*block*-polybutadiene *block*-polystyrene filled with 5% microbubbles containing DCPD (black line; self-healing features not activated) and polystyrene-*block*-polybutadiene *block*-polystyrene filled with 5% microbubbles containing DCPD and loaded with 1% Grubbs catalyst.

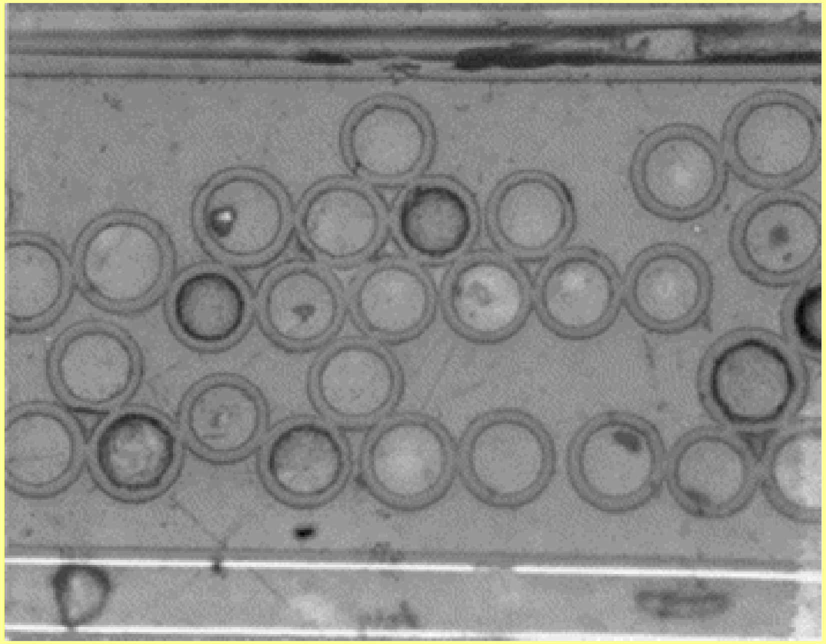
IONOMERS USED IN SH

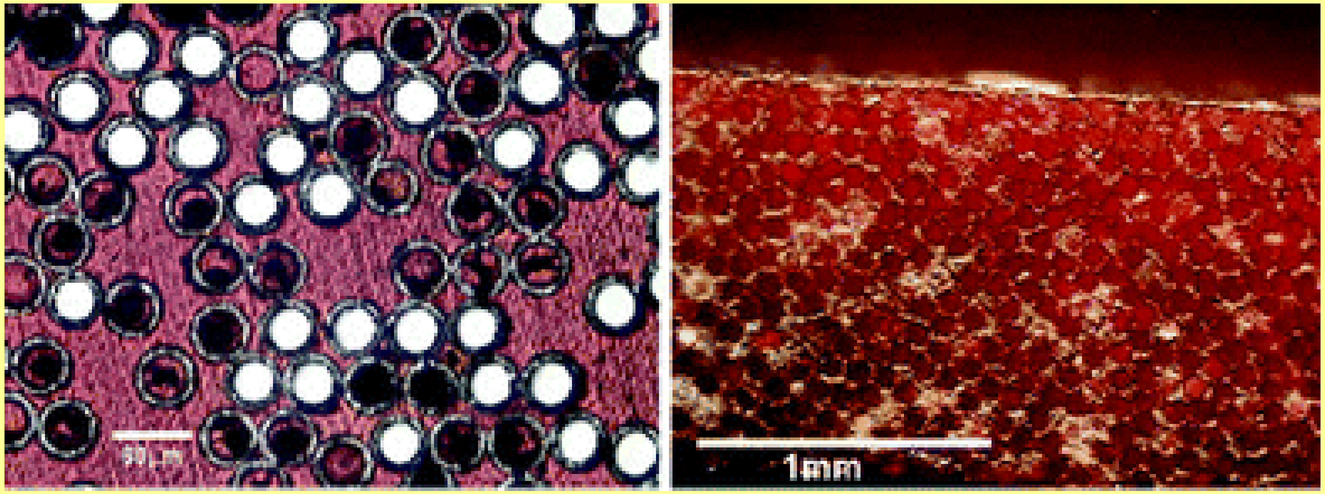


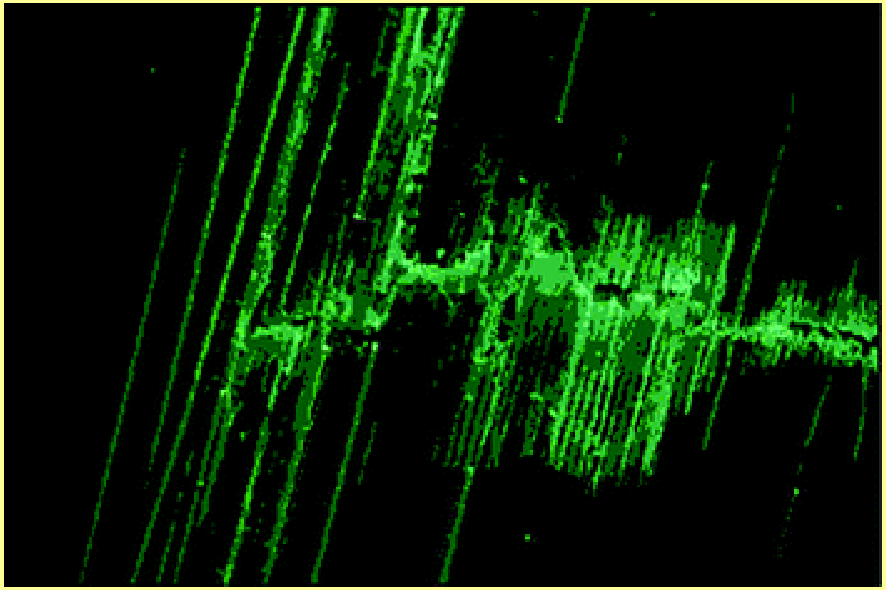
THERMALLY CONTROLLED HYDROGEN-BOND XL

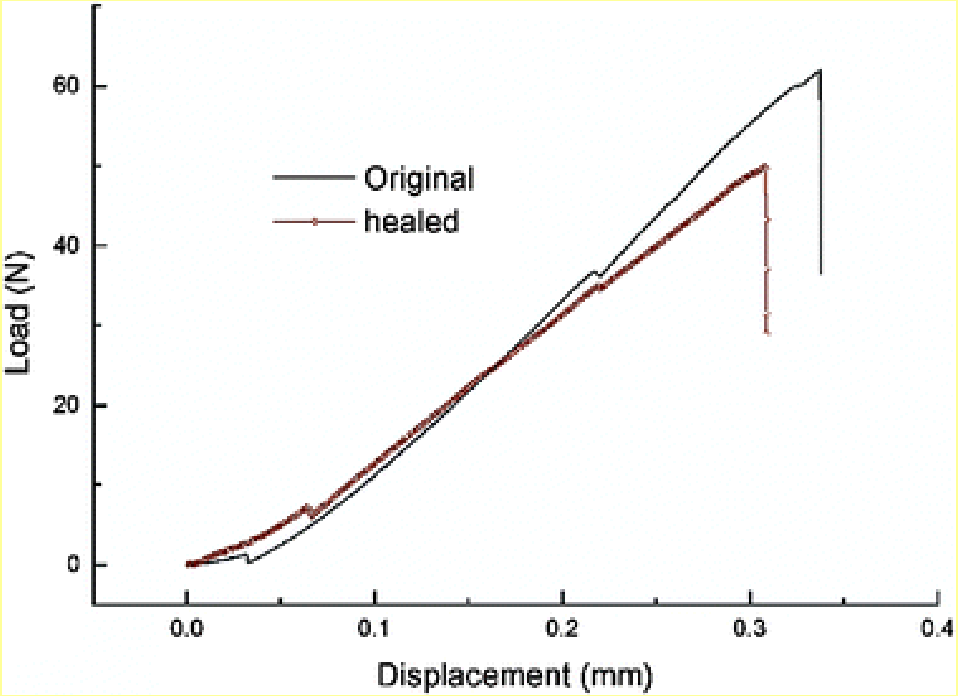


HOLLOW GLASS FIBRES




1mm





Original
healed
Load (N)
Displacement (mm)
0
20
40
60
0.0
0.1
0.2
0.3
0.4

2007-01-3211

Self-Healing Technology for Gas Retention Structures and Space Suit Systems

J. Ferl, J. Ware, D. Cadogan and J. Yavorsky
ILC Dover, LP

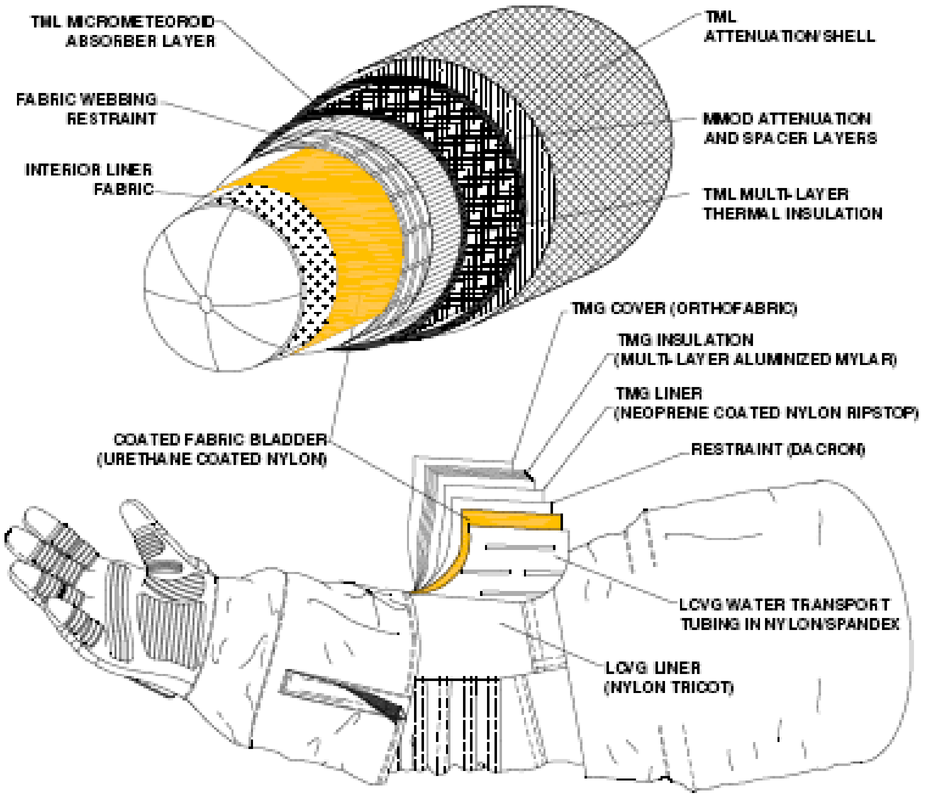


Figure 1. Typical Space Suit and Inflatable Structure Ply-Up

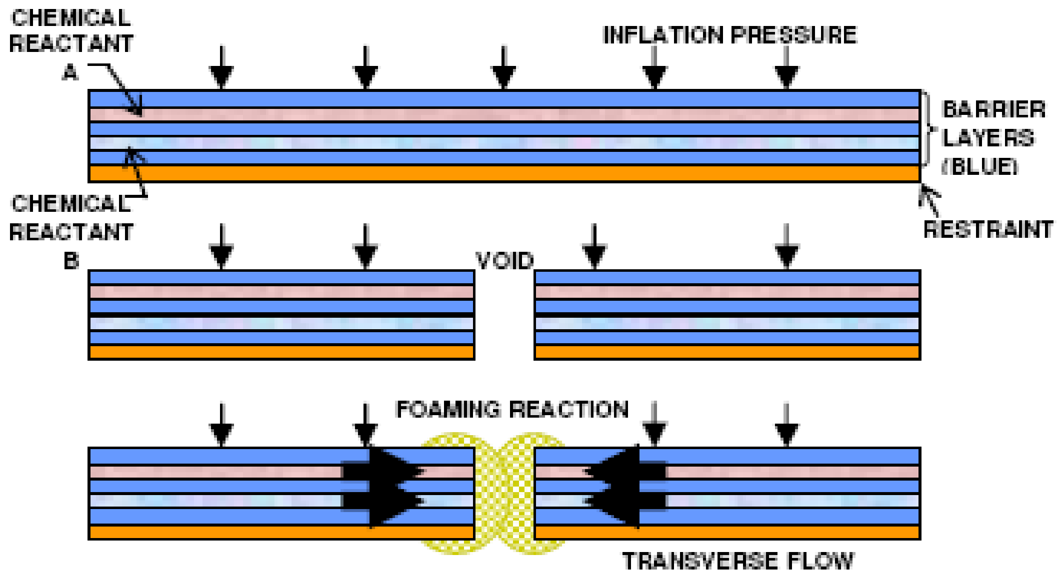


Figure 9. Chemical Reaction Concept Schematic

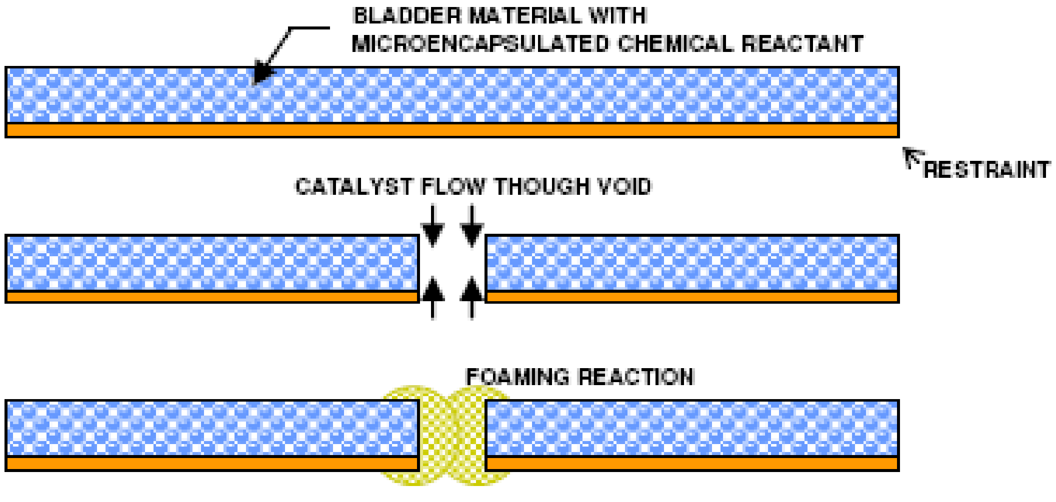


Figure 8. Environmental Reaction Concept Schematic

Figure 17. Self-healing Viscoelastic Gel Localized on Each Pattern Piece of SSA Lower Arm Bladder

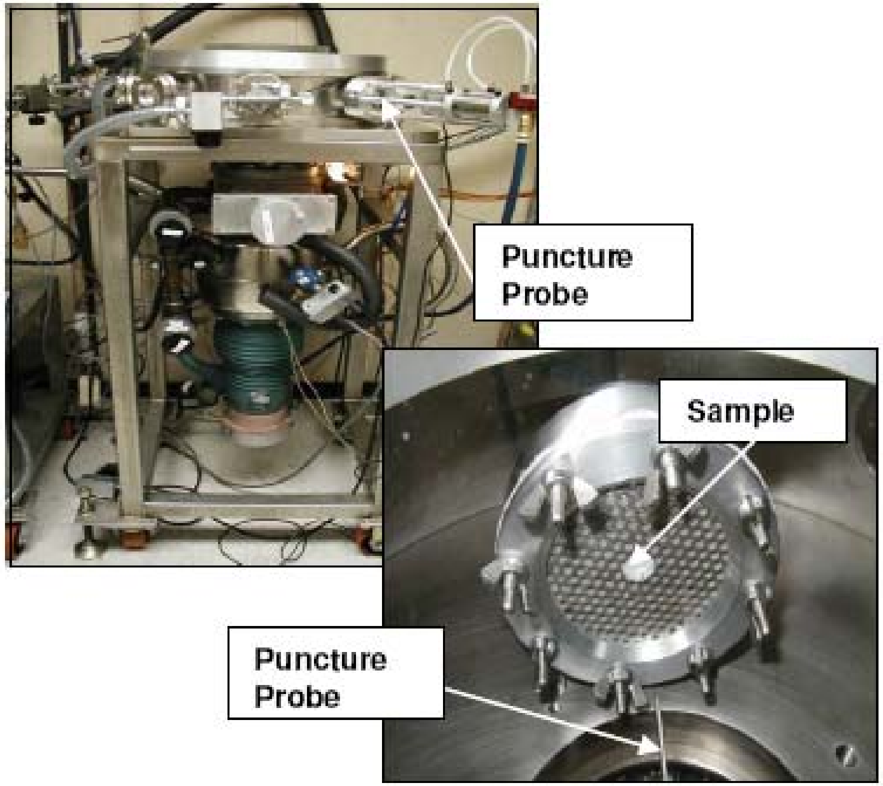


Figure 19. Self-Healing Sample Test Fixture in Vacuum Chamber

PUNCTURE TESTS IN VACUUM CHAMBER

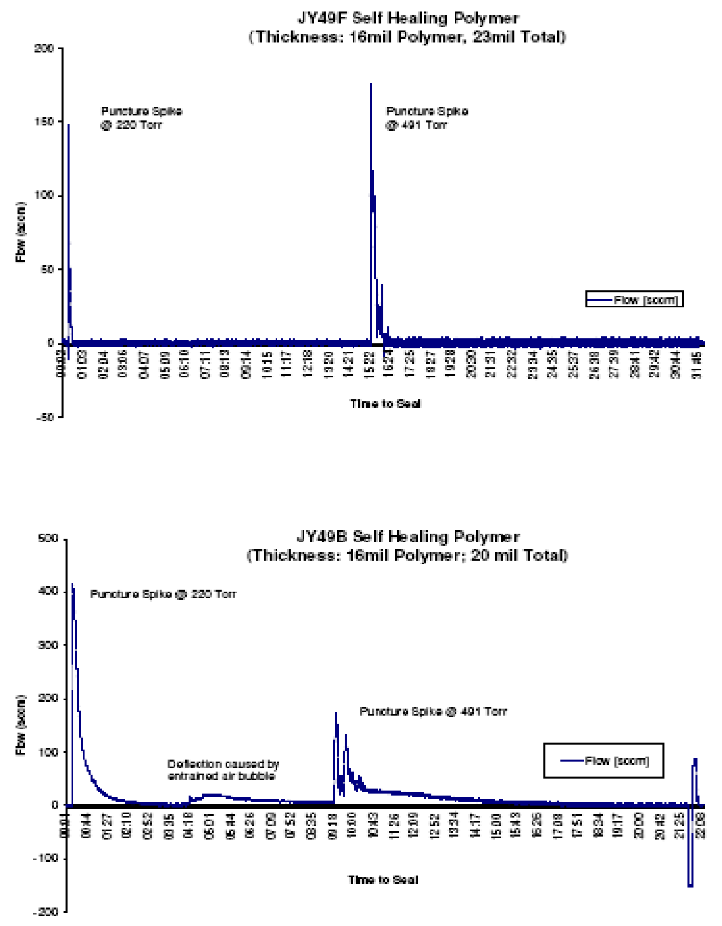


Figure 20. Results of Self-Healing Viscoelastic Material Puncture Tests in Vacuum Chamber

INVERSE TEMPERATURE-ANNEALING PHENOMENA

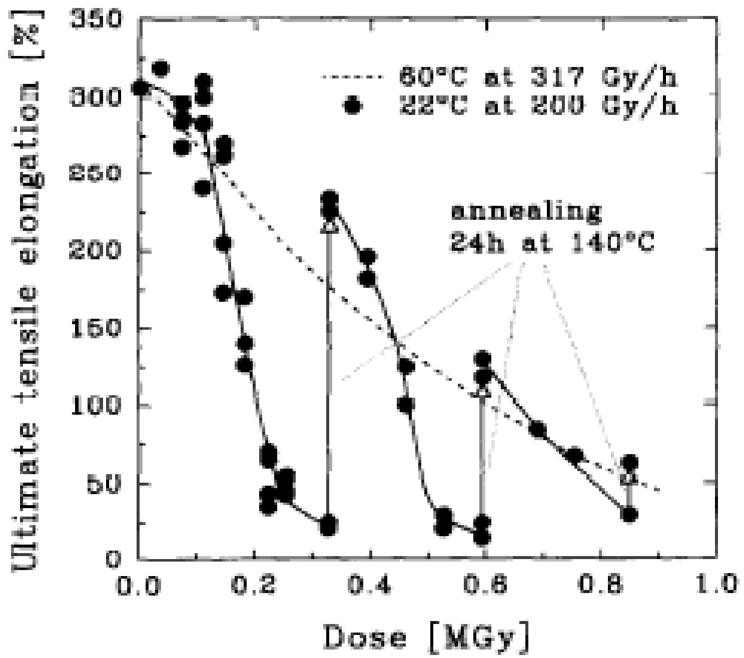


Fig. 1. Decrease in ultimate elongation for material A during degradation at 22°C and 200 Gy h^{-1} and the recovery of mechanical properties upon annealing at 140°C for 24 h after 328, 594 and 849 kGy. Note the slower degradation for the material when aged at 60°C.

lina et al.

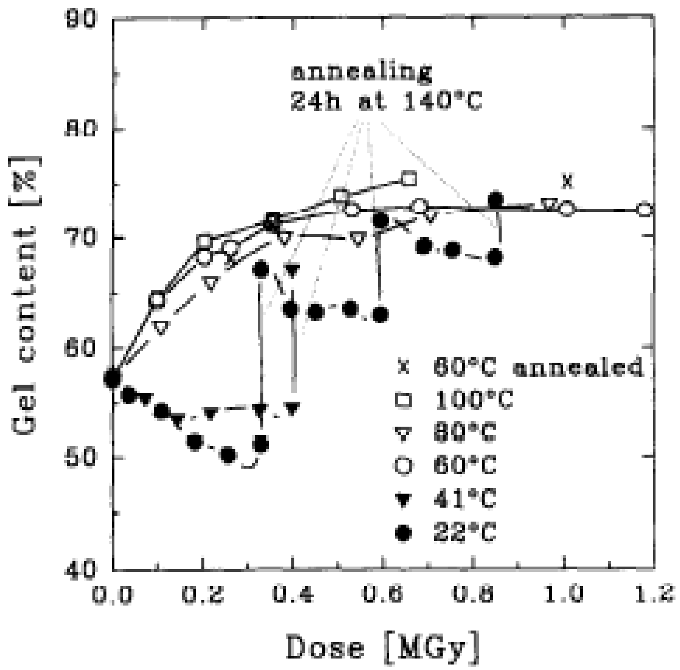


Fig. 2. Changes in the gel content of material A during combined radiation–temperature exposures as a function of temperature showing predominantly scission at lower temperatures and crosslinking at higher temperatures as well as a marked increase in the gel content during annealing of samples aged at 22 and 41°C.

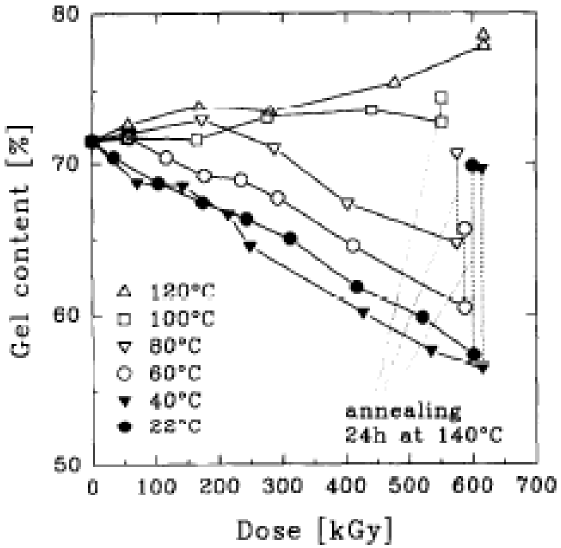


Fig. 5. Changes in the gel content of material B during aging at different temperatures and dose rates ranging from 0.21 to 0.35 kGy h^{-1}.

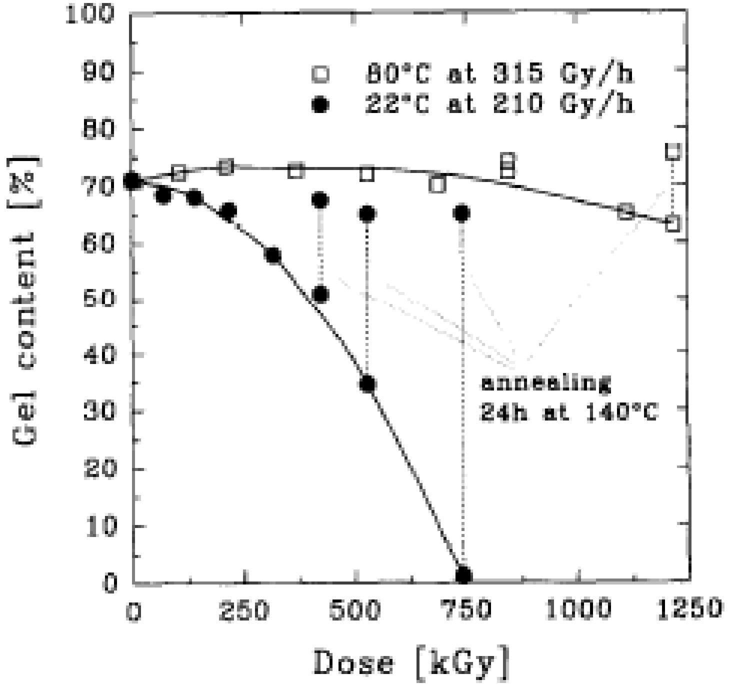


Fig. 6. Changes in the gel content of material C during aging at 22°C ($0.21\,kGy\,h^{-1}$) and 80°C ($0.315\,kGy\,h^{-1}$).

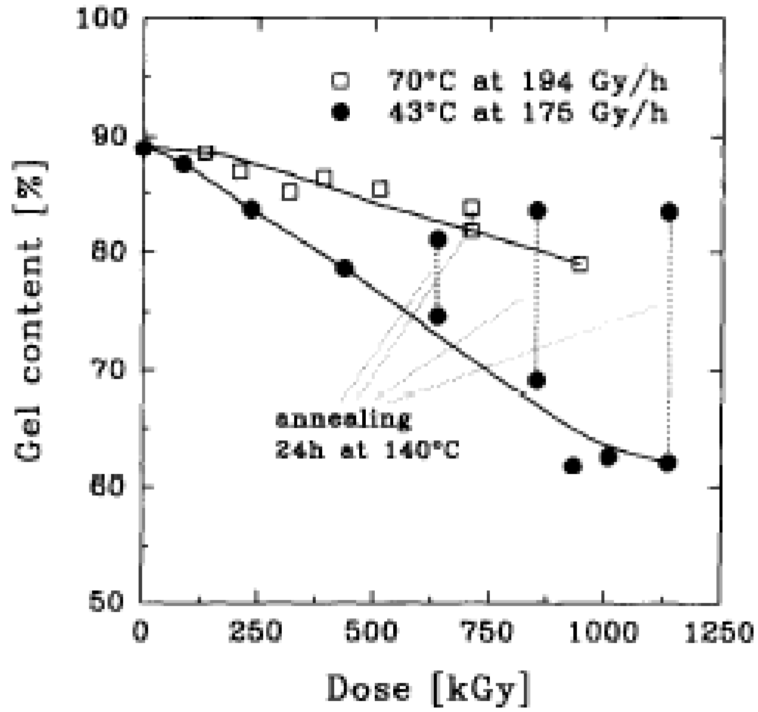


Fig. 7. Changes in the gel content of material D during aging at 43°C (0.175 kGy h^{-1}) and 70°C (0.194 kGy h^{-1}).

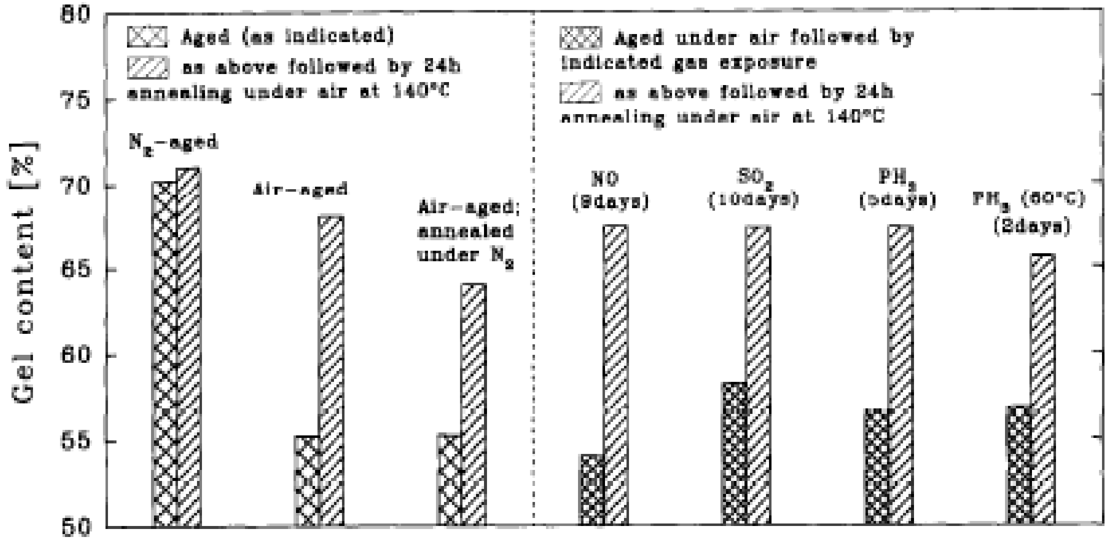


Fig. 11. Gas treatment of material A, aged at 22°C to 400 kGy at 485 Gy h^{-1}, and its influence on subsequent crosslinking during annealing at 140°C (deactivation of any hydroperoxides).

THANK YOU

FOR YOUR KIND ATTENTION