# Conductive carbon microfibers derived from lignin-nanocellulose hydrogels

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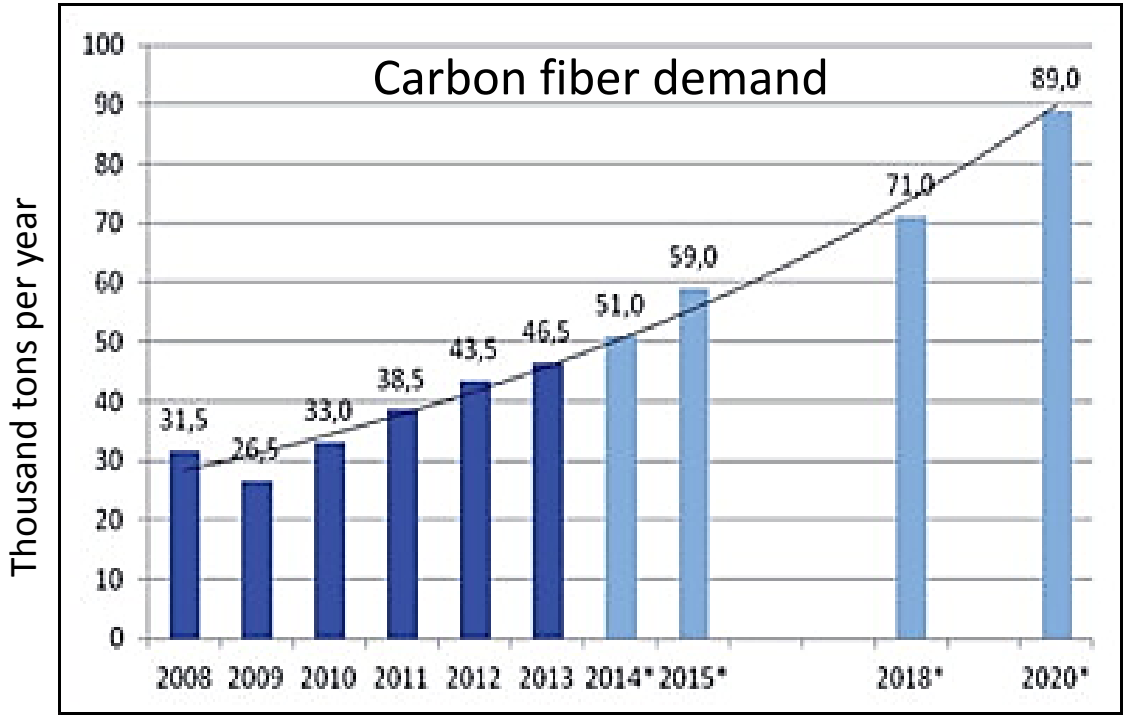
# Carbon fibers are highly demanded

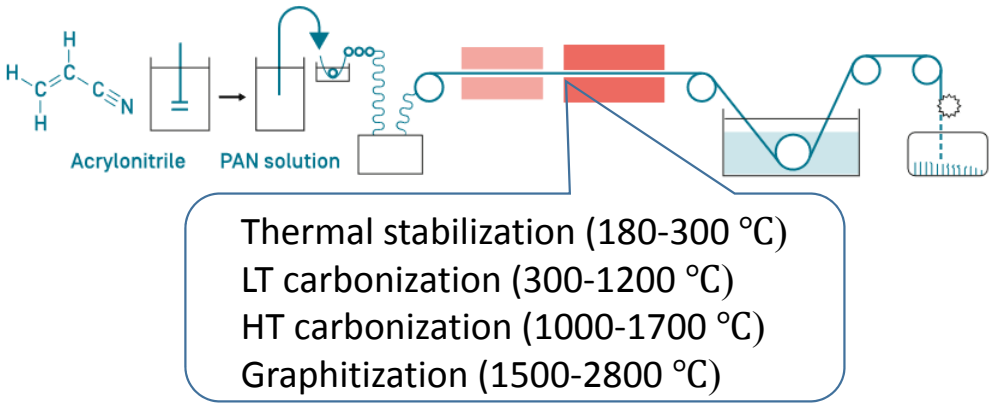



Holmes, M. *Reinf. Plast.* **2014**, *58* (6), 38–45.

# AN and Pitch as conventional precursors

Ploy acrylonitrile (PAN)

Coal pitch




**Issues:**

- **Petroleum-based precursors, unstable market.**
- **Non-ecofriendly process**
  - **Hazardous solvent**
  - **Toxic pyrolysis gas release (hydrogen cyanide)**
  - **Energy-intensive**

https://www.sglcarbon.com/en/markets-solutions/material/sigracet-fuel-cell-components/

# Carbon fibers from renewable resources

**Cellulose**

- Easy to spun (continuous fiber, strong)
- Low carbon yield (44% C in cellulose)

**Lignin**

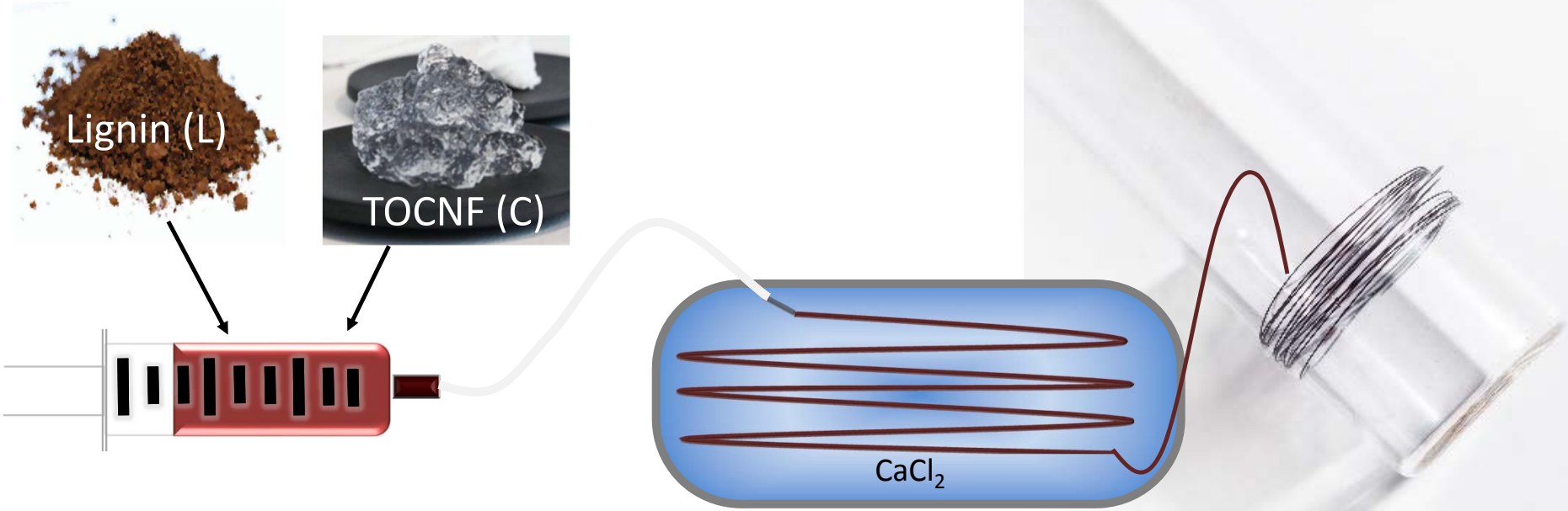
- High carbon (50-60%), aromatic structure
- Demands control of thermal stabilization

**Cellulose and lignin**[1-5]

- Ionic liquid to dissolve polymers
- Solvent recovery issues


[1]Byrne, N. Cellulose 2018, 25 (1), 723–733
[2]Olsson, C. In *ISWFPC*; 2015, Vol. 2, pp 126–129
[3]Olsson, C. *Holzforschung* **2017**, *71* (4), 275–283.
[4]Vincent, S. *ACS Sustain. Chem. Eng.* **2018**, *6* (5), 5903–5910
[5]Bengtsson, A. *Holzforschung*. De Gruyter July 27, 2018

# Wet spinning into filaments

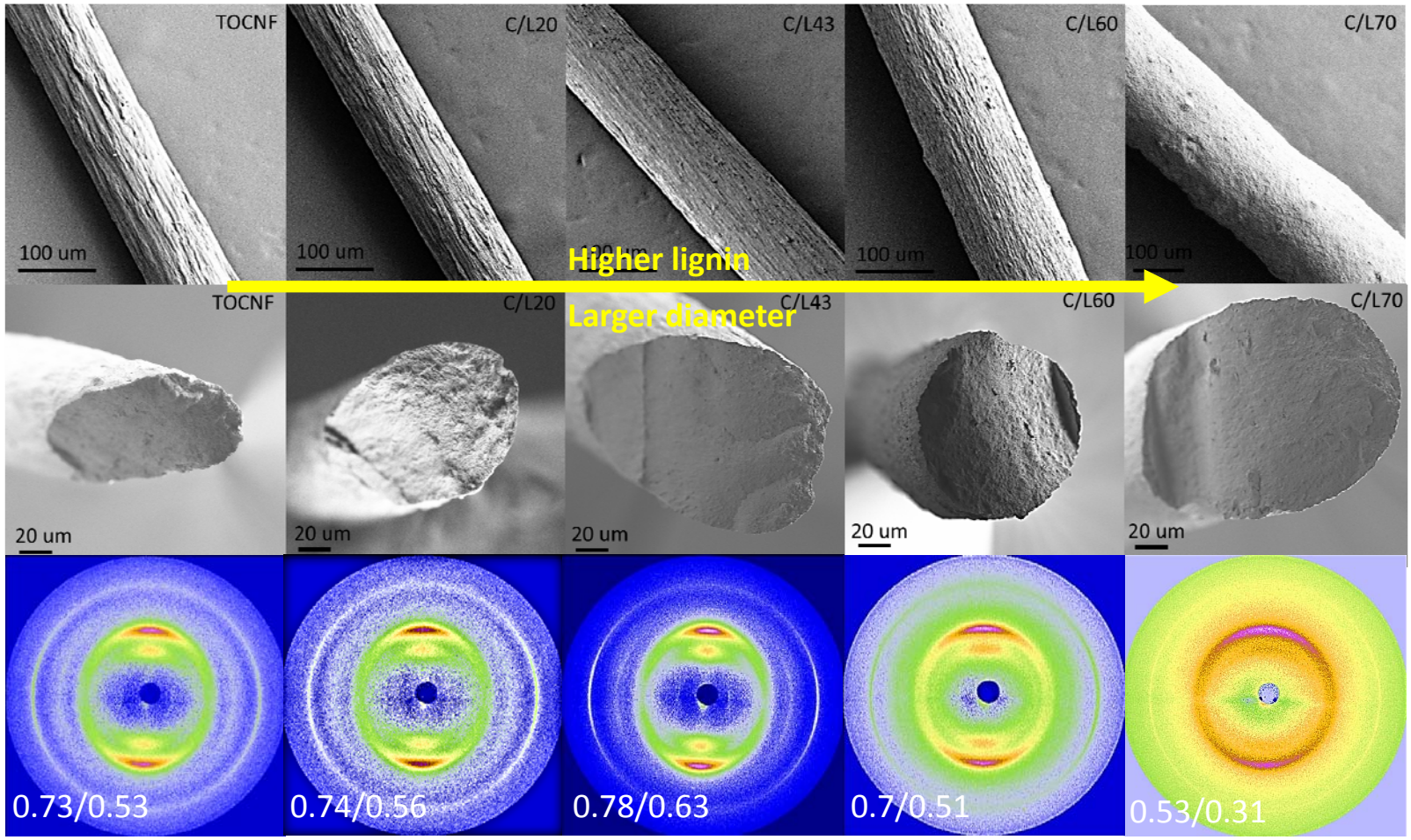


# Dope formulation and spinnability

| Dopes | Lignin content/% | Spinnability |
|---|---|---|
| TOCNF | 0 | YES |
| C/L20 | 20 | YES |
| C/L43 | 43 | YES |
| C/L60 | 60 | YES |
| C/L70 | 70 | YES |
| C/L80 | 80 | NO |
| LIGNIN | 100 | NO |

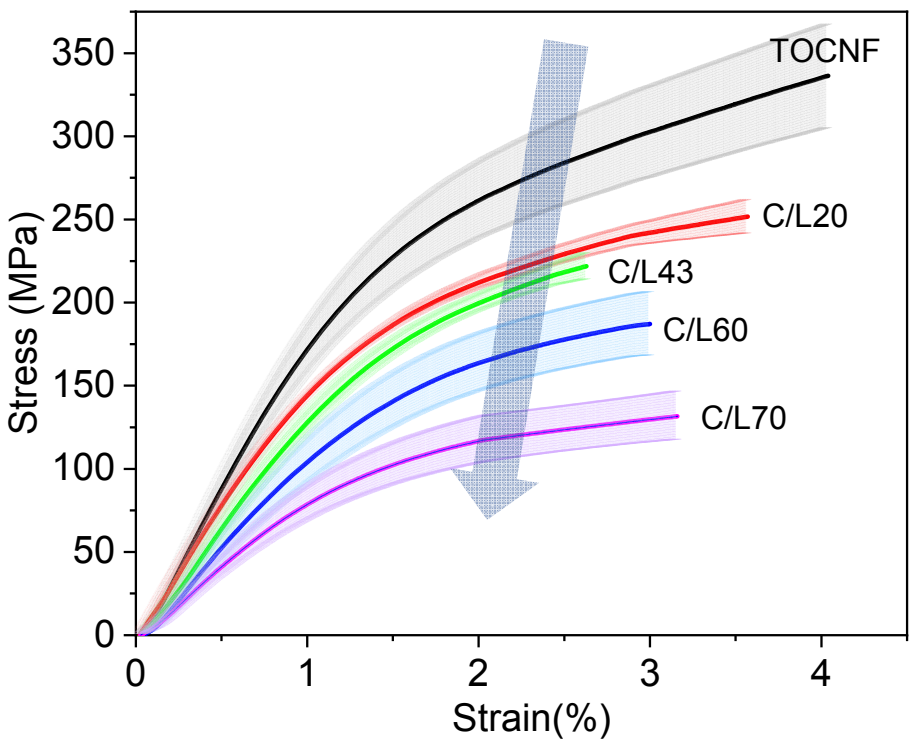
- ✓ Lignin is not spinnable in aqueous phase.
- ✓ TOCNF helps lignin spin into filaments.
- ✓ **Up to 70% lignin in the dope is wet-spinnable.**

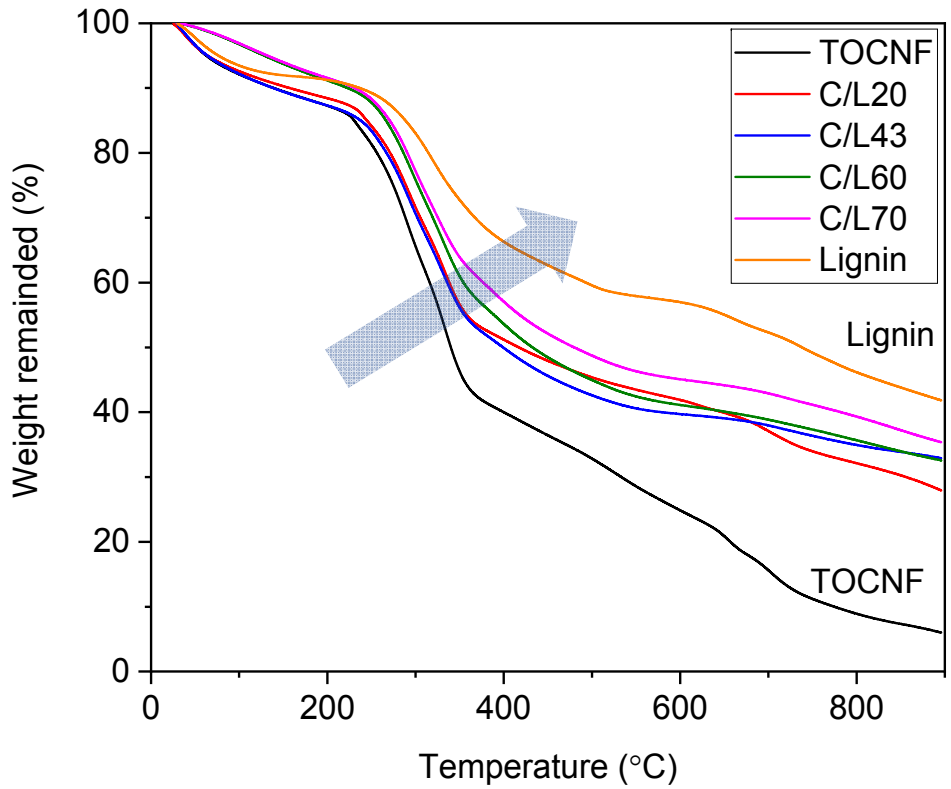
# Fiber morphology & orientation




Fiber orientation first increased and then decreased with lignin addition

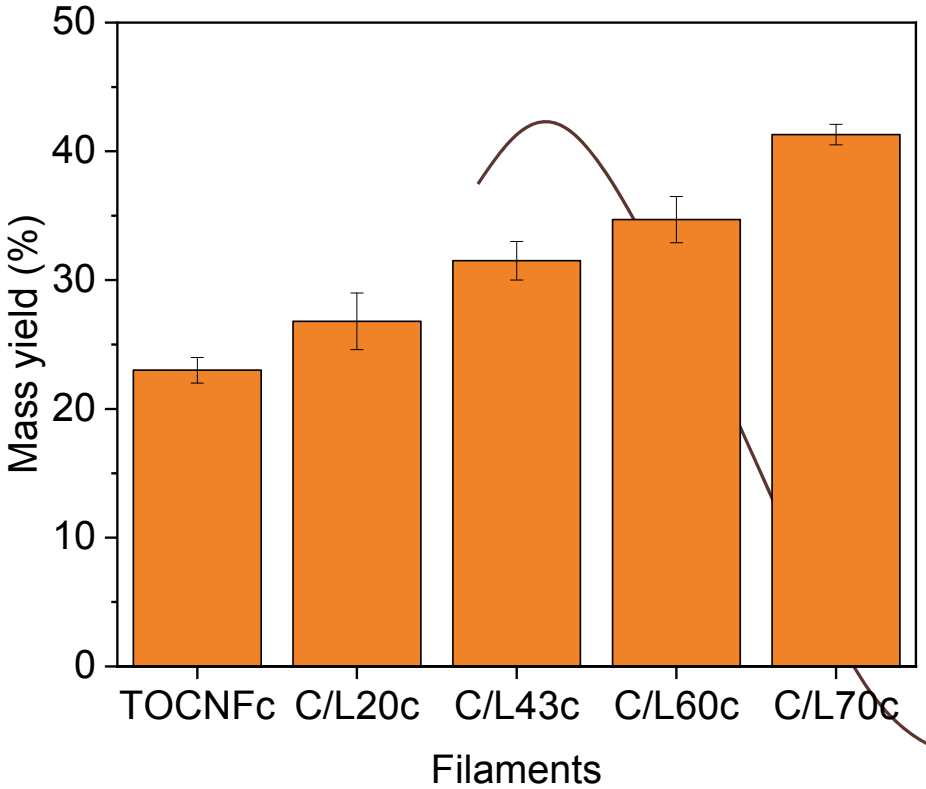
# Mechanical strength and thermal stability



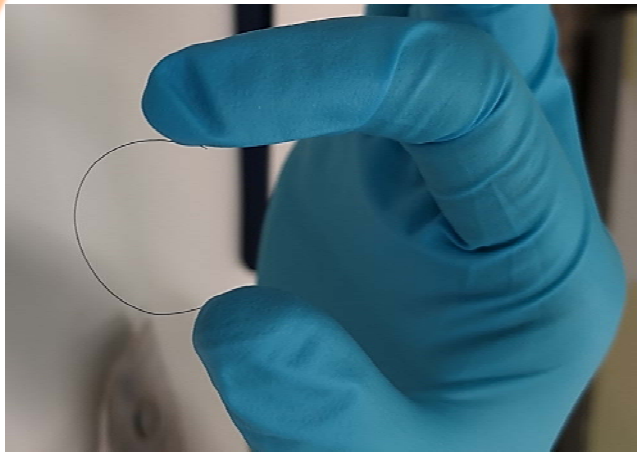

**Lignin addition: Lower tensile strength and higher thermal stability**

# Carbonization and mass yield

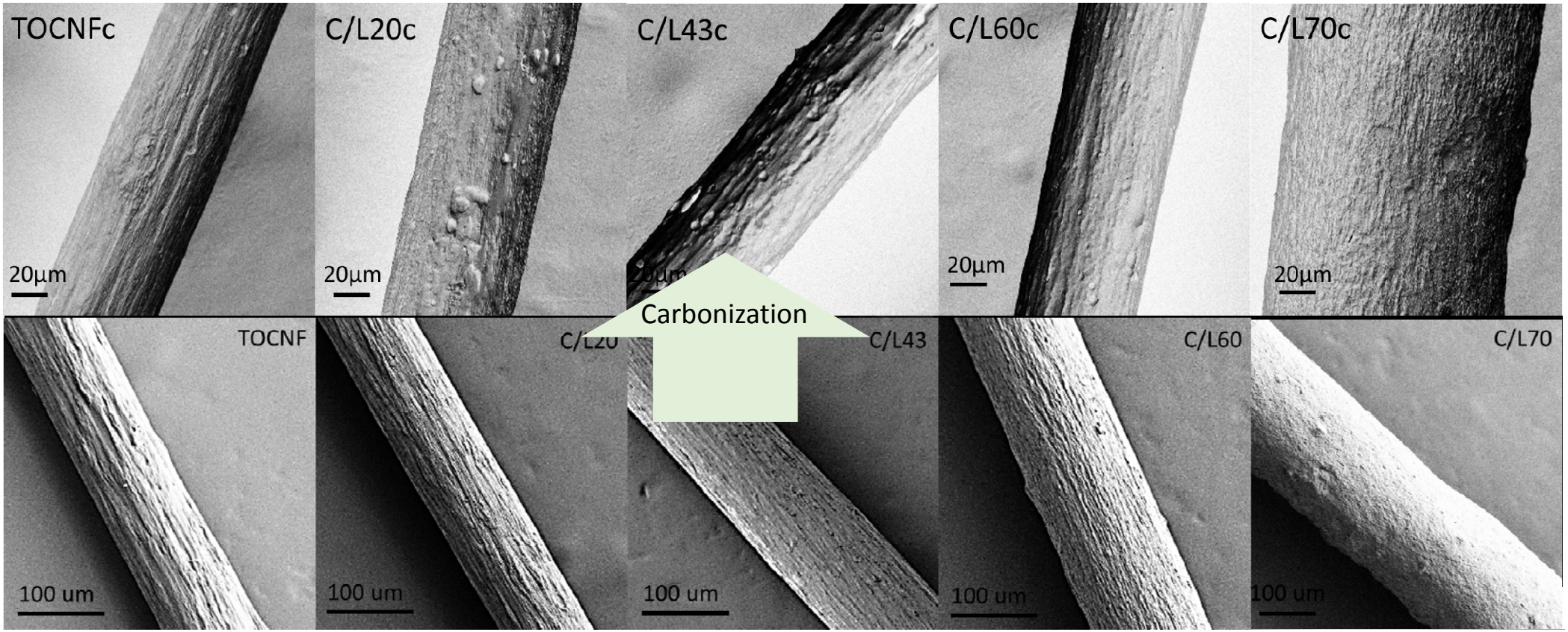



Lignin: Higher C yield

**One step carbonization !!!**
Tubular furnace (900 °C, 60 min)

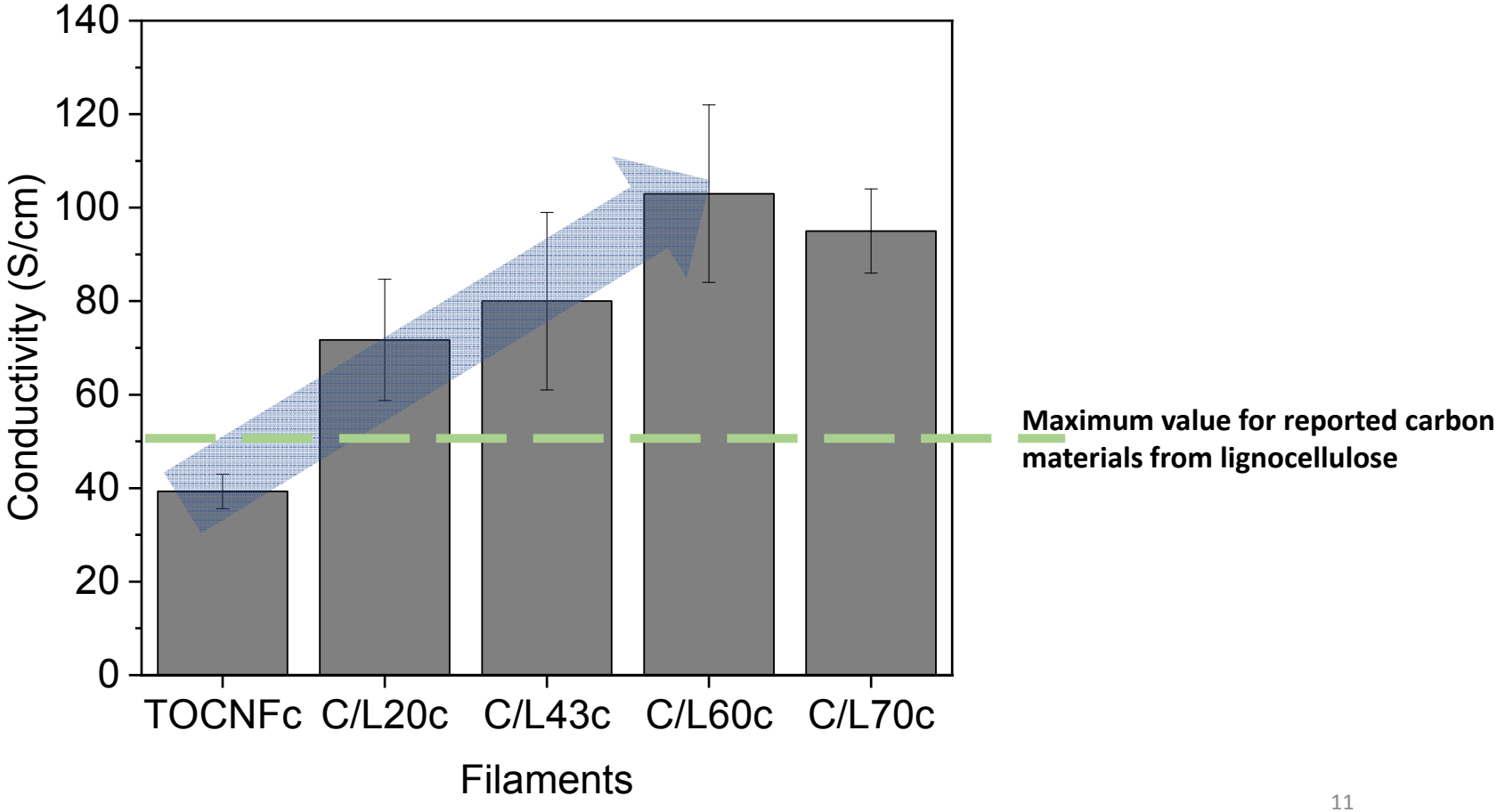


# Carbon Fiber morphology




Carbon fiber (CF) retained morphology

# CF conductivity

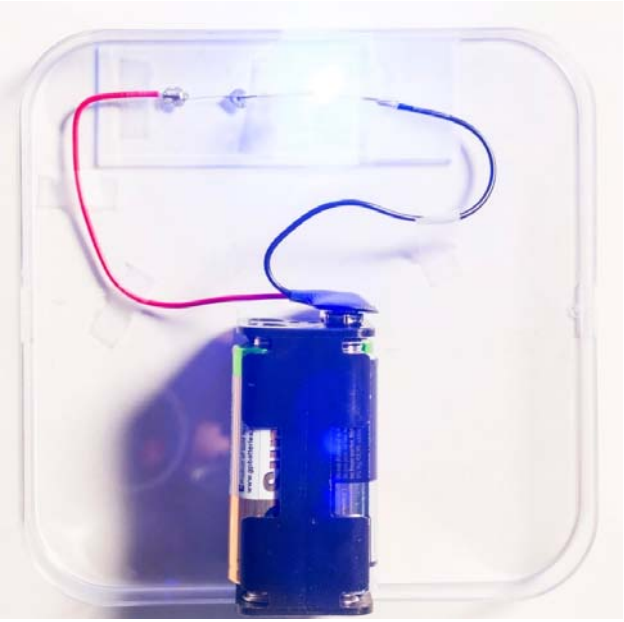


# Conclusions

ACS Sustainable Chem. Eng. 2019, 7, 6013−6022

- Filaments with up to 70% lignin (wet spinning)

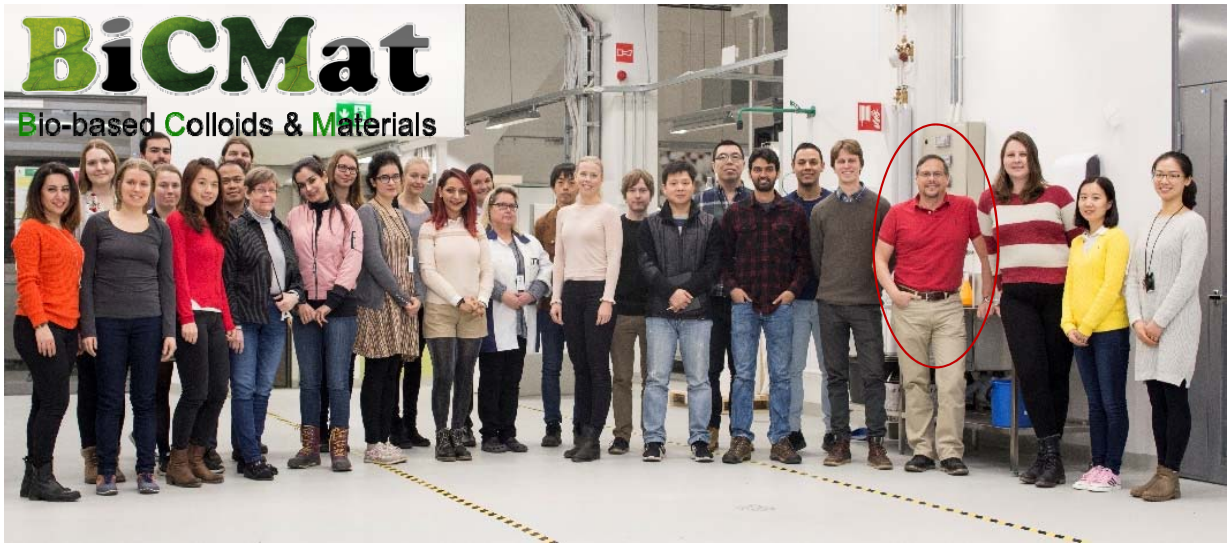
- Lignin:
  - *Higher thermal stability*
  - *Higher mass yield upon carbonization*
  - *Higher conductivity of carbon fibers*



# Acknowledgement


Consortium Workshop 2018

LiFT
High-Value Products from Lignin

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# Thank you!

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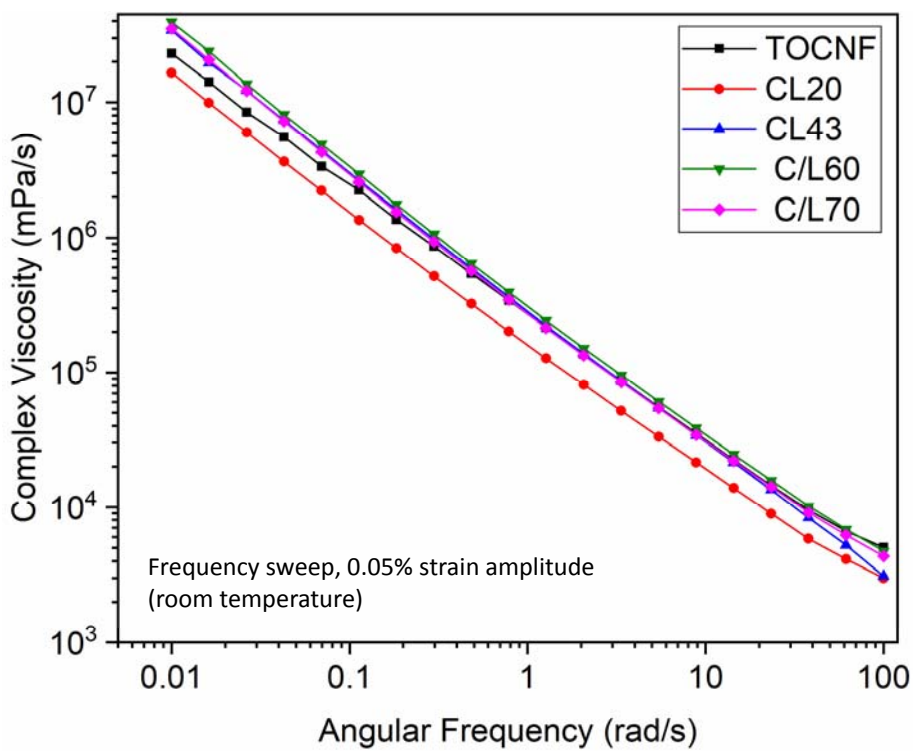
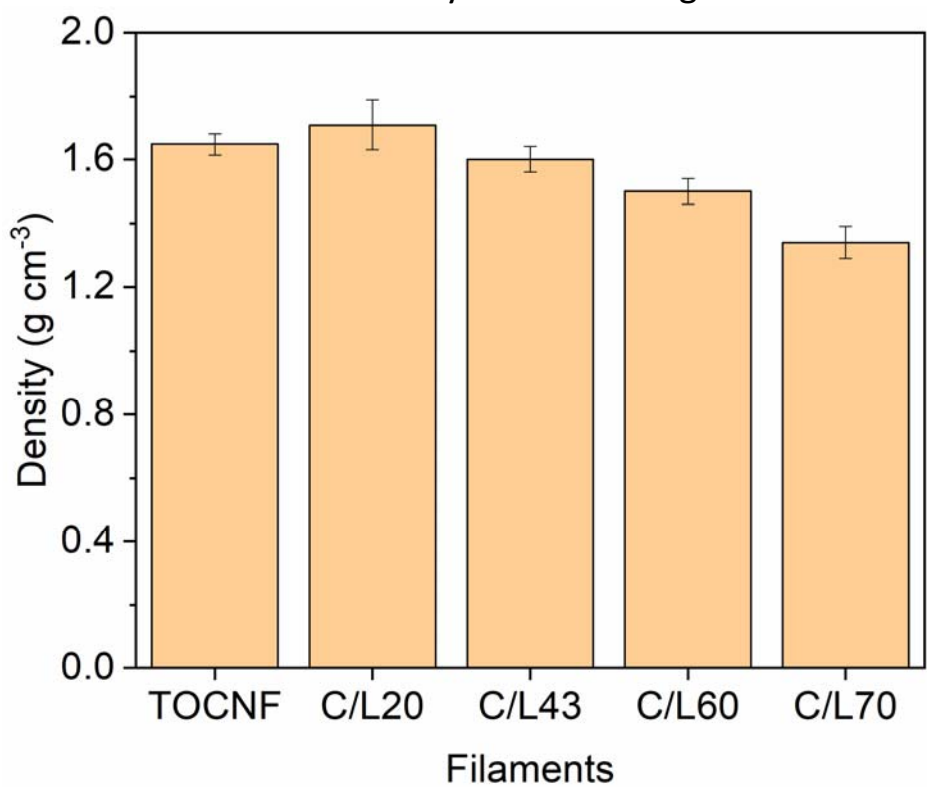
# Filament density: related to dope viscosity

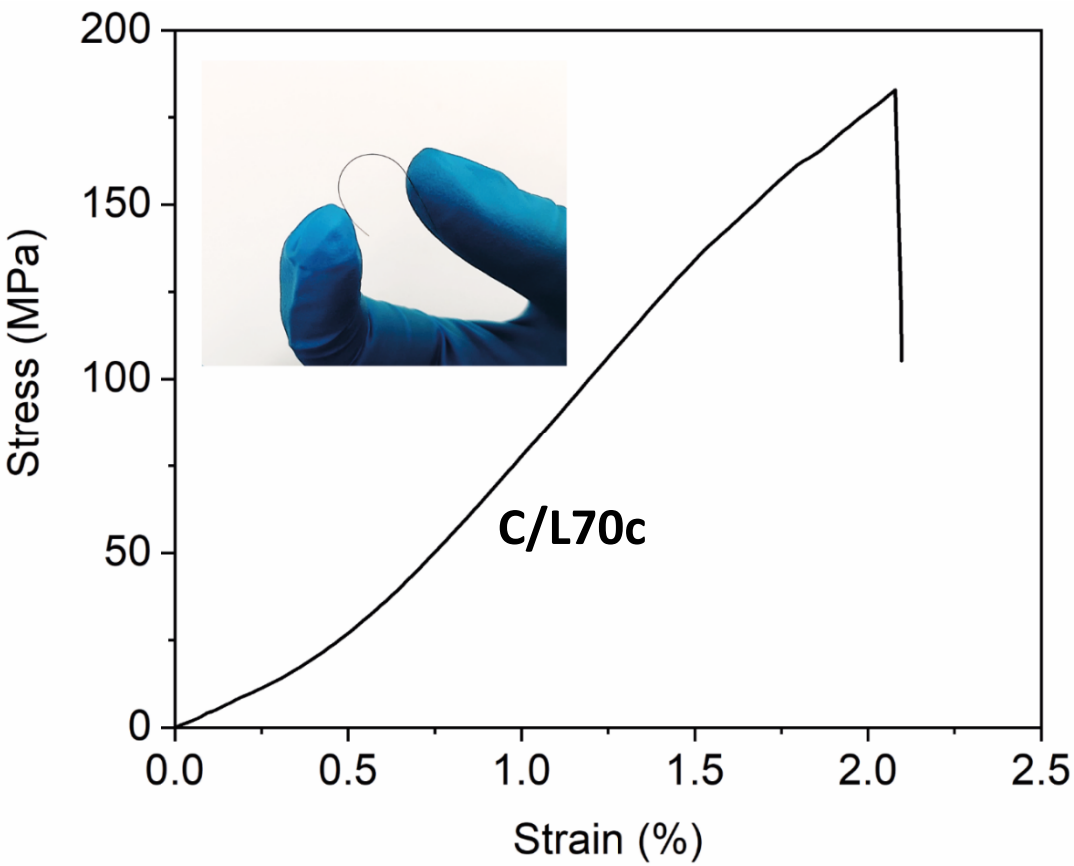


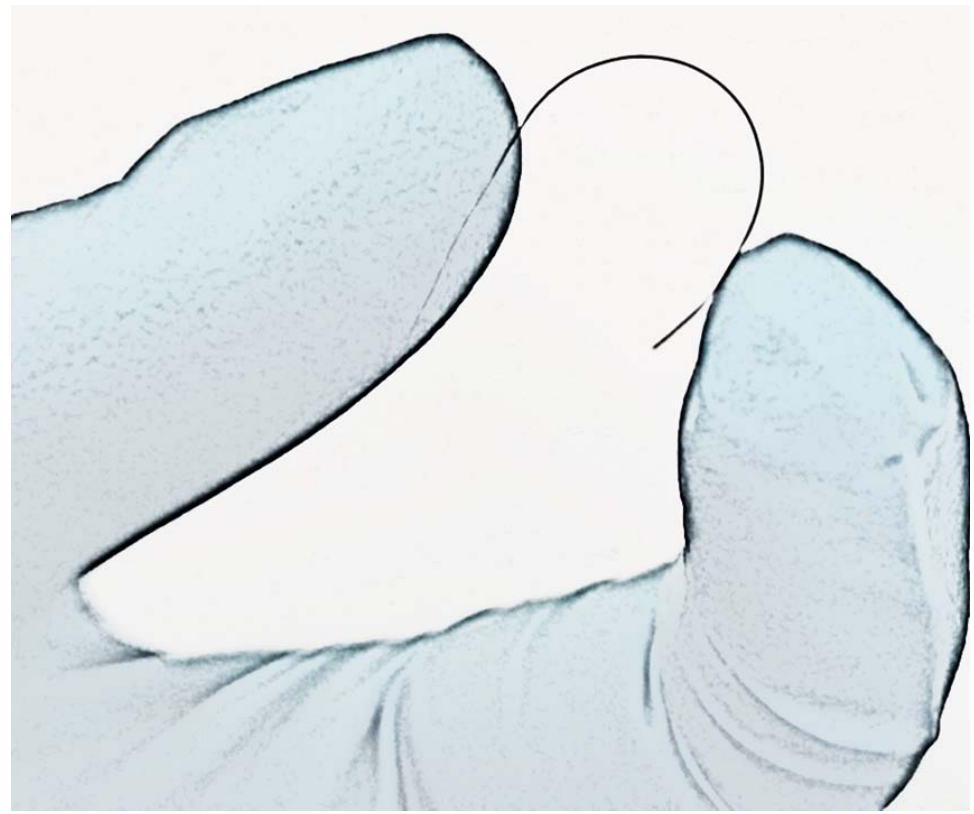

Filaments density at different lignin content




Lower lignin content (≤20%): densified filaments due to lubrication effect.

# CF strength: higher than precursor's



Lignin: more bendable carbon fibers