Radiation Effects on Polymeric Systems

Elastomers

Radiation Vulcanization of Elastomers Commercial Process

- Most elastomers can be radiation vulcanized to give crosslinked products similar to those obtained by conventional thermal vulcanization
- Some radiation vulcanization on commercial scale is being done
- Conventional formulations can be radiation vulcanized
- Optimizing the formulations for radiation vulcanization gives better products

Bradley (1984)

Radiation Vulcanization of Elastomers
Free Radical Mediated

- Radiation crosslinking of natural rubber (cis-1,4-polyisoprene) and gutta percha (trans-1,4-polyisoprene) is inhibited by oxygen
  - Gamma irradiation requires inert atmosphere
  - Electron irradiation can be done in air
- Radiation crosslinking of EPDM proceeds more efficiently than that of EPR
  - Crosslinking efficiency of EPDM depends on its ethylene content, and also varies with the crosslinking agent present e.g., ENB (5-ethylidene-2-norbornene) is very efficient
- Radiation crosslinking of polybutadiene is quite efficient

Radiation Vulcanization of Elastomers Wide Applicability

- Radiation vulcanization of polychloroprene, polychloroprene/polyethylene blend, vinylidene fluoride based fluoroelastomers, silicone rubbers, and blends of conjugated diene butyl rubber with polyethylene and polybutylene, also proceeds well

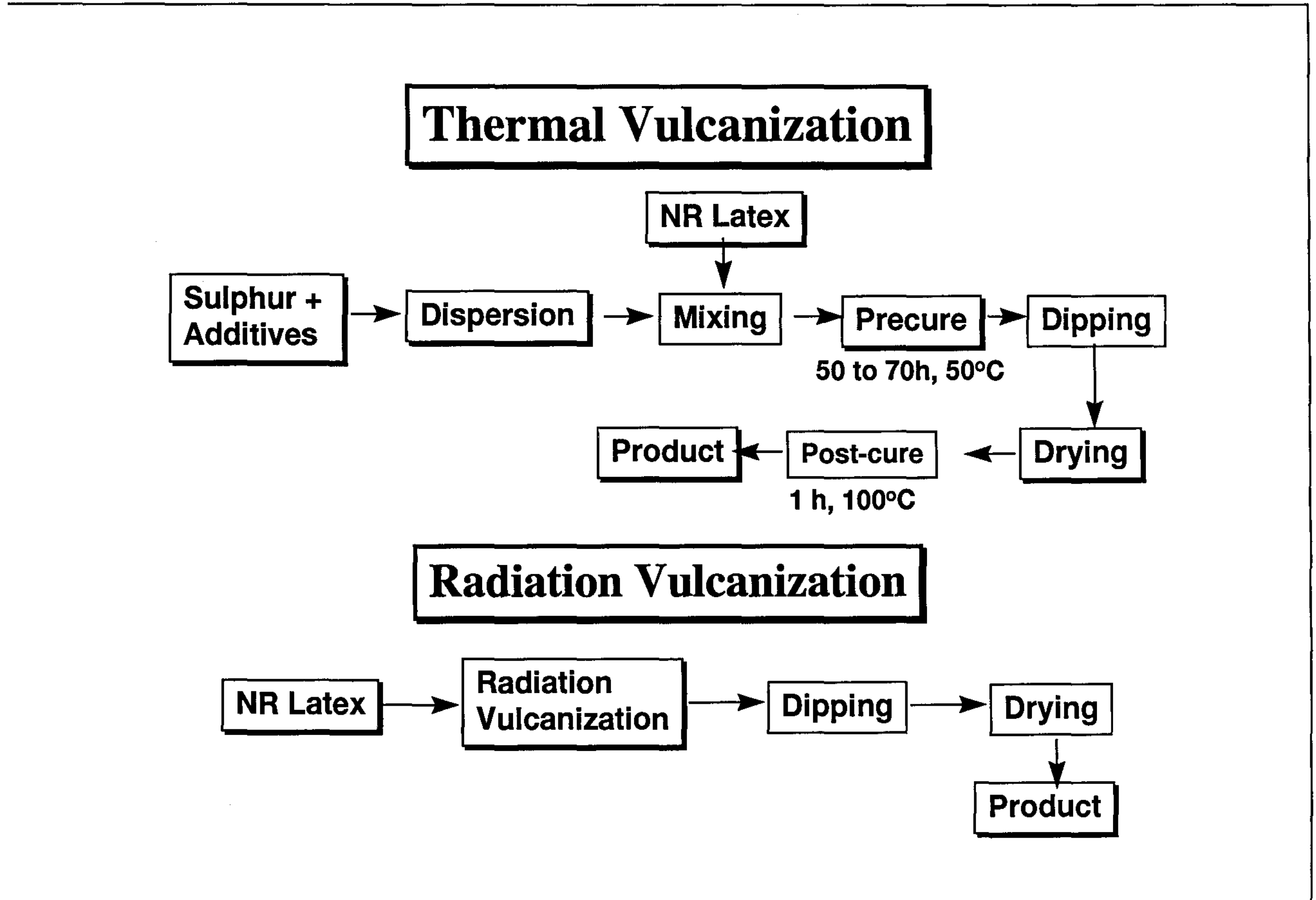
- In contrast, polyisobutylene and butyl rubber degrade on irradiation

Natural Rubber Latex (NRL)

- Studied since 1960
- Many Asian countries involved including Japan and Thailand, along with IAEA
- Technical feasibility demonstrated
- Pilot plants operating
- Cost comparable to thermal vulcanization
- Commercialization in progress

Radiation Vulcanization of NRL (RVNRL)

- Much simpler than thermal vulcanization
- Requires flushing with nitrogen and stirring
- Crosslinking promoters (<5%) added, e.g., CCl_4, mono- or multi-functional acrylates
- Dose required, 10-30 kGy
- Product has very low cytotoxicity
- Nitrosamines, sulfur and zinc oxide eliminated (potential health risks)
- RVNRL safer than thermally vulcanized NRL


Thermal Vulcanization
NR Latex
Sulphur +
Additives
Dispersion
Mixing
Precure
Dipping
50 to 70h, 50°C
Product
Post-cure
Drying
1 h, 100°C
Radiation Vulcanization
NR Latex
Radiation
Vulcanization
Dipping
Drying
Product

Properties of Thermally Cured NRL and RVNRL

Property	RVNRL[1]	Thermally Cured NRL
Tensile Strength (T_b), MPa	38	41
Elongation at Break (E_b), %	900	870
Acid Resistance (10% HCl, 48h)		
T_b, MPa	23	33
E_b, %	900	850
Alkali Resistance (10% NaOH, 48h)		
T_b, MPa	32	35
E_b, %	920	920
Ageing Resistance (70°C, 48h)		
T_b, MPa	37	41
Combustion:		
Gas Production, mg/g	58.5	346.3
Ash, wt.%	0.5	2.2
Ignition Temperature, °C	348	333

[1] Crosslinking promoter, mixture of 2-ethylhexyl acrylate and ammonia; dose, 12 kGy

Tire Manufacture
Synergy with Conventional Technology

- Radiation crosslinking of innerliner has helped make tire manufacturing a more efficient and economical process
- It is an electron irradiation application (1-3 MeV)
- Irradiation of the green rubber innerliner allows a precise control of its strength and tack
- This enables precise assembly of the multi-layered tire, and the tack of the innerliner results in good adhesion between layers during conventional vulcanization

Tire Manufacture
Synergy with Conventional Technology (contd)

- A good example of radiation technology and conventional technology working synergistically
- Most conventional formulations can be radiation crosslinked
- Optimization of the formulations for radiation crosslinking gives a better product

Economics of Irradiation in Tire Manufacture
(Bradley, 1984)

Orginial liner 24" wide x .047" thick x 72" long x ρ 1.2 = 3.5 lbs = 1.59 kg

Reduced liner 24" wide x .040" thick x 72" long x ρ 1.2 = 2.9 lbs = 1.32 kg

Material savings of 0.6 lbs or 270 g/tire

Cost savings are based on $0.35/lb for the inner liner
Material cost saving is approx. $0.20/tire
Irradiation cost is approx. $0.03/tire
Actual savings $0.17/tire

Product Throughput

(Bradley, 1984)

- 800 kV electron accelerator, 31.25 kW
- 40 kGy dose
- 1077 Tires (innerliners)/h

Conclusions

- Crosslinking of elastomers is very important for the final mechanical properties of their products
- Radiation crosslinking has carved out a place in this industry
- With focussed R&D and involvement of visionary entrepreneurs, the use of radiation processing in the elastomer industry should increase