Electrically Conductive Acetals for Fuel Environments

SPE ACCE
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Overview

- Charge mitigation - impetus
- Test methods and fuels
- Polymer charge mitigation – additives
- Polyoxymethylene (POM) material performance
  - Mechanical, electrical, fuel exposure
- Future direction – conductive POM
- Acknowledgements

“Driving” Force ....

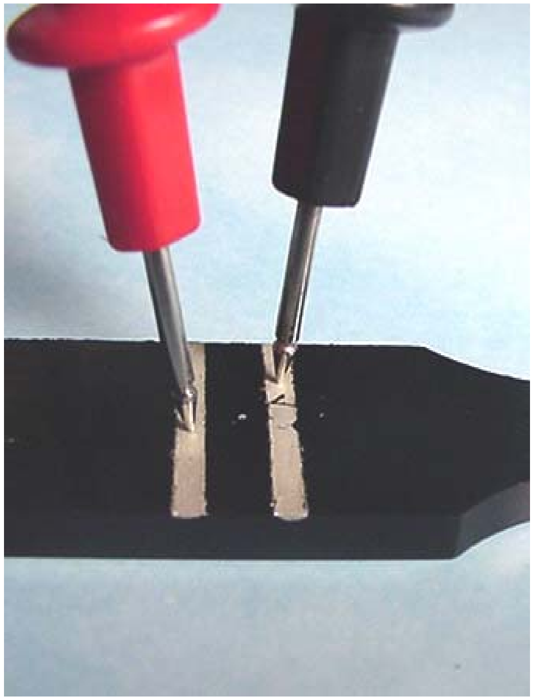
SAE J1645 – Fuel Systems & Components
– Electrostatic Charge Mitigation

- Liquid, flowing fuel in autos
- 4.1.6 Material Recommendation
  - Virgin material representative of intended production process
    - $\rho_V \leq 1 \times 10^4\ \Omega \cdot m$ **AND**
    - Surface resistance not exceed empirically derived value consistent with recommendations of 4.1.5
- 4.1.5 Component Recommendations
  - In its system application, Resistance $\leq 1 \times 10^6\ \Omega$ **OR**
  - Static dissipation time $t_d \leq 0.5$ sec (when $V = 0.1 V_i$)

Material → **Component** → **Assembly**

Challenges in Electrical Testing

- All electrical testing is not created equal!
- Sample size and preparation
  - Geometry & molding
  - Conditioning
  - Contact resistance reduction
    - conductive paint
    - other means
- Test instrumentation
  - Electrode shape and size
  - Contact force
- Measurement parameters
  - Test voltages (non-Ohmic responses)
  - Voltage sequencing
  - Electrification/charging time



From Ticona ESD Webinar
With Stan Weitz
President,
ElectroTech Systems

Fuel Exposure of Dissipative Materials

- Alcohol, non-alcohol, aggressive, diesel (including bio) fuels
- From SAE J1645
  - The effect of prolonged immersion in fuels described in 5.4.1 should be evaluated by physical testing. Where it is found that such immersion adversely affects the material......
  - A.3.1.3.2 Many plastic and rubber materials can be made conductive by blending them with conductive additives. However, increasing conductivity may alter other properties of the material, such as:
    - Mechanical properties (e.g., impact resistance, flexibility, etc.)
    - Chemical resistance (e.g., fuel, sour gas, exposure to road chemicals)
    - Permeation resistance
- The proper <u>balance</u> of properties is critical

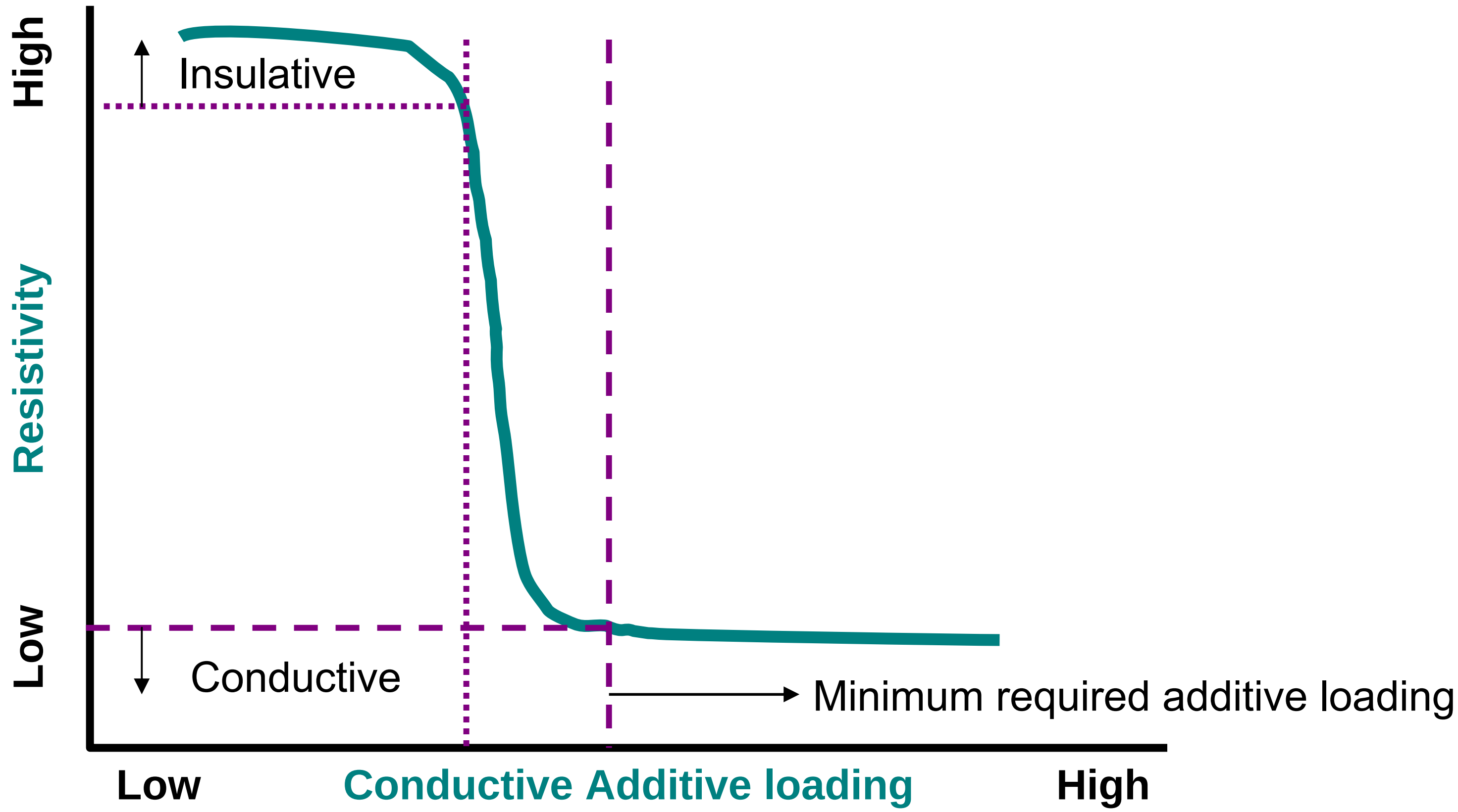
Polymer Systems that Dissipate

- Inherently conducting polymers or blends
- Conductivity imparted to POM by additives
  - Carbon powder
  - Carbon fiber
  - Carbon/graphite nano-material
  - Metals

Property vs. unfilled POM	Carbon Fiber	Carbon Powder	Stainless Steel Fiber	Nano-filler
Stiffness & strength	Much Higher	Similar	Slightly higher	Potentially Higher
Elongation	Lowest	Low	Unchanged	Unchanged
Shrinkage	Anisotropic	Isotropic	Minor Anisotropy	Minor Anisotropy

Percolation & Dispersion

- Ideally, the level of conductive additive needed to impart dissipative characteristics is...
  – Governed by the aspect ratio of the filler
- In reality, dispersion is never perfect



POM – Carbon Experimental

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- Hostaform® POM base material used for all formulations
- Stabilization consistent across like groups
- Processing common across like groups
- Functional levels of conductive fillers used
- Performance*:
  - Flow
  - Impact
  - Mechanical
  - Electrical resistance
  - After fuel exposure

Reference	
POM – Standard Flow	Hostaform C9021
POM – Improved Flow	Hostaform C13031XF
POM – Steel Fiber	Celcon® CF802
POM – Carbon Powder	Hostaform EC140XF
POM – Carbon Fiber	Celcon EF10
POM – Nanofiber	Development
POM – Nanotube	Development

* in-house laboratory testing except for fuel-exposed tensile specimens

Carbon Comparisons

- Taken from published datasheets

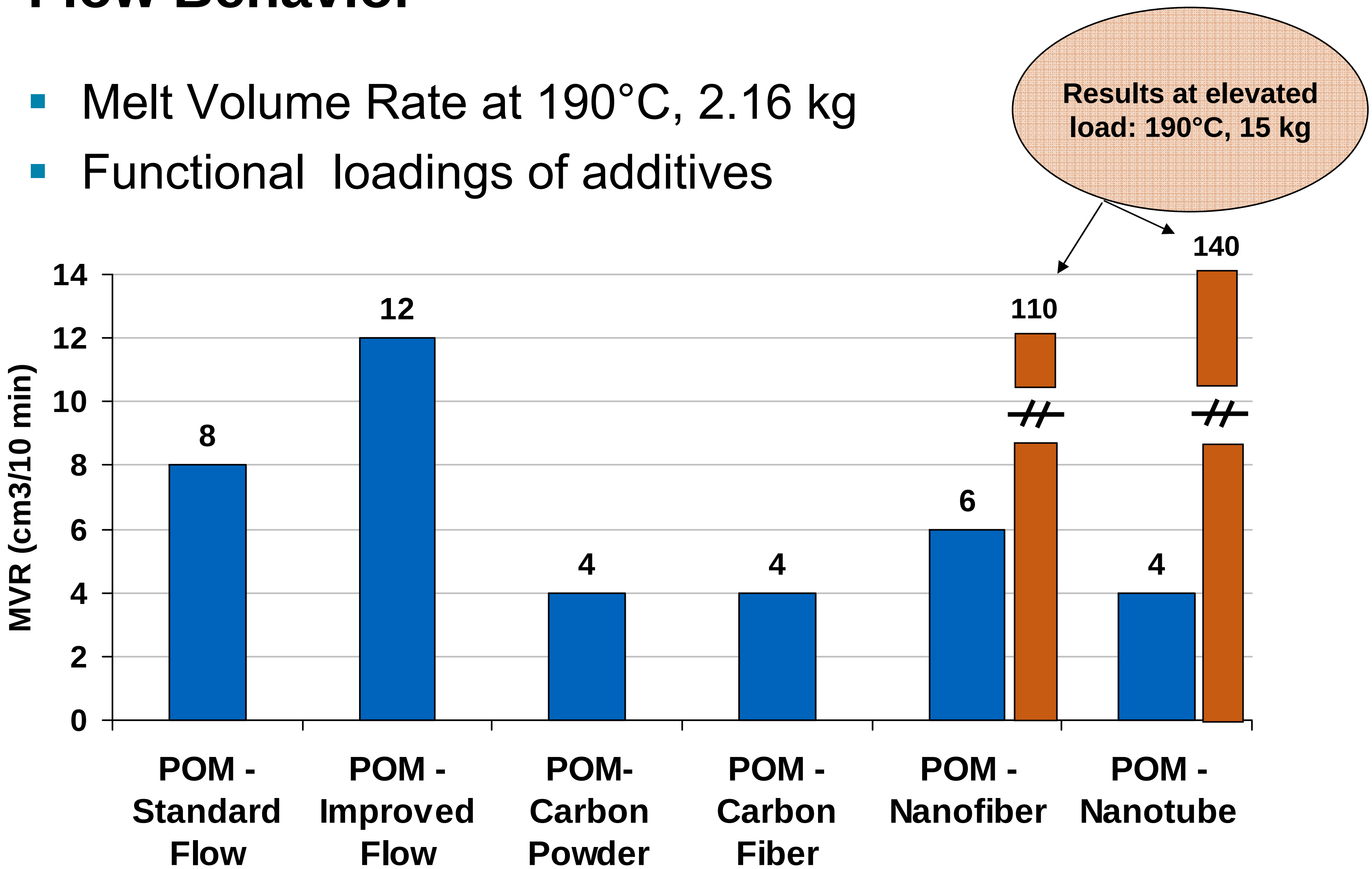
Representative Values

	Bulk Density (kg/m3)	Characteristic Size* (nm)	Aspect Ratio	Surface Area (m2/g)	Resistivity (Ω·cm)	Relative Particles Per Given Mass
Conductive Carbon Powder	*150*	*500*	*<10*	*1000*		
Carbon Fiber	*500*	*10000 x 1000000*	*100*	*<5*	*1.50E-03*	*1*
Nanofiber	*15*	*100 x 10000+*	*100+*	*20*		*20 E+03*
Nanotube	*150*	*10 x 1000+*	*100+*	*200*	*1.00E-04*	*200 E+06*

* Carbon black denotes aggregate size, others represent effective size after compounding

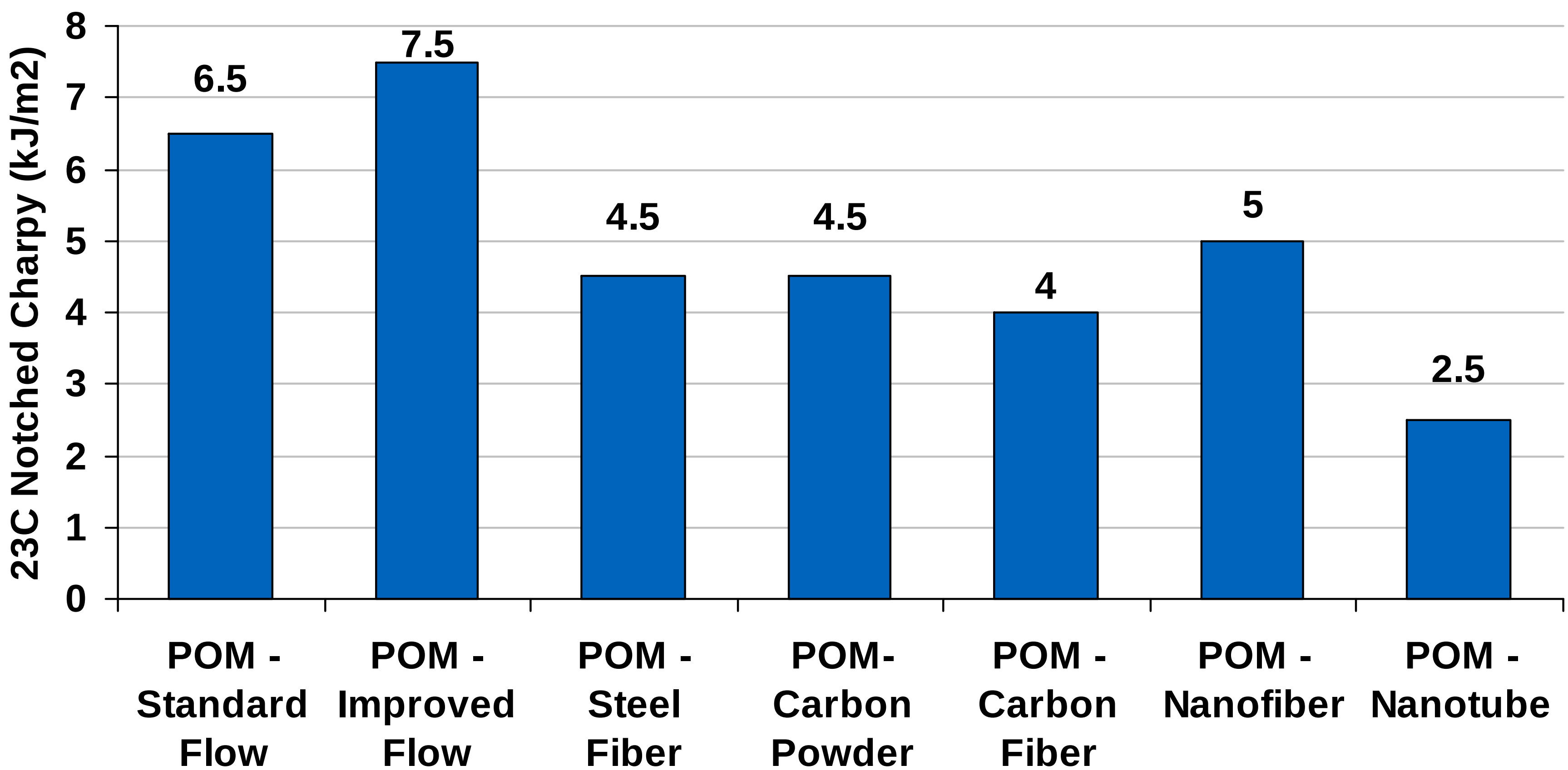
Flow Behavior

- Melt Volume Rate at 190°C, 2.16 kg
- Functional loadings of additives



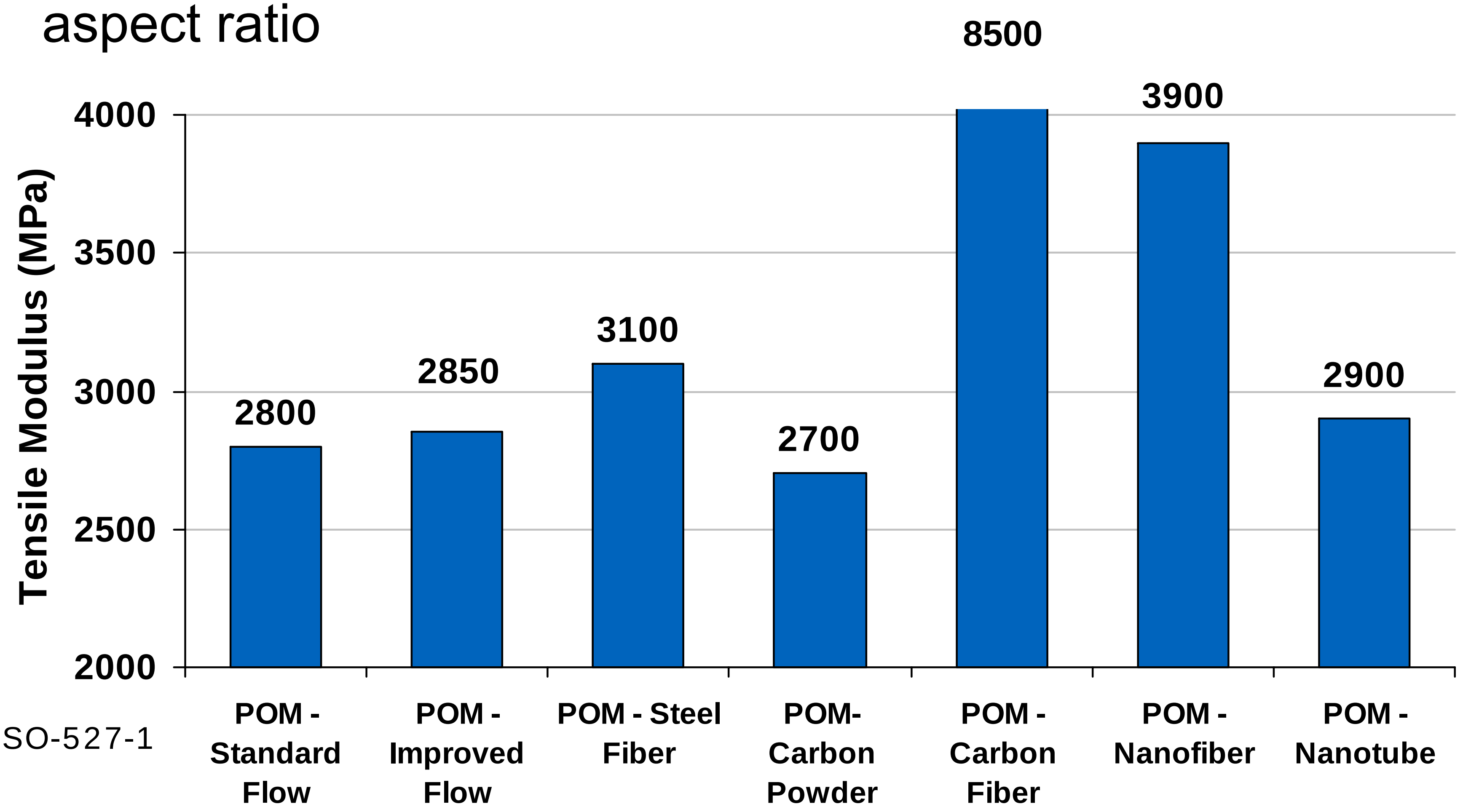
Impact Results

- Notched Charpy (***ISO 179)*** - room temperature



Tensile Modulus Values

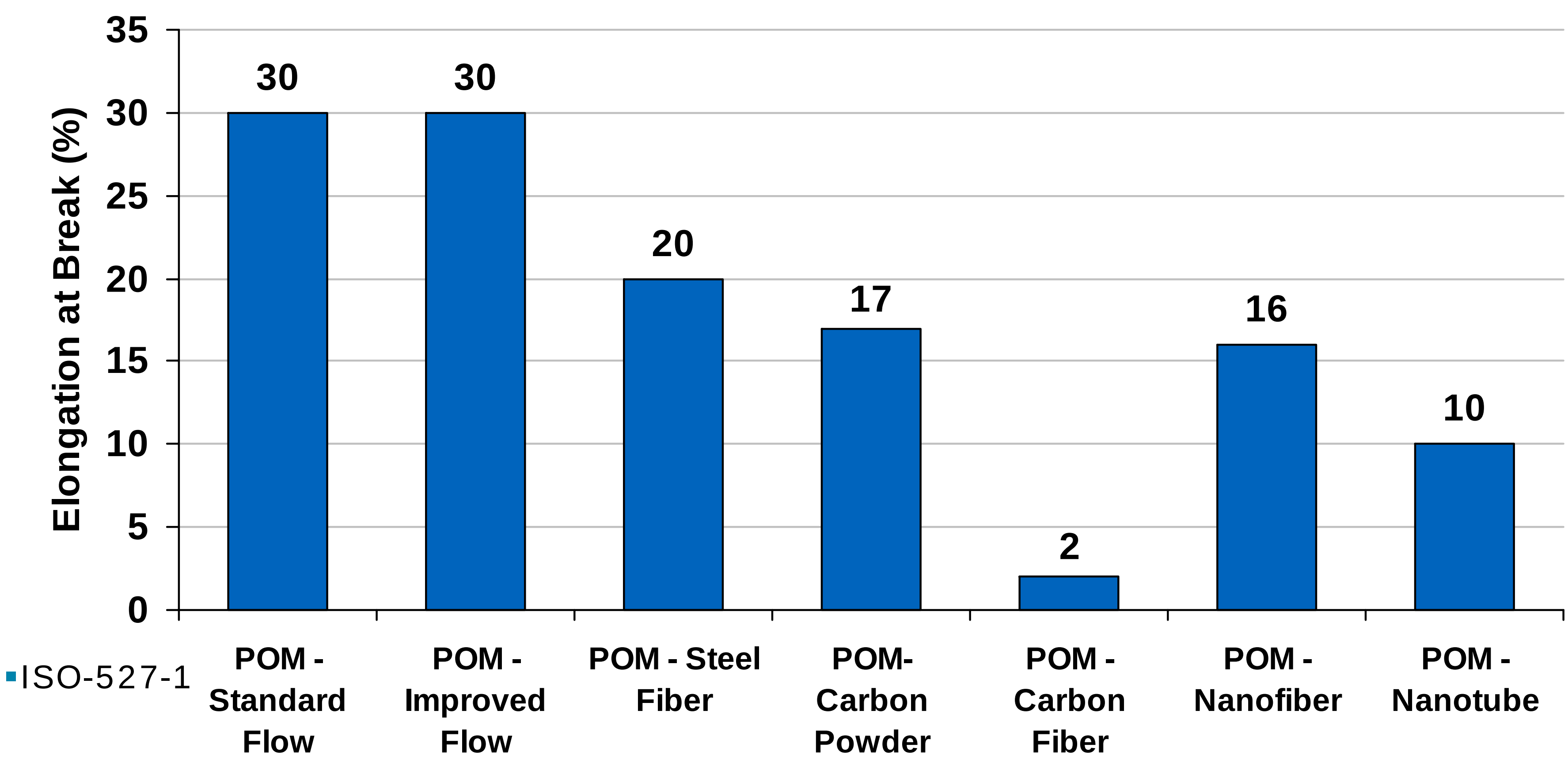
- Primarily governed by additive content, modulus, aspect ratio



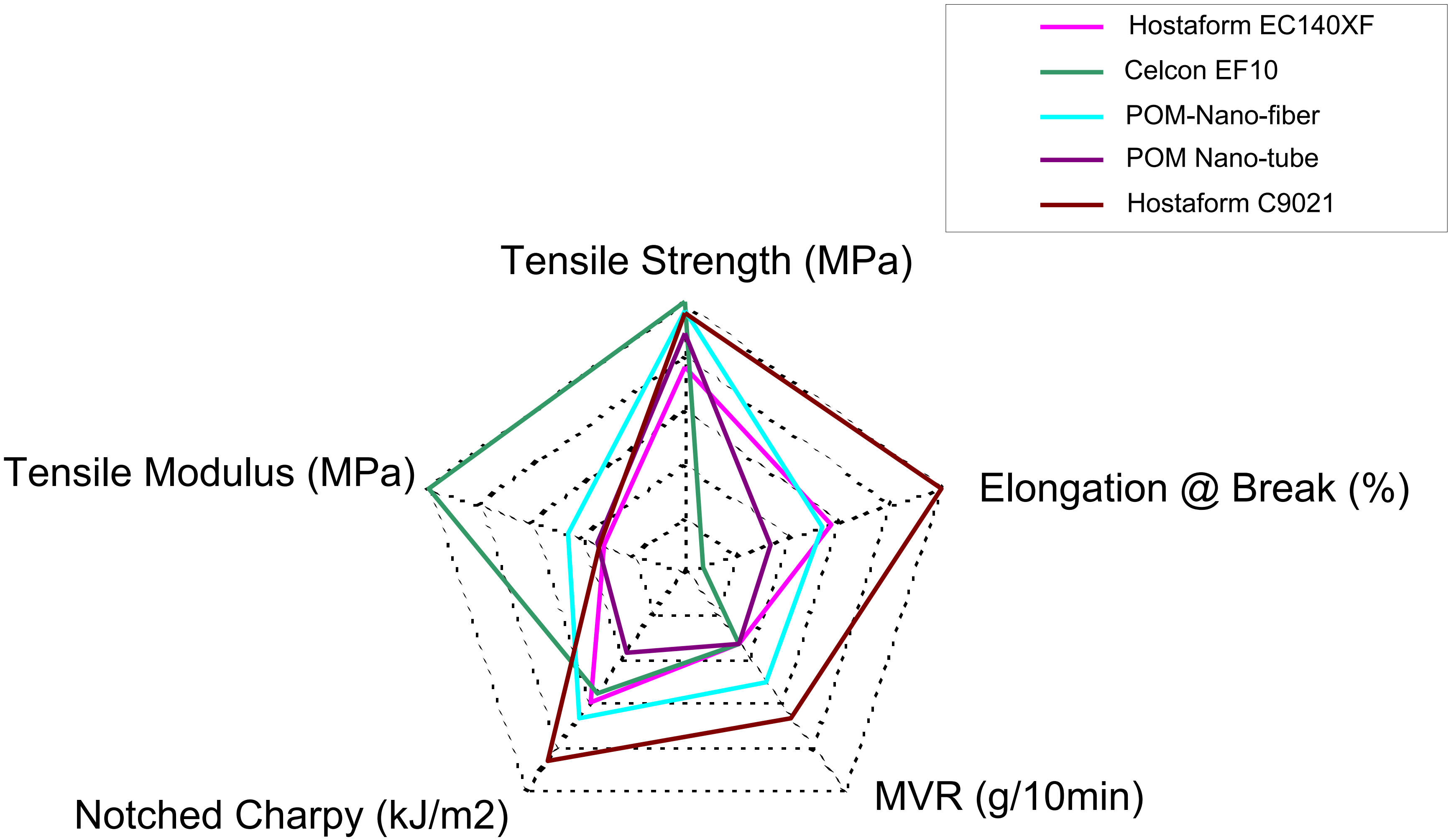
- ISO-527-1

Elongation at Break Results

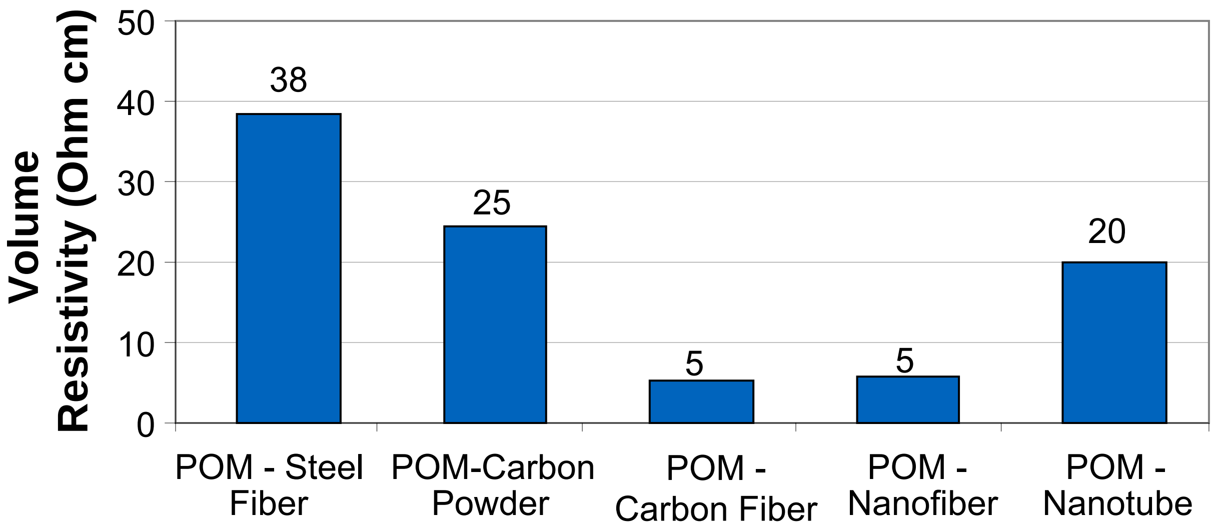
- Response prone to more variability

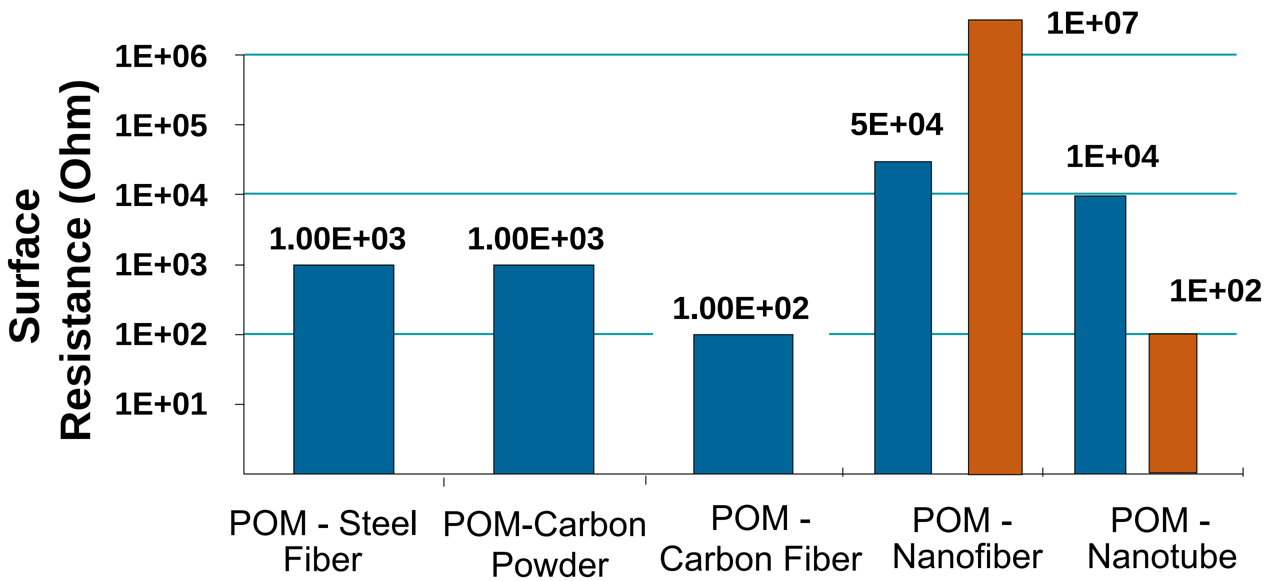


Mechanical Property Comparison



Electrical Resistance





Volume resistance via:

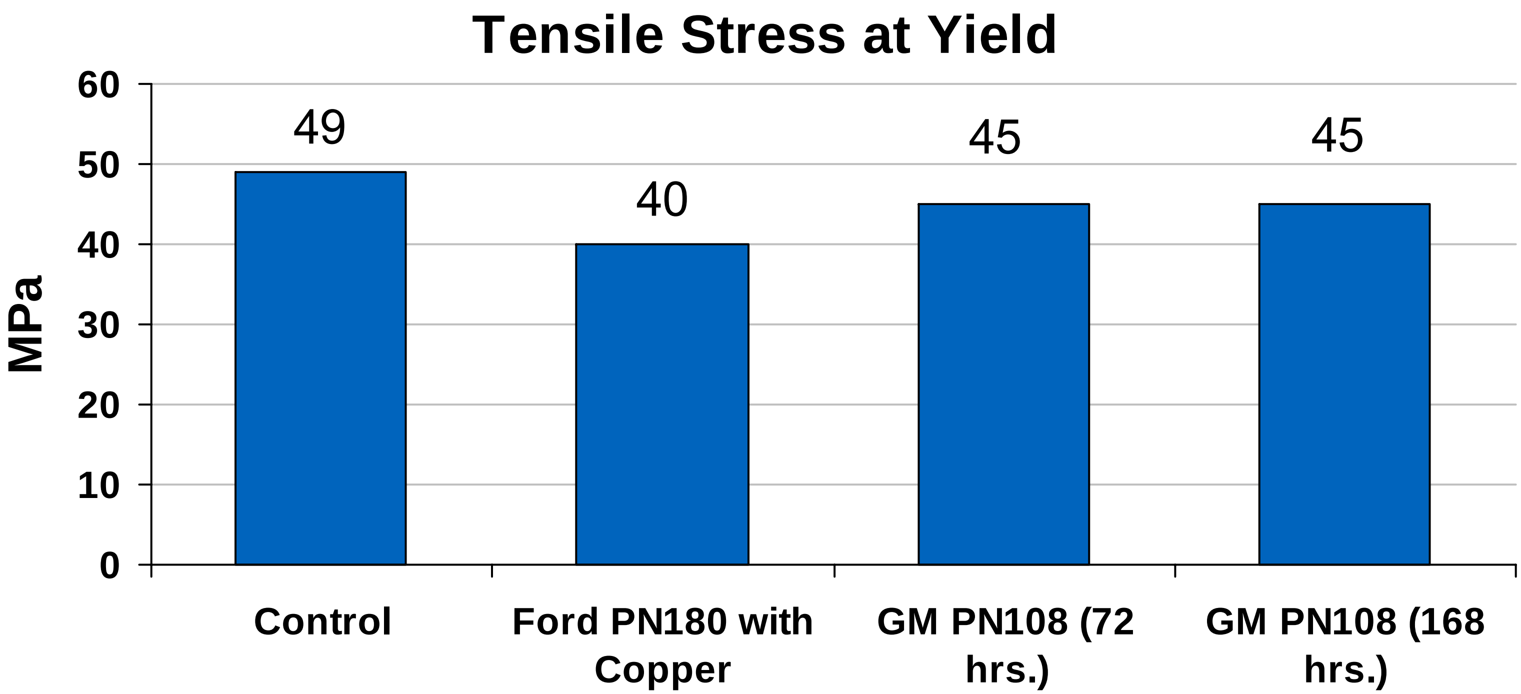
- ISO tensile bars
  - Cut to 80 mm
  - Ag painted ends
  - Tested at 10V
  - Reading after 10 seconds

Surface resistance via:

- **ISO tensile bars**
  - **ETS Model 880**
  - **10V**
- **IM plaques 2 mm thick @ 3V**

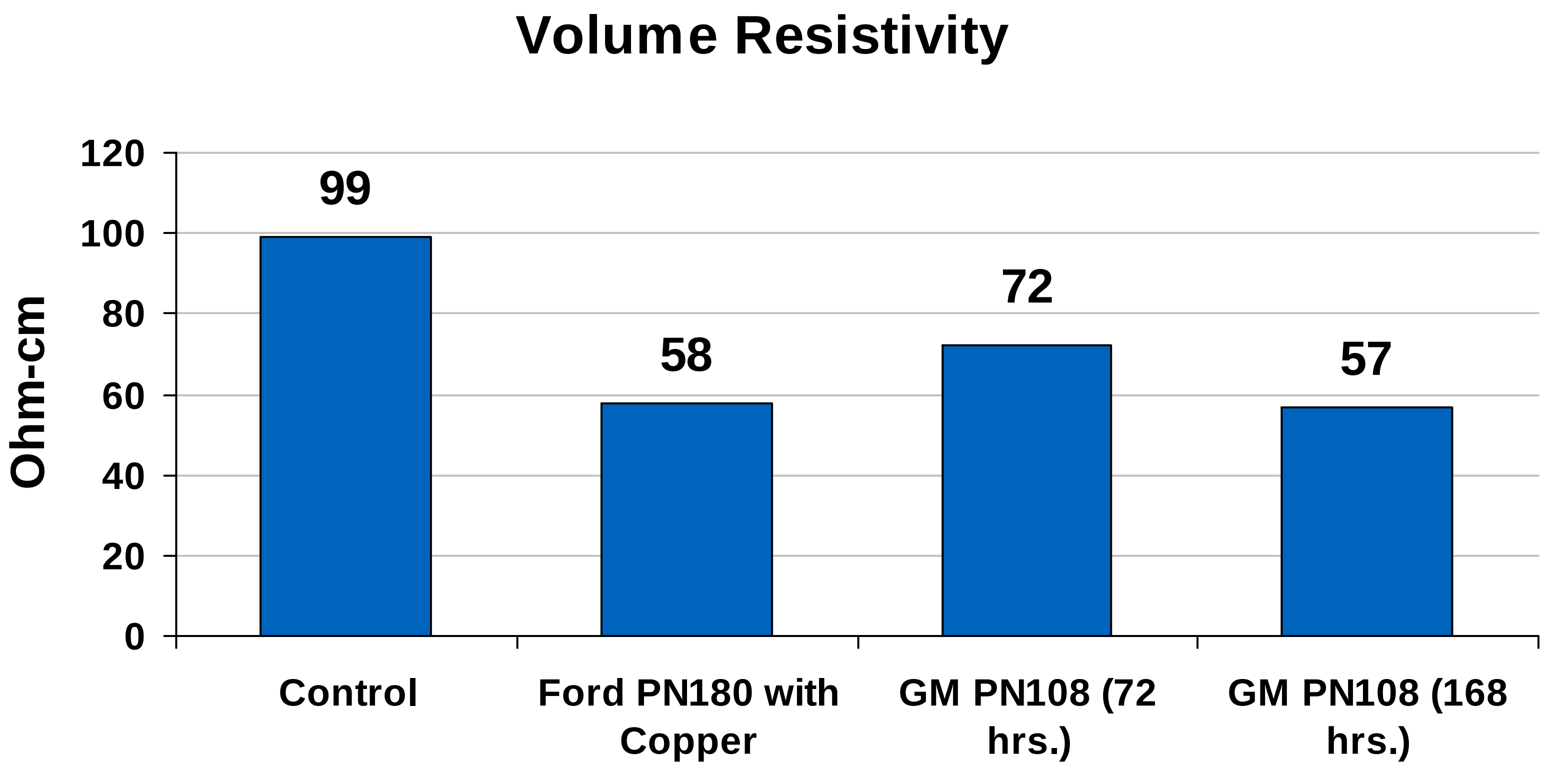
Peroxide Fuel Performance - I

- POM - Carbon powder formulation
- Fuel exposure
  - – Ford PN180 w/copper test for 360 hours, 60°C
  - – GM PN108 test for 336 hours, 40°C; two refresh rates



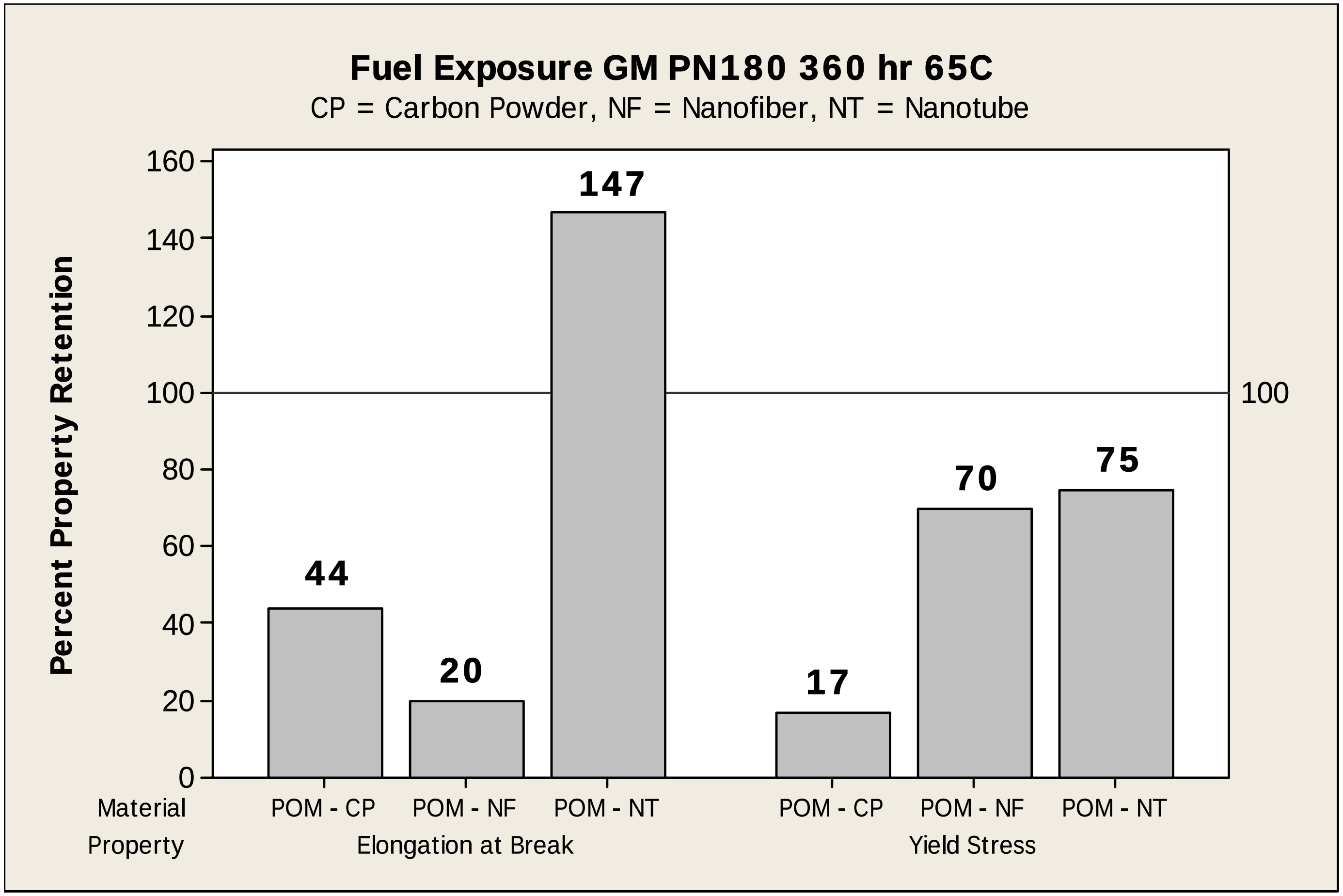
Peroxide Fuel Performance - I

- POM - Carbon powder formulation
- No indications of resistivity increase



Peroxide Fuel Performance – II

- More Aggressive fuel exposure
  - Ford PN180 w/copper test for 360 hours, 65°C, one fuel refresh

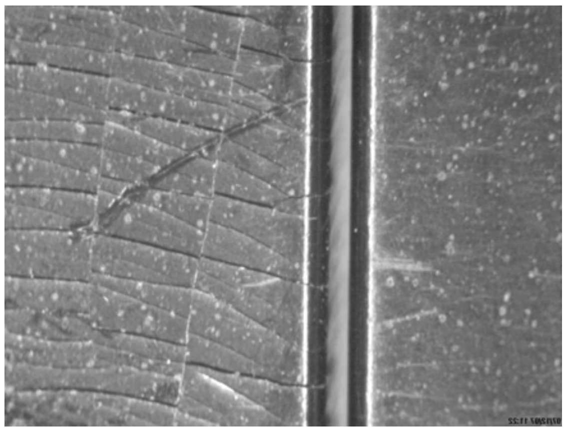


Degrading Peroxide Exposure

- Extended time, elevated temperature or peroxide number can lead to degradation

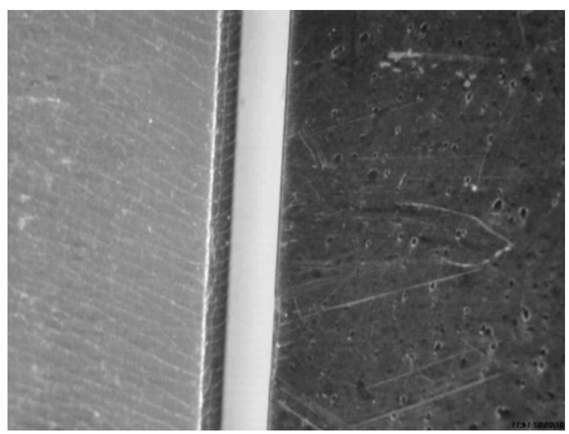
Degraded

POM - Carbon powder



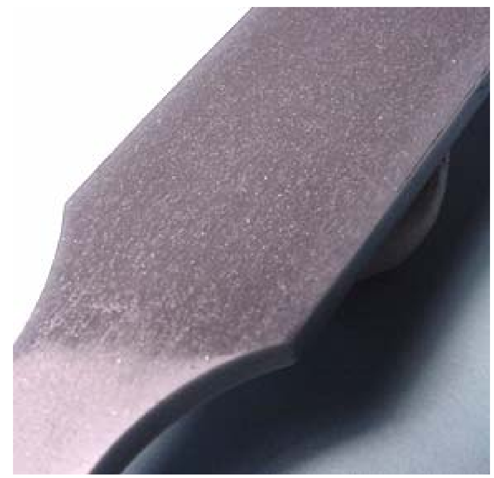
POM - Nanofiber

POM - Nanotube



Unaffected

Ticona POM -
Steel fiber formulation
(from a different study)



Future Direction - Conductive POM

- “Nano” benefits and challenges
  - Lower functional loadings
  - Robust manufacturing
  - Strength enhancements
  - Understanding of resistivity & molding
  - Safety/regulatory & intellectual property
- Dispersion improvements
  - Understand fundamentals & drive to better levels
- Improved stability to aggressive fuels

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Acknowledgements

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  - John Stieha   Ticona Product Specialist

THANK YOU!

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