SAND2017-9103C

Radiation Effects on Teflon Wires

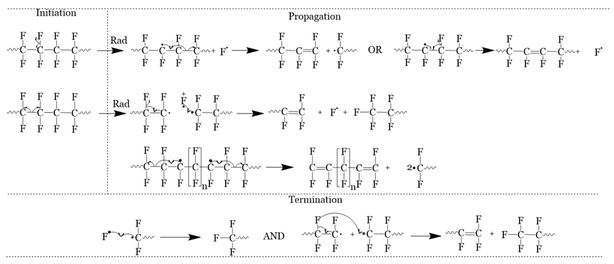
LeRoy Whinnery, Alexis Abelow, Wei-Yang Lu, Karla Reyes, Donald Ward, Dustin Murtagh, Zachary Meinelt, Nathalie Le Galloudec, Al Ver Berkmoes, Raymond Friddle

Problem

- Nuclear Safety Assurance asked a question along the lines of… "given that Teflon is the most radiation sensitive polymer used in NW, how do we know that the Teflon insulation of the wires exposed to radiation for decades is not flaking off leaving the conductors without adequate insulation?"
- Given the context, a quick study to find a preliminary answer was needed.

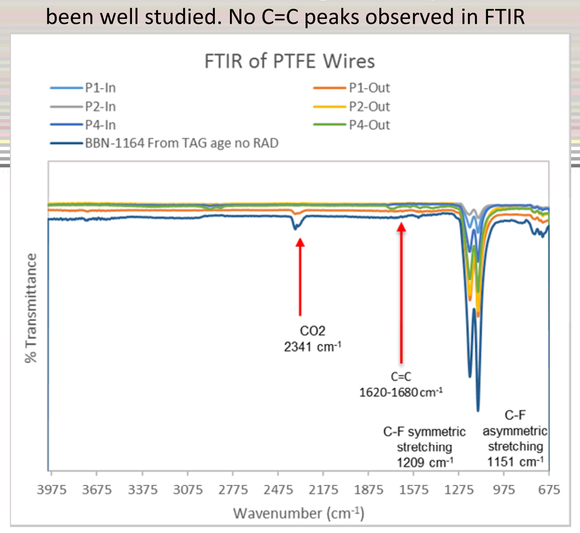
Approach

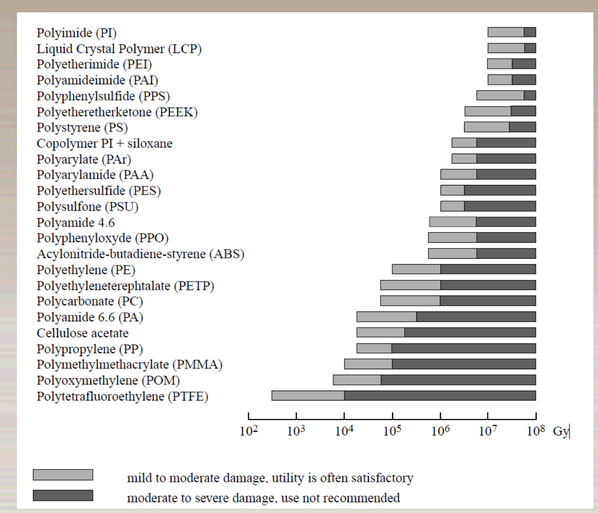
1. Perform electrical testing to ensure wires are behaving normally
2. Remove cables from MC3501
3. Remove the outer sheath from the cable
4. Examine the cable/wires for discoloration
5. Bend the wire(s), look for cracks and record images
6. Cut and prepare sample for nano-indentation
7. Strip wire(s) and tensile test Teflon only



Radiation Damage Mechanism

The mechanism of Teflon degradation by radiation has been well studied. No C=C peaks observed in FTIR





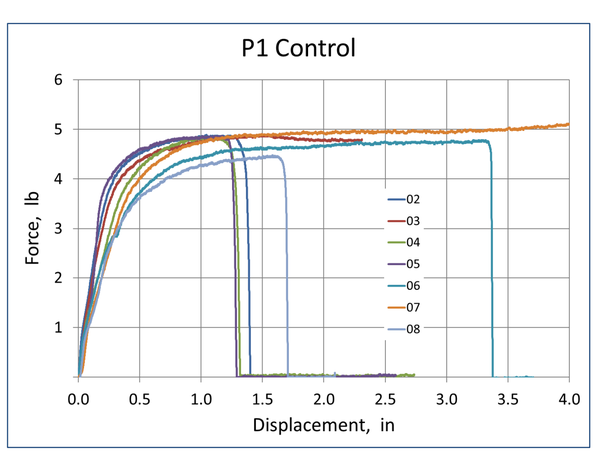
Polymer Radiation Sensitivity

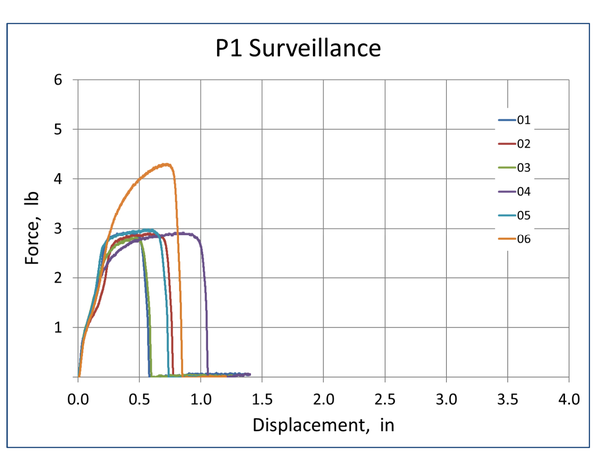
Teflon is one of the most radiation sensitive polymers

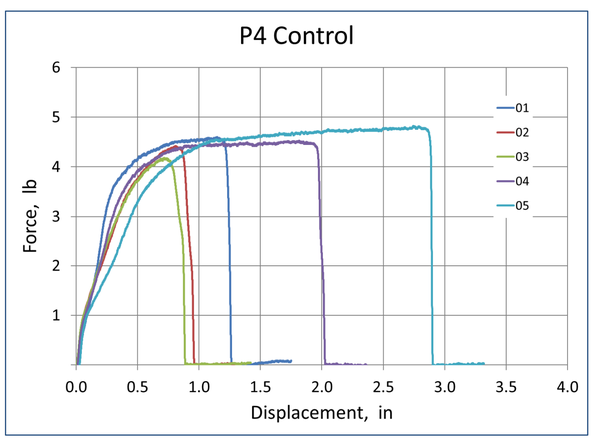
Teflon Wire Bend Test

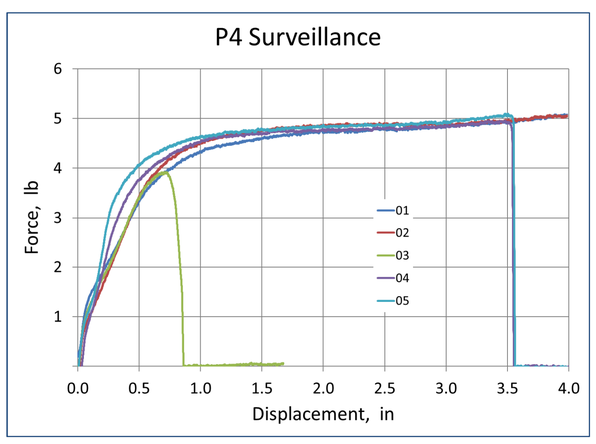
No cracks were observed when put in tension.

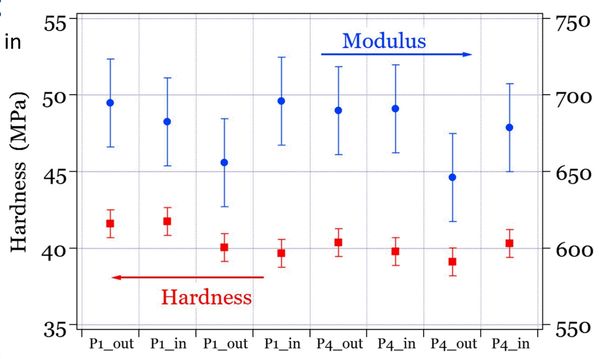
Quasi-Static Uni-Axial Tensile Testing









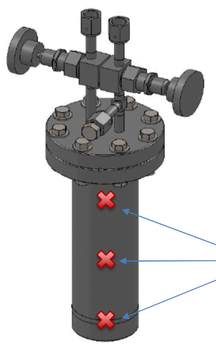


Nano-indentation

The hardness is calculated as the maximum load divided by the actual contact area made between the indenter tip and the material. Hardness is essentially the how resistive a material is to deformation (elastic + plastic). The Modulus is the slope of the load-displacement curve upon unloading, divided by the root of the contact area. So modulus is the ratio of elastic stress to strain.

Results

Tensile testing showed ~35% reduction in strength and a significant reduction in elongation to failure. Substantial variability was observed, particularly in the elongation. This variability may be due to flaws introduced during sample preparation. Additional testing is underway to provide better statistics.



Labels	Sample	Dose (rad)	Time (days)
PTFE # 1	PTFE	1,250	2.31
PTFE # 2	PTFE	2,500	11.57
PTFE # 3	PTFE	5,000	23.15
PTFE # 4	PTFE	15,000	34.72
PTFE # 5	PTFE	30,000	69.44
Empty (control)	Empty	5,000	23.15

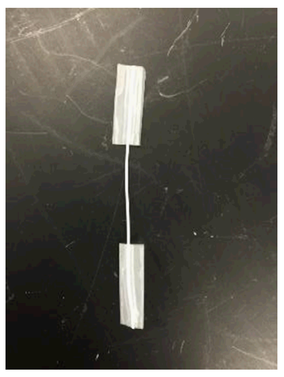
Additional Dose Testing

Additional Radiation Exposure

- Expose the Teflon coated wires to additional radiation and examine their physical/mechanical properties.
- Determine how much additional exposure is needed to compromise their ability to provide electrical isolation.
- Samples are irradiated at the GIF using a Co-60 source.
- Dose rates from 10^{-3} rad/s to over 10^{3} rad/s.
- Samples irradiated in an inert atmosphere (N_2).

Tensile Testing of Insulation Only

Test set-up



Typical sample before test

- Ends were wrapped with tape for hydraulic grip

Conductor removal for tensile testing -a possible source of variability (flaws)

- Wire strippers were used to remove a small amount of insulation.
- Pliers were then used to grab the copper conductors.
- Sliding my grip down the wire many times allowed it to slowly release from the insulation and be removed.
- Gloves helped with gripping the Teflon.
- Care was taken to not pull too hard or too fast.

Future Work

- High voltage breakdown and insulation resistance will be performed
- Additional radiation to look for a cliff in the properties
- Vessels irradiated at GIF (ABQ) (gamma)
  - 5mrad/second (0.432 krad/day)

Summary

- No discoloration was observed
- No cracking was observed upon bending (1/4" radius)
- Nano-indentation did not show any differences in hardness or modulus
- Elongation of Teflon appears to be sensitive to radiation
- Need to perform more tensile testing for better statistics

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND No. 2011-9283P. SCG.MV.