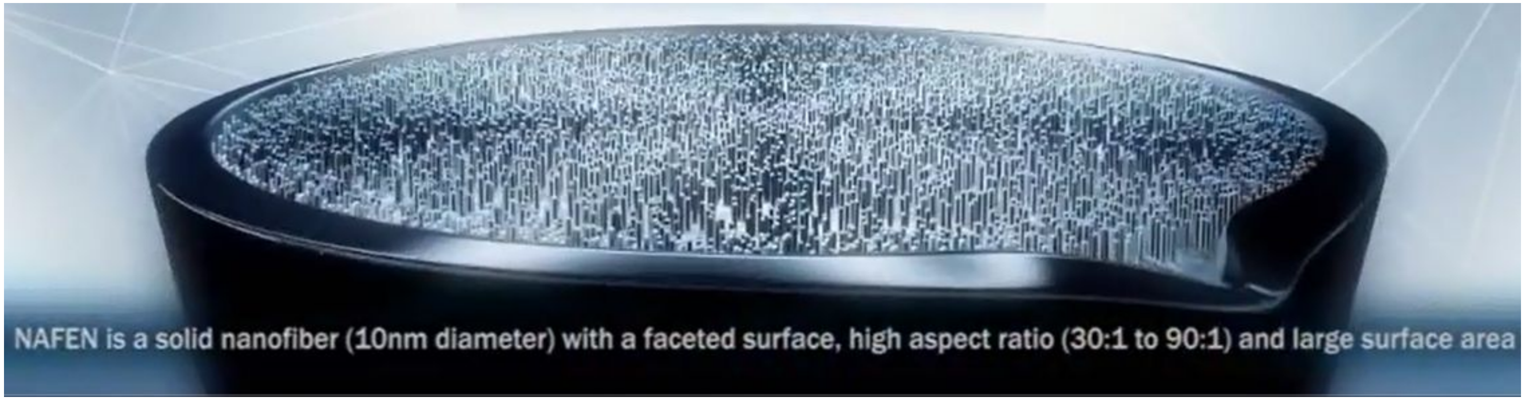
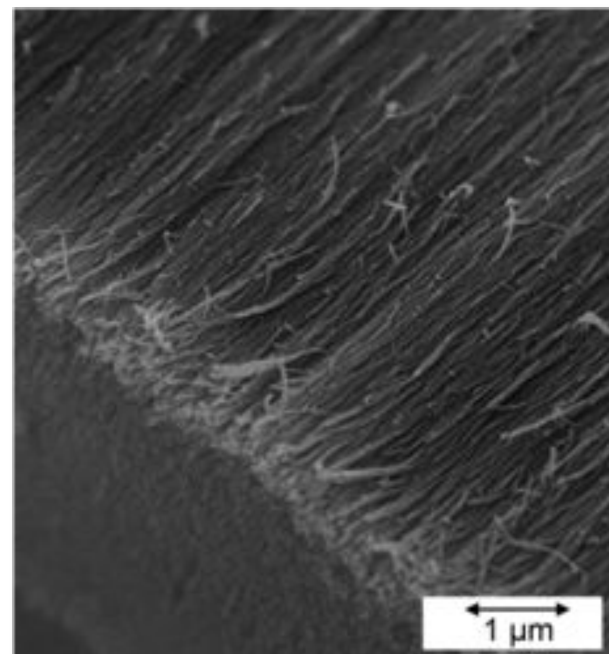
NAFEN

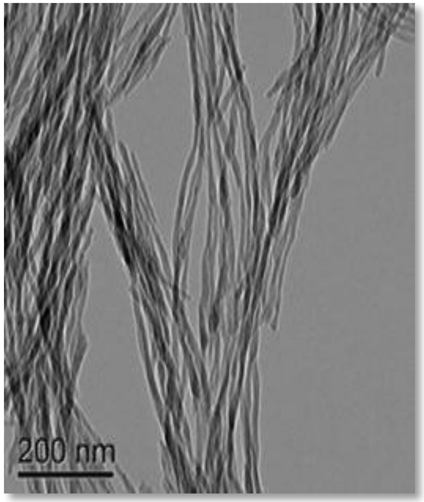
Nanofibers of aluminum oxide

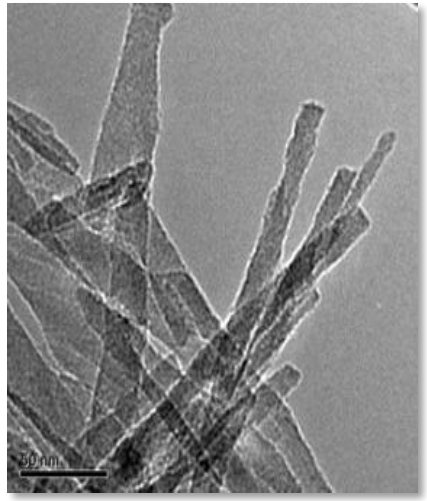
Nafen is produced from melt: industrial-scale technology

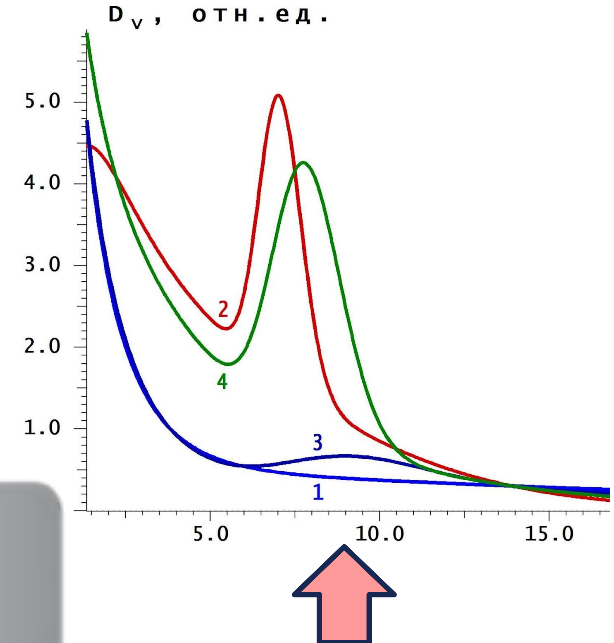


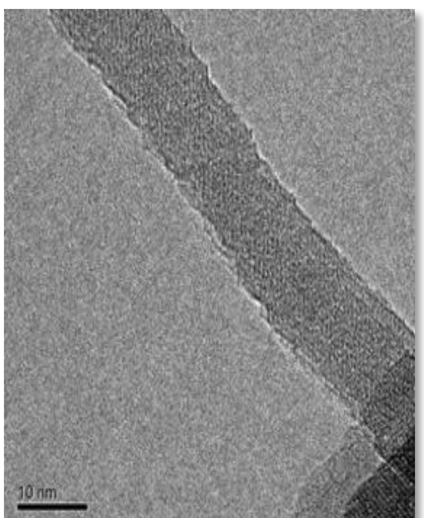


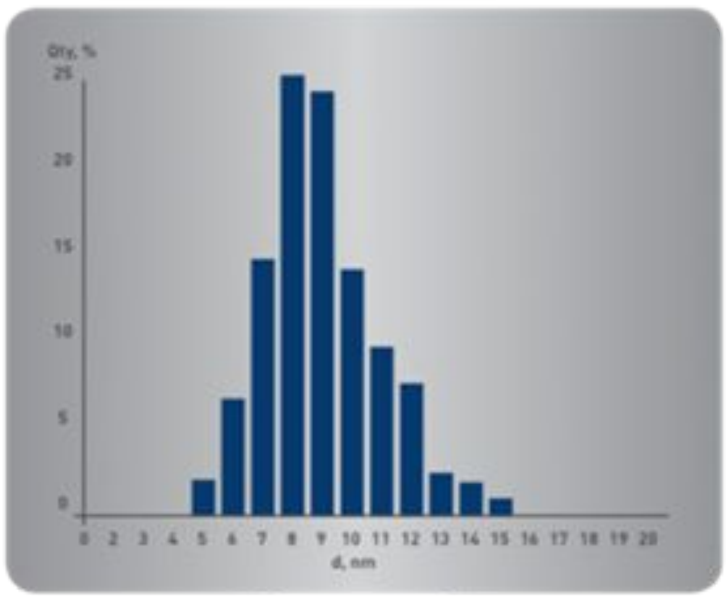
TEM micrographs / SAXS data











small-angle scattering (SAXS);

also indicate high degree of alignment

Nafen nanofibers : summary of properties

Parameter	value
Phase	gamma / chi ~ 15:85 *
Mean fiber diameter, nm	7-10
Fiber length, mm	1–150
Specific surface area (BET), m^2/g	100-150
Purity, %	99.7
Bulk density, g/cm^3	0.1 to 0.4

* - phase composition can not be accurately quantified because of lack of structure model for χ-phase

Is it unique?

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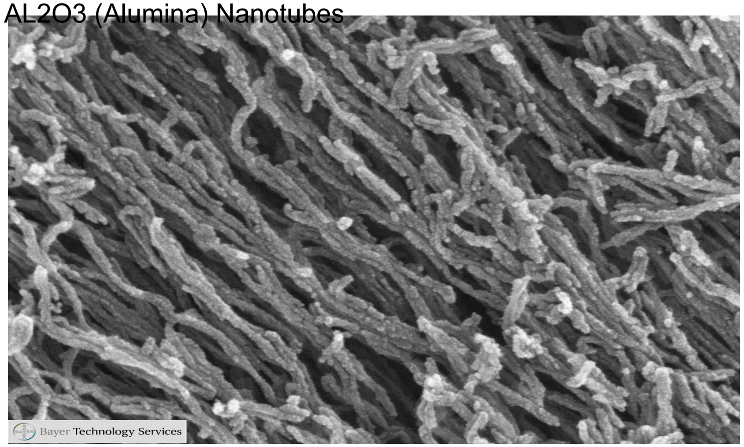
Reference 1:
AlOOH “aerogel” (FEI)

Reference 2:
Nano Technology Inc. (Korea):

“diameter is approximately 5-10 nm, and the aspect ratio is in the 50 to 200 range”

AL2O3 (Alumina) Nanotubes



99360 : 1

200nm

3258 *Bull. Korean Chem. Soc.* **2012**, Vol. 33, No. 10 *Byung-Joo Kim et al.*
http://dx.doi.org/10.5012/bkcs.2012.33.10.3258

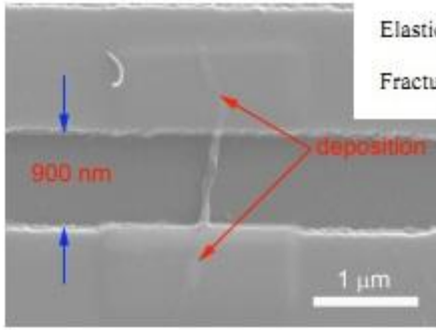
Effects of Surface Nitrification on Thermal Conductivity of Modified Aluminum Oxide Nanofibers-Reinforced Epoxy Matrix Nanocomposites

Byung-Joo Kim, Kyong-Min Bae,[†] Kay-Hyeok An,[*] and Soo-Jin Park[†,*]

Mechanical properties of individual fiber

NAFEN

Calculation of Elastic modulus, fracture strength, and fracture energy of Nafen fibers



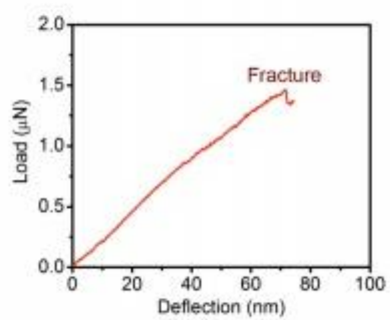
Elastic modulus: 402.8 ± 99.3 GPa.

Fracture strength: 12.2 ± 3.2 GPa.

$$E = \frac{FL^3}{192 d_n I} = \frac{K_n L^3}{192 I}$$

where I is the moment of inertia, L is the suspended length of the sample, and F is the applied load at its midpoint position. K_n, the spring constant of the sample.

Calculation of fracture strength



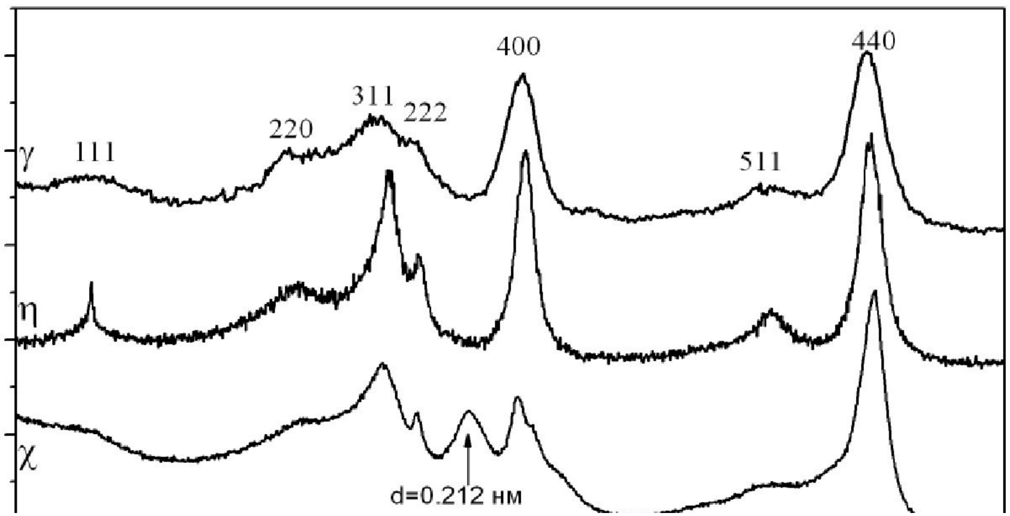
$$\sigma = \frac{FL}{2\pi r^3}$$

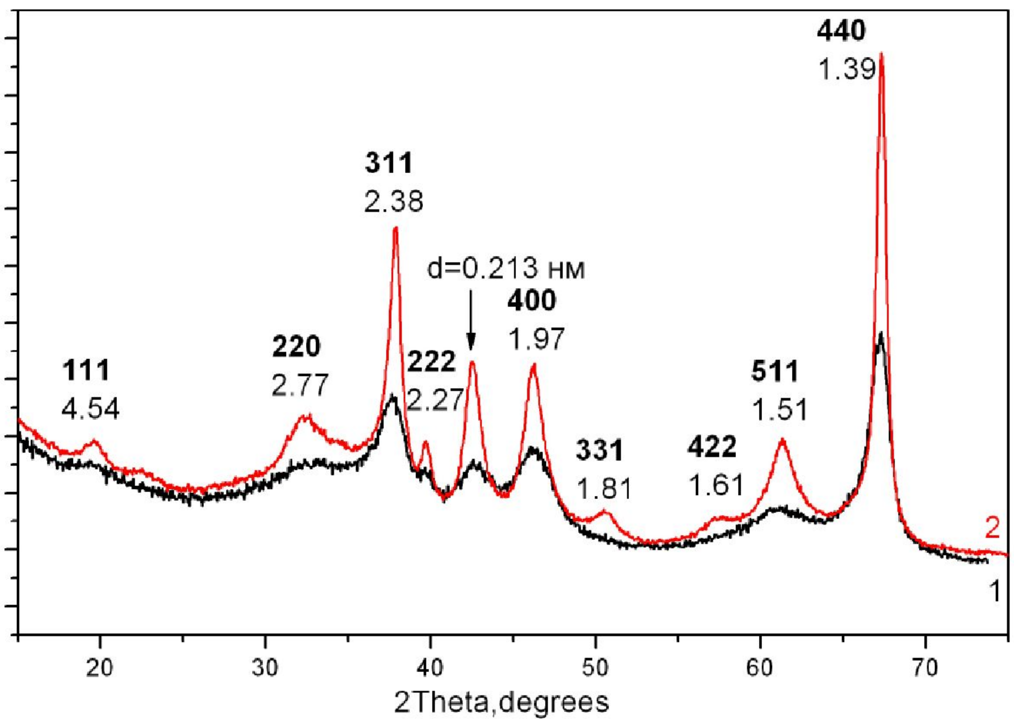
Where F is load when the nanowire cracks, L is the suspended length of the sample; r is the radius of nanowire.

CNTs (Wiki):

Young's modulus on the order of 270 - 950 GPa and tensile strength of 11 - 63 GPa

Phase analysis (XRD)





Typical diffraction patterns for low-temperature phases of alumina

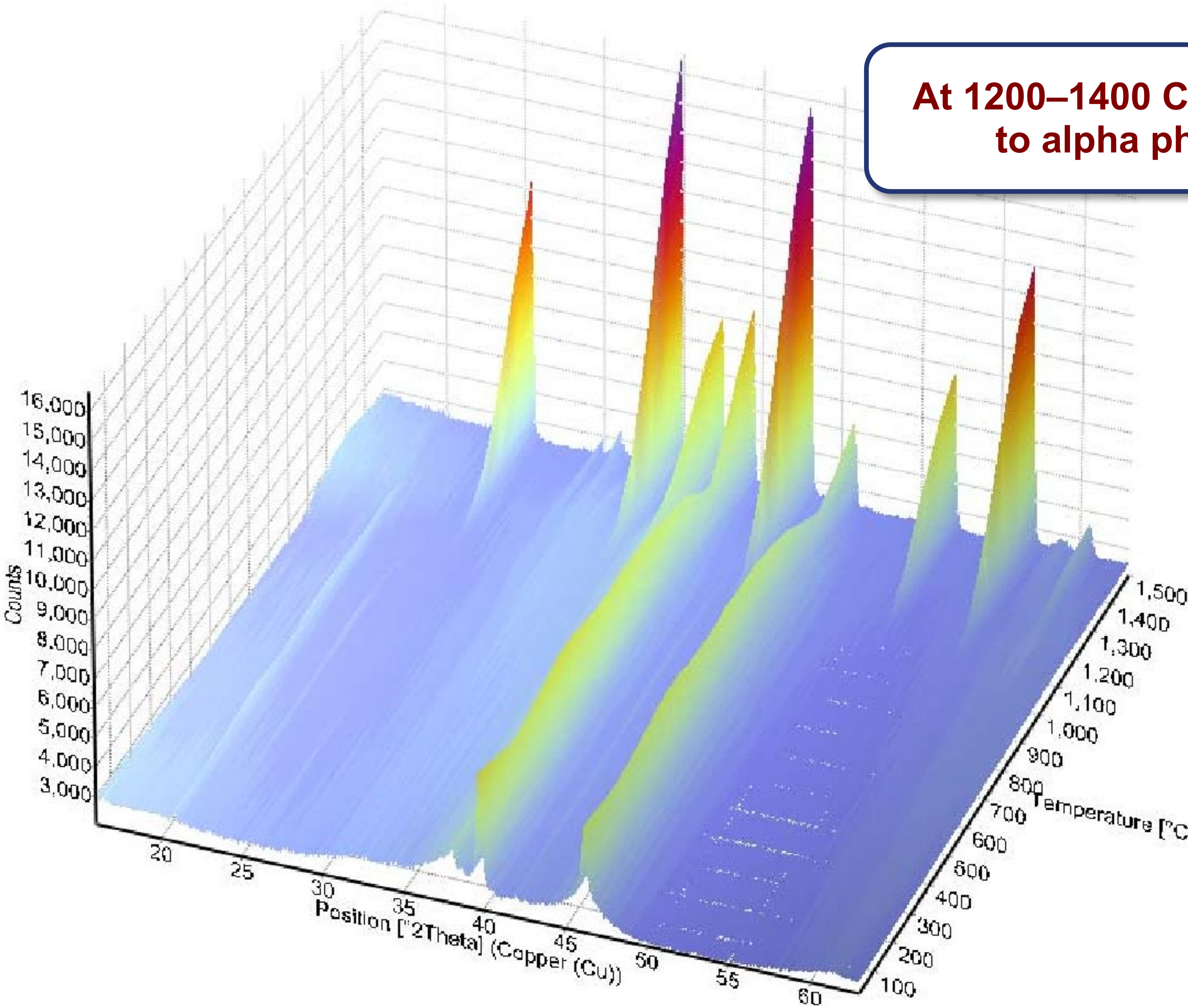
- chi is identified by the peak at 2θ=42.8

Diffraction patterns of two samples of Nafen

- the phase is identified as mostly chi, with some gamma
- crystallite (CSR) size 50-100 nm

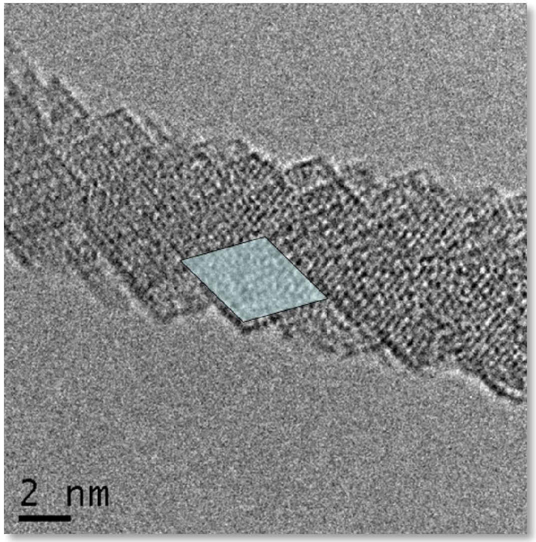
Nafen fibers are polycrystalline alumina in gamma and chi phases

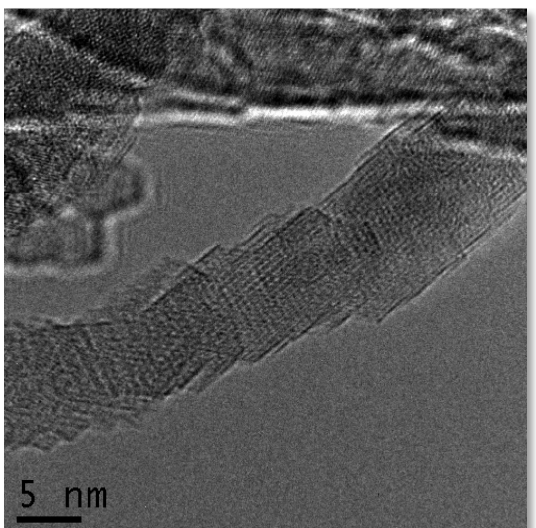
High-temperature phase transformation (XRD)

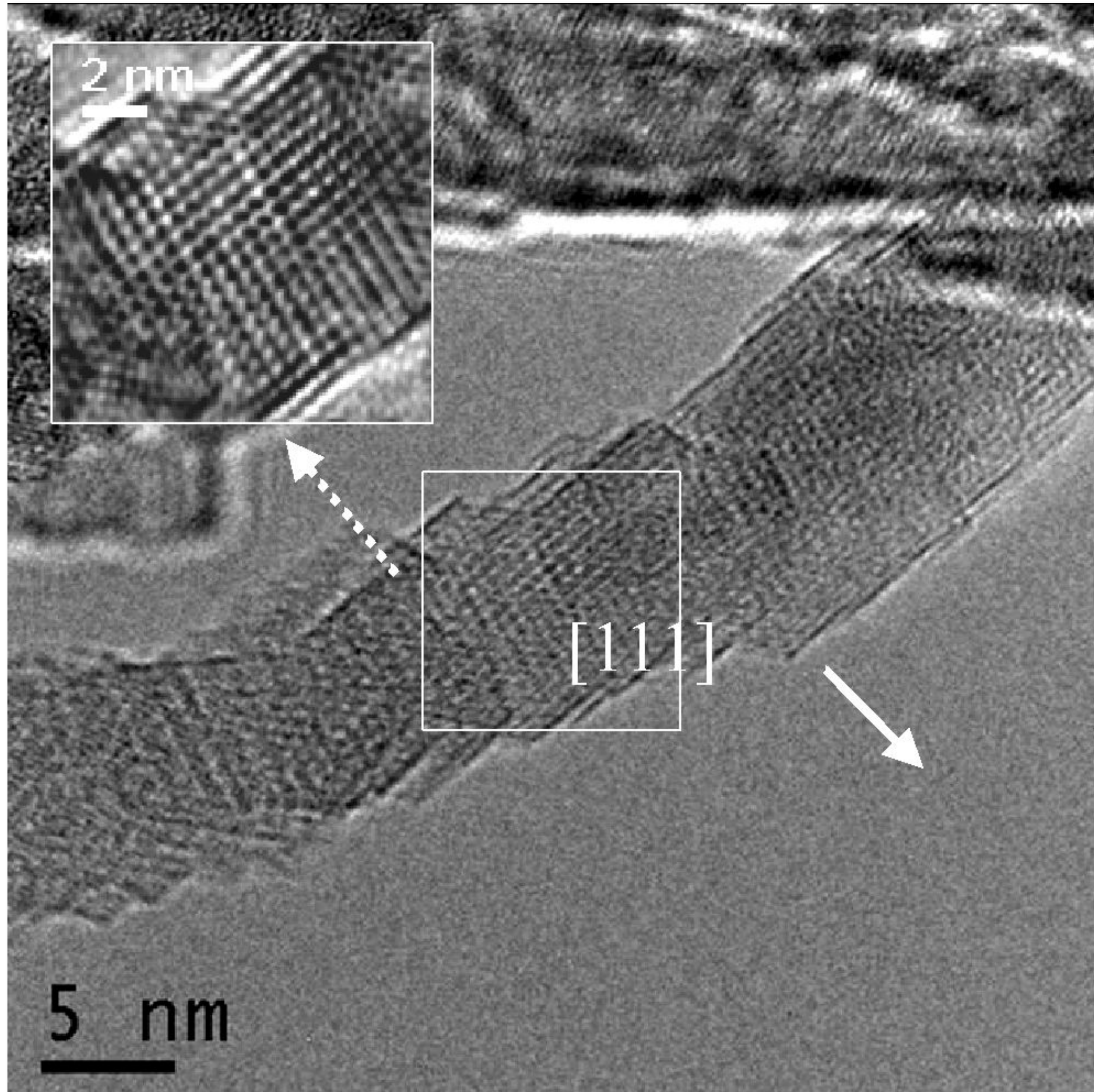


At 1200–1400 C, transformation to alpha phase occurs

The surface is ‘saw-shaped’ (TEM)



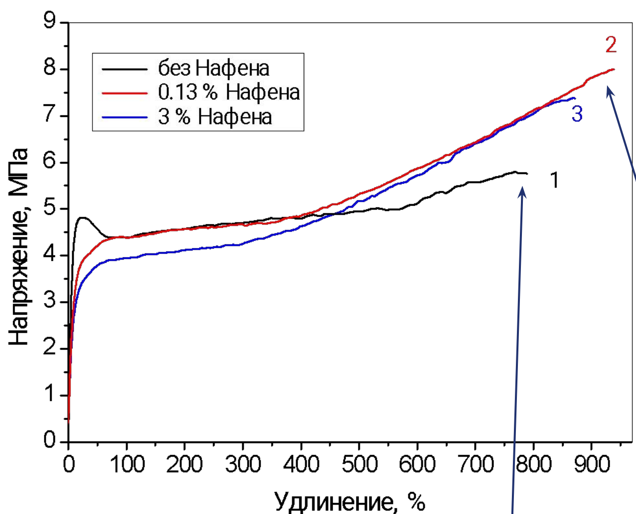


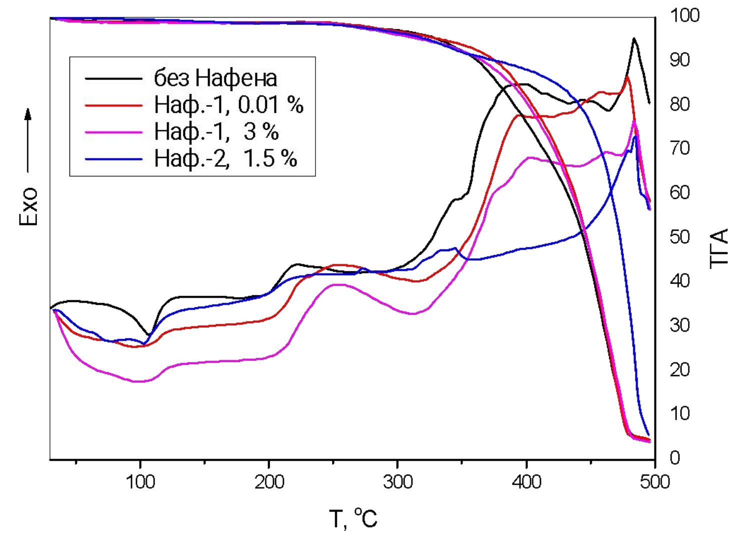


Main application:
reinforcing filler for thermoset-based adhesives

EP-PP copolymers:
"as co-monomer"

Surface treatment type affects the performance, including level of TOD stability enhancement



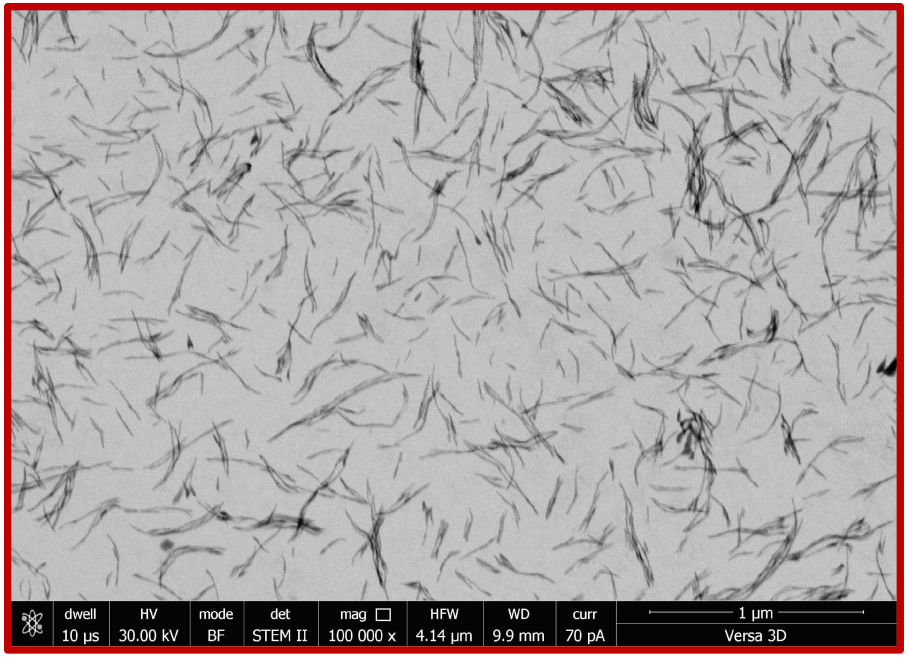


940% / 8.0 MPa

790% / 5.8 MPa

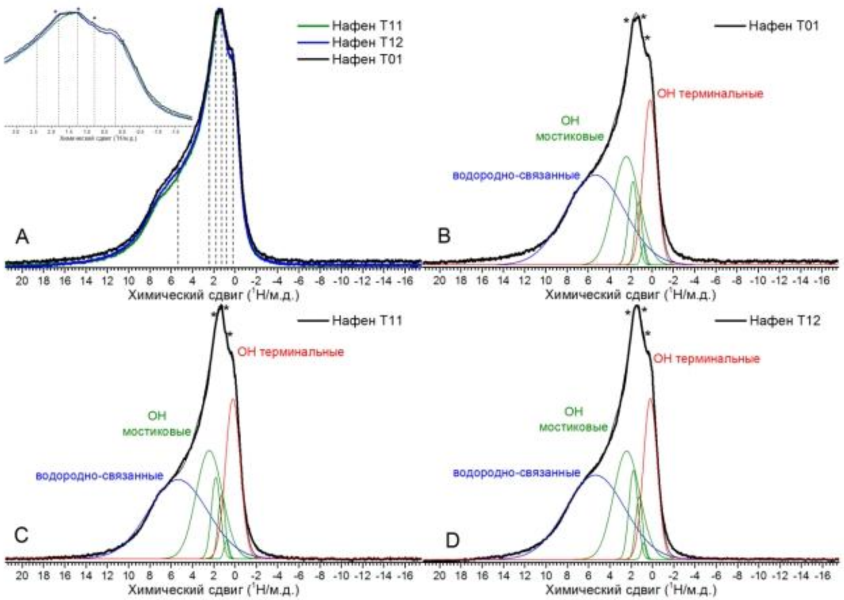
Refefence:
N.M. Bravaya et al.,
J. Appl. Polymer Sci. (2017) – accepted for publication

Technological challenges & solutions



Ultrasonic dispersion and/or targeted surface treatment (functionalization) allows good (almost to single fiber) level of dispersion

Surface chemistry



^{1}H MAS NMR:

three types of surface protons:
- terminal
- bridge
- hydrogen-bonded

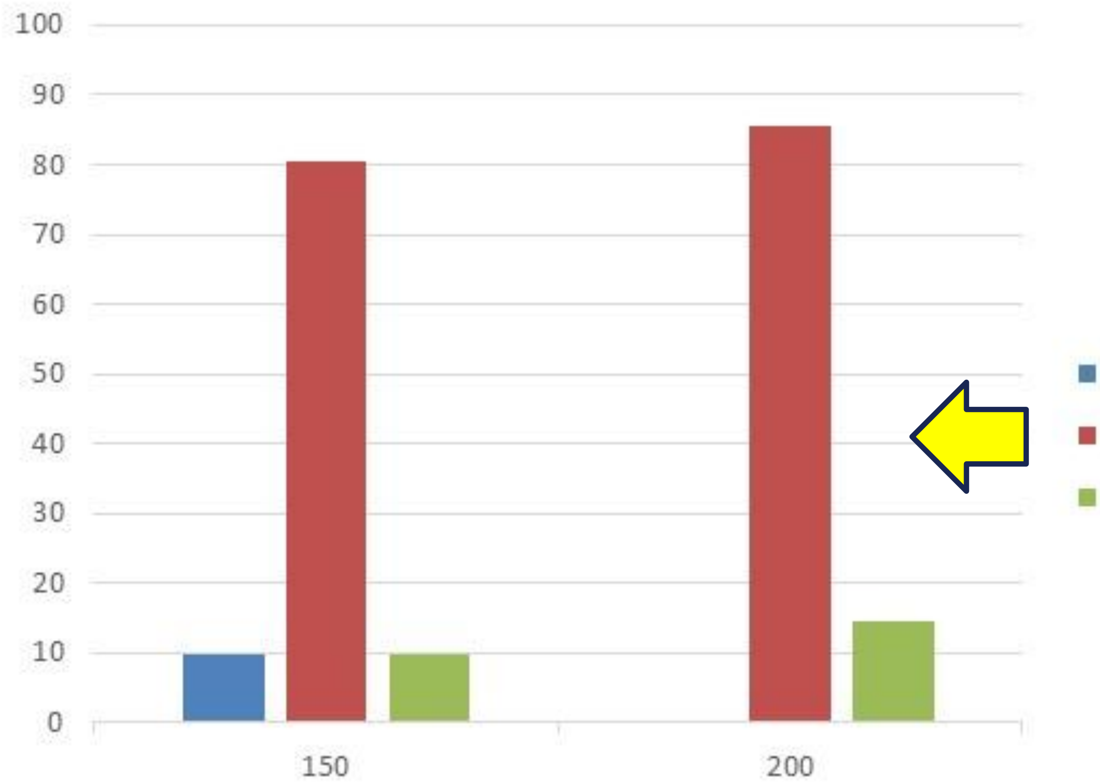
IR spectroscopy / CO absorption:

only weak and medium-strength Brønsted and Lewis centers are present:

max Q(LC) = 39 kJ/mole - considerably lower than for “conventional” Al_2O_3 types

Nafen as support for heterogeneous catalysts: first trials

1) HDC of halogen-aromatic compounds: application for waste treatment (unpublished)



Temperature

Cl-benzene

cyclohexane

benzene

2) Emulsion hydrogenation of substituted phenols (unpublished data):

23 compounds tested

Nafen-supported catalyst showed up to 95% yield and up to 94% selectivity

2) Low-temp CO-oxidation 95% conversion already with unmodified commercial catalyst

Nafen as support for heterogeneous catalysts: potential / advantages

1) low-T Al_2O_3 polymorph
2) relatively high SSA and “highly-defective” surface:
   allows easy anchoring of catalytically active components
3) low acidity: no / minimal side reactions → selectivity
4) surface chemistry can be tailored:
   - three subtypes of Nafen available
   - functionalization is possible
5) ready masterbatches for liquid dispersion type processes
   can be produced
6) “bonus” reinforcement effect (?)

Thank You for Attention