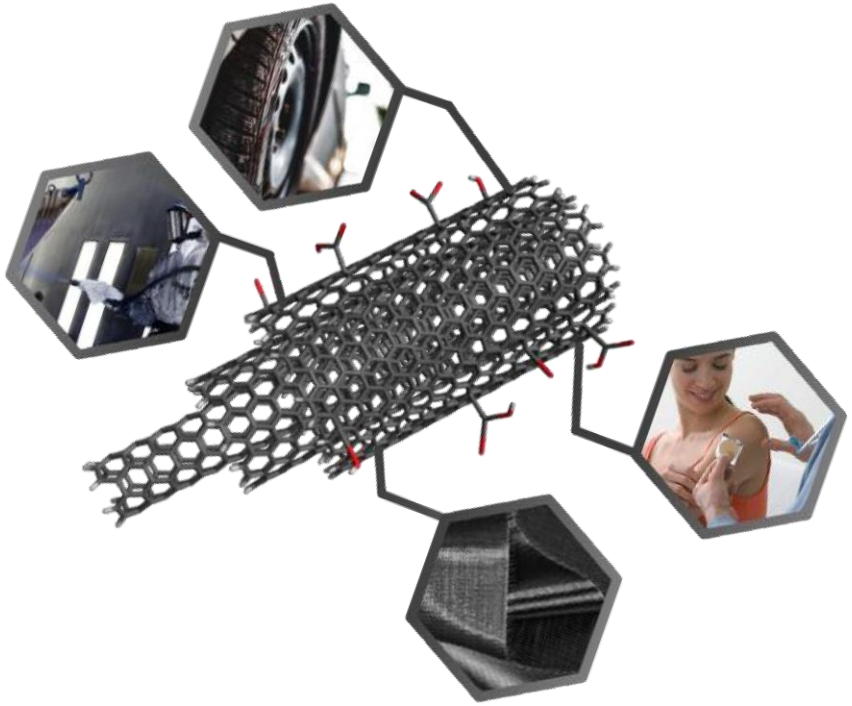
Multi-wall Carbon Nanotubes (MWCNTs) and Light-Weighting EVs

October 14th 2021



THE Advanced Materials SHOW | USA

THE NANOTECHNOLOGY SHOW

MOLECULAR REBAR® DESIGN

Transforming Businesses with Nanotechnology

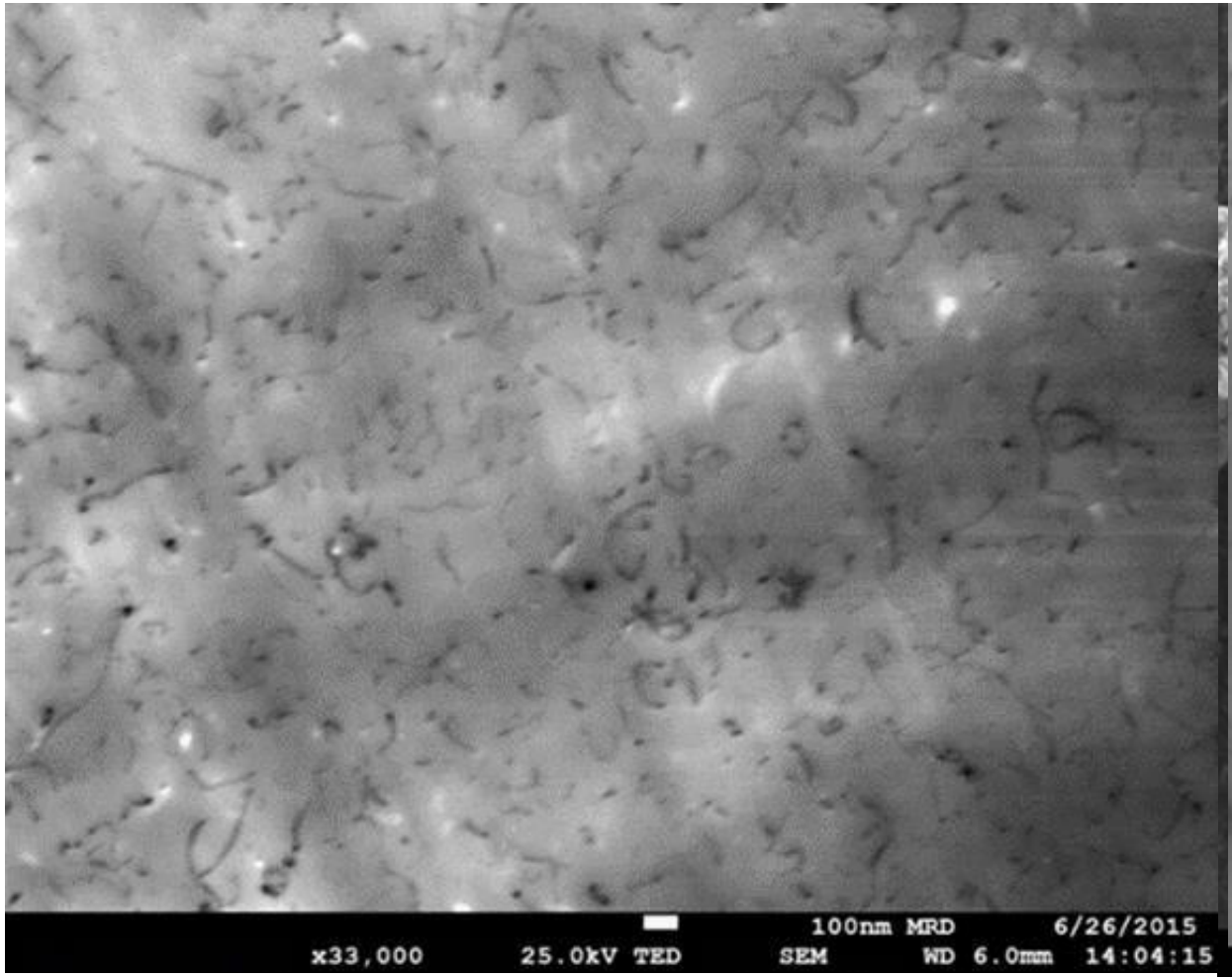
Molecular Rebar Design Overview

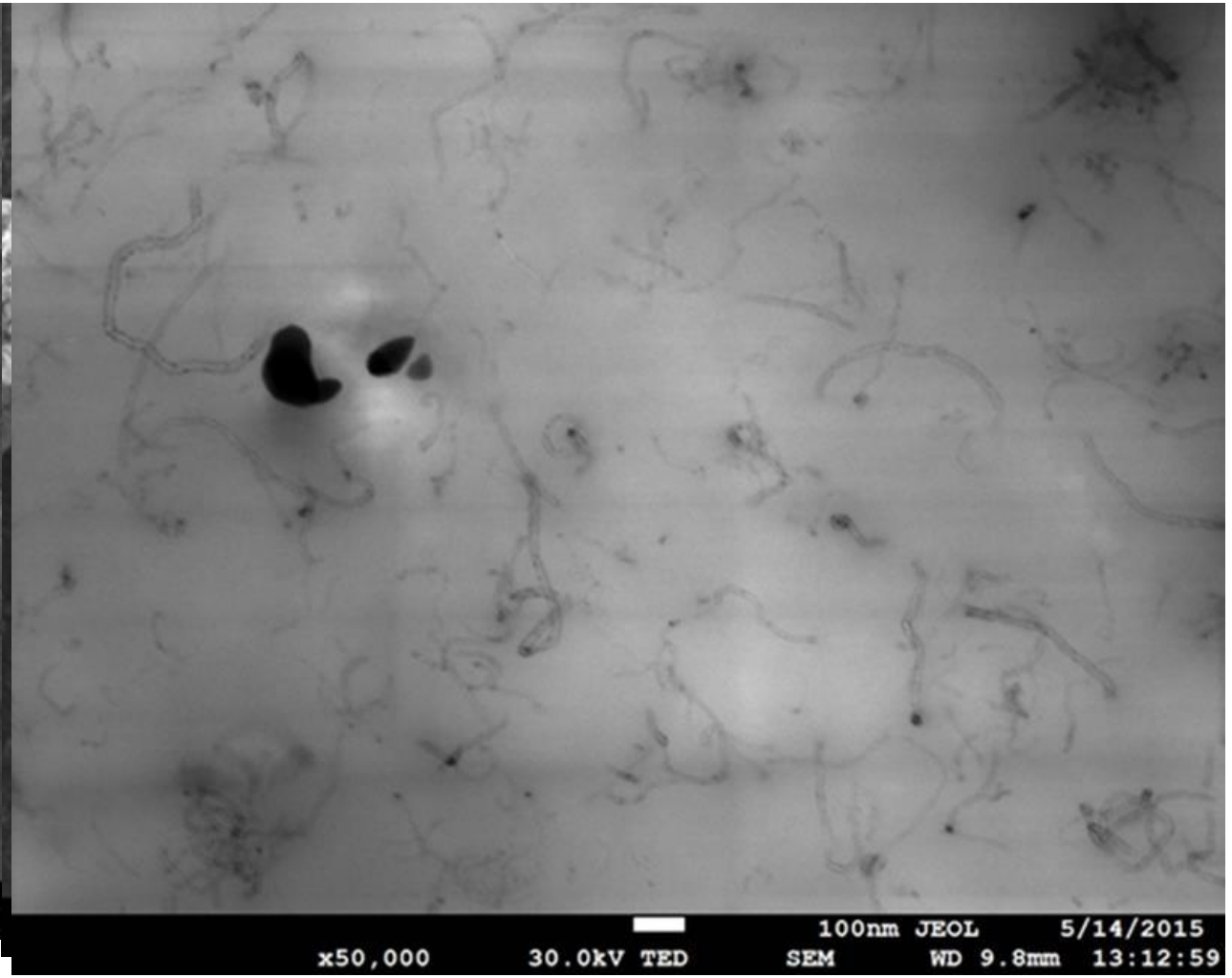
- Based in Austin, TX
- ‘Expansion Stage’ startup
- Established in 2009, to develop and commercialize a breakthrough form of discrete, surface modified multiwall carbon nanotubes (MWCNT’s), called MOLECULAR REBAR® (MR)
- R&D and Manufacturing based in Austin, TX including 100 tonne capacity, ISO 9001:2015 certified plant
- 100+ Granted/Allowed Patents
- Fast-growth thru commercial partnerships for targeted markets for MOLECULAR REBAR®
  - Black Diamond Structures: Energy storage, commercial globally in LIB and Pb Acid batteries
  - Biopact Ventures: Targeted biomolecule delivery into cells
  - MECHnano: Additive manufacturing (3D printing)
- Highly technical: ~20% PhD scientists, ~20% engineers

What is Molecular Rebar?

- Discrete or individual nanotubes
  - Typically, Multi-wall (MWCNTs)
  - High aspect ratio; ‘fibers’
- High purity
  - Lack of catalytic residue
- Chemical functionalization
  - Basis for dispersion quality
  - Good interaction with matrices
  - -OH and –COOH
    - ‘Hand-holds’ for extra chemistry

Seeking good dispersion of MWCNTs





Electric Vehicles and Tires

- EVs are up to 30% heavier than ICE counterparts (1)
- EVs' direct-drive electric motors produce near-instant torque
  - EVs are FAST

(3)

- These factors = increased tire wear
- 'Traditional tires can wear out up to 30% faster on EVs' (2)

"It's where improvement of one will reduce the other two performances. Developing a bigger triangle is the focus on compound development."
– Niknam, *Tire Technology: The Science & Engineering Behind Making a Tire*, 2018.

Use of Nanotechnology in Tires

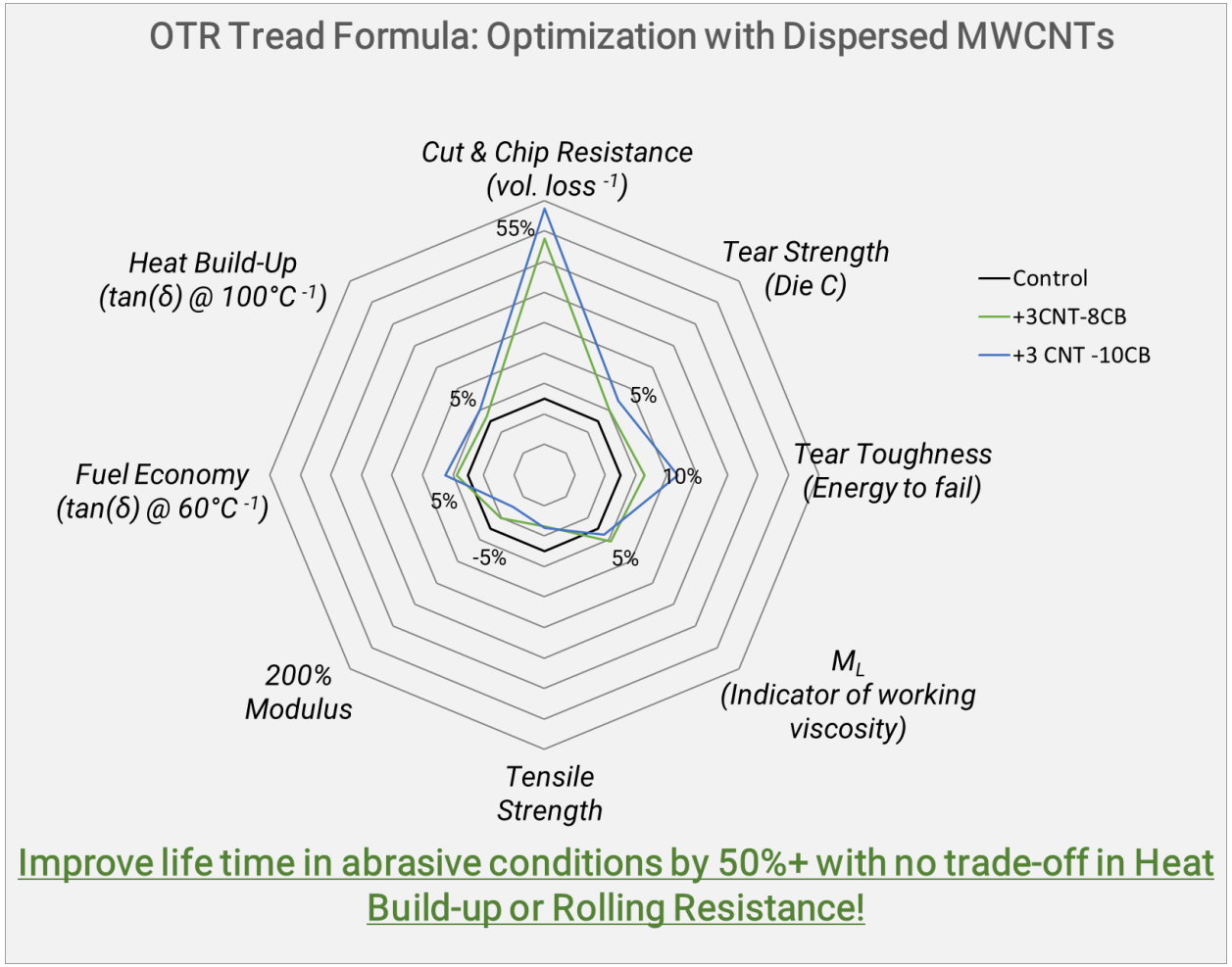
- ‘Nanotechnology’ is already used in tires, by broad definition
  - Carbon black = 100s of years old
  - Silica = more modern, but still 20+ year old technology
- Nearly always spherical structures
  - Innovate with rods, plates, etc.
- Important factors
  - Cost
  - Risk – EH&S and tire safety
  - Volume
  - Development time

Certain types of carbon black used in tires, plastics and paints

Name	Abbrev.	ASTM desig.	Particle Size nm	Tensile strength MPa	Relative laboratory abrasion	Relative road wear abrasion
Super Abrasion Furnace	SAF	N110	20–25	25.2	1.35	1.25
Intermediate SAF	ISAF	N220	24–33	23.1	1.25	1.15
High Abrasion Furnace	HAF	N330	28–36	22.4	1.00	1.00
Easy Processing Channel	EPC	N300	30–35	21.7	0.80	0.90
Fast Extruding Furnace	FEF	N550	39–55	18.2	0.64	0.72
High Modulus Furnace	HMF	N660	49–73	16.1	0.56	0.66
Semi-Reinforcing Furnace	SRF	N770	70–96	14.7	0.48	0.60
Fine Thermal	FT	N880	180–200	12.6	0.22	–
Medium Thermal	MT	N990	250–350	9.8	0.18	–

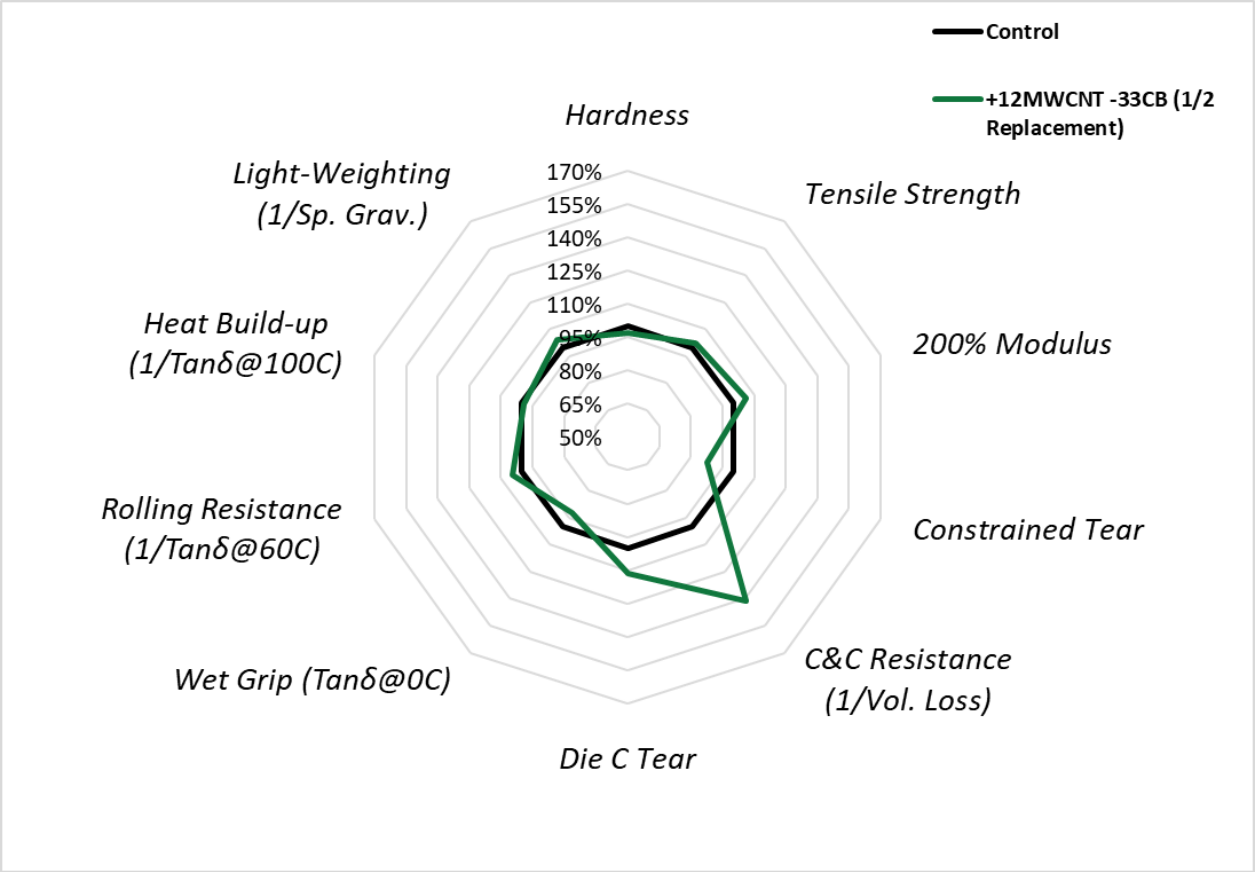
Dispersed & Discrete MWCNTs Improve Tires

- MWCNTs have been shown to improve tire tread compounds for wear resistance (4)
  - No change to RR- Fuel econ.
  - No change to HBU- blowout & catastrophic failure prevention
- Reduces the need of carbon black for treads
  - CNTs improve physicals more per gram than CB
    - Different structure & higher surface area
  - Improves hysteresis



MWCNTs can improve and light-weight tires

- Dispersion at lower filler loadings & thus lower shear forces during mixing
- Article published in Rubber & Plastics News ’21
- 5% density decrease via ½ replacement of CB
  - 3:8 replacement ratio
  - Only ~1.5 lbs / tire today, how can increase use case scenarios?
- Similar tensile
- Improved RR & Wear Resistance



Dealing w/ weight in the interim + long term benefits

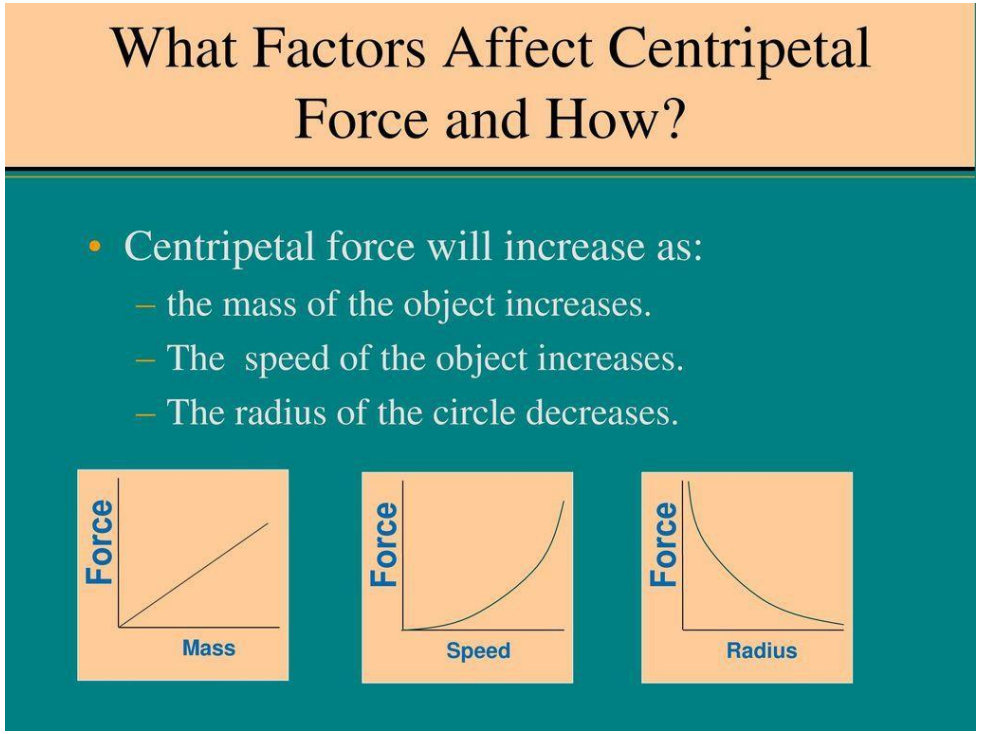
- Potential for improvements to silica-silane ‘green’ tires with replacement of silica for functionalized MWCNTs
  - Sp. Gr. of silica = 2.25
  - Sp. Gr. of CNT = 1.85

  } -16%
- Even at a 1:1 replacement, ‘green’ tires could be better performing & lighter-weight
- The Department of Energy has awarded Molecular Rebar Design, LLC a grant to identify improvements in tire tread composites for EVs
  - Award DE-SC0021823

	Model 1 - Green		Model 2 - Gray	
	Low	High	Low	High
SSBR	96.25	→	96.25	→
BR	30.00	→	30.00	→
ULTRASIL® 7000 GR	80.00	100.00	55.00	80.00
ULTRASIL® 9100 GR				
N234	6.00	→	30.00	6.00
Si 363™ silane	3.20	12.00	2.20	9.60
Si 266® silane	1.20	6.00	0.80	4.80
Zinc Oxide	2.00	→	2.00	→
Stearic Acid	2.00	→	2.00	→
TDAE Oil	8.75	→	8.75	→
Vulkanox HS/LG	1.50	→	1.50	→
Vulkanox 4020/LG	2.00	→	2.00	→
Protektor	2.00	→	2.00	→
Sulfur	2.00	→	2.00	→
TBzTD	0.40	→	0.40	→
Vulkacit CZ/EG-C	1.60	→	1.60	→
Total	238.90	272.50	236.50	272.90
PHSF Si 363	4.0	12.0	4.0	12.0
PHSF Si 266	1.5	6.0	1.5	6.0
Silica CTAB SSA [m^2/g]	160	→	160	→

Benefits of Light-weighting

- Improved energy efficiency- less force to move tire
  - Less weight at the edge = lowered centripetal force
  - Also reduced centrifugal force, lowering stresses on tire treads
- Typically, reduced heat build-up & improved rolling resistance
- Remove weight = less material per tire



Conclusions

- Rod-like nanotubes (if dispersed) are more reinforcing per gram than spherical carbon black structures
  - Can utilize a replacement ratio of 3:8 CNT:CB (N234)
    - Reduces necessary carbon content by 3/8 – 5/8
- Shape of structure influences composite properties differently than total surface area
  - Improved cut & chip resistance due to rod-like CNTs, while overall tensile properties are similar to carbon black compounds
- Improving weight of the tire can create compounding improvements to EVs
  - Less destructive force on outer tread- better wear
  - Better rolling resistance + lighter weight = better battery efficiency
  - Improved wear resistance = even lower operating costs w EVs, improving adoption

Extrapolations for EV Applications

- If nanotube ‘rods’ are more reinforcing than spherical structures, how else can they be applied?
  - Can gauge thicknesses be reduced with tougher materials?
    - Thinner carbon fiber body panels?
    - Reduced thickness plastic components?
    - Reduced carbonaceous content in Li-ion batteries?
- Onus is inevitably on the suppliers of nanotechnology to ‘push’ innovations into the automotive market
- Other ideas?

Cited Sources

(1) - https://www.continental-tires.com/car/tire-knowledge/tire-basics/electric-vehicle-tires

(2) - https://electrek.co/2018/03/08/goodyear-tire-electric-cars-reduce-wear-instant-torque/

(3)- All Answers Ltd. (November 2018). Assessing Silica Particles in Tyre Formulations. Retrieved from https://ukdiss.com/examples/silica-particles-tyre-formulations.php?vref=1

(4)– Krupp RubberWorld Article 2020

(5)– Swogger, Krupp RPN Article 2021