In situ formation of electrospun graphene nanofibers

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Abstract

Graphene-based materials are currently in the focus of research, but toward any application a simple and reliable fabrication process is mandatory. To date, graphene nanofibers (GNF) made via electrospinning have been established, using graphene oxide (GO) as templating agent. However, relying on GO as a solid insoluble precursor makes the process harder. We present a method to produce in situ neat GNFs made of solely electrospun polyacrylonitrile (PAN). Besides heating in an oven up to 1700 □C, the GNFs were heated by self-resistive heating. For this the nanofibers were placed into an electrical circuit and a rising electrical power was applied reaching over 3200 □C directly in the nanofibers. The Raman, XPS, and XRD results show high crystalline GNFs, with little to no defects and high graphitization degree. Furthermore, the electrical transport measurements revealed an eightfold increase in the conductivity. The deeper analysis of the 2D-band indicates the graphene structure. This simple way of electrospun GNFs with a commonly used polymer precursor opens the door to easier access and broader functional application of said nanofibers.

Supporting Information

Table S1 The values of the refraction angle 2θ, FWHM of it, L_c and d_{Bragg} for reference samples.

Sample	2θ / °	FWHM / °	L_c / nm	d_{002} / pm
CNT	25.52	1.689	4.77	349
GNP	26.12	1.202	6.708	341
Graphite	26.42	1.534	7.083	337

Table S2 The values of the FWHM of the 2D peak, ratio of I_D/I_G and I_{2D}/I_G and L_a for the reference samples.

Sample	FWHM_{2D} / cm^{-1}	I_D/I_G	I_{2D}/I_G	L_a / nm
CNT	58.3	0.75	0.83	26
GNP	75.9	0.31	0.95	63
Graphite	73.6	0.29	1.06	66

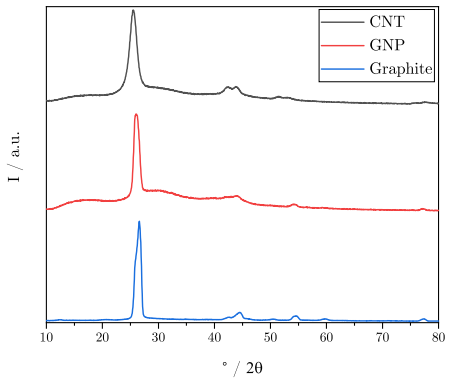

Fig. S1 X-ray diffractogramm of multi-walled CNT, GNP and Graphite.

Comparison of the GNFs with commercially available carbon products, such as carbon nanotubes (multi-walled) (CNT), graphene nanoplatelets (GNP), and graphite (all purchased from abcr), clearly show the difference in the structure. The FWHM of the GNFs is lower than any other sample, and references [19, 20] indicate, with the high symmetry of the measured 2D band, that it is a folded single-layer structure. It also

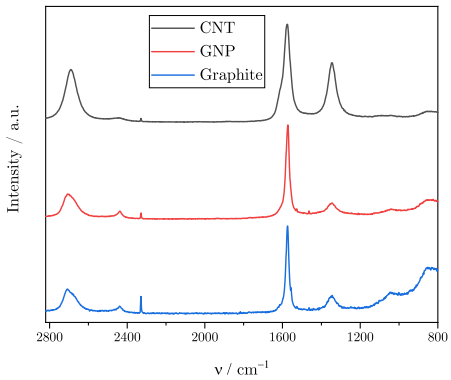

Fig. S2 Raman spectra of multi-walled CNT, GNP and Graphite.

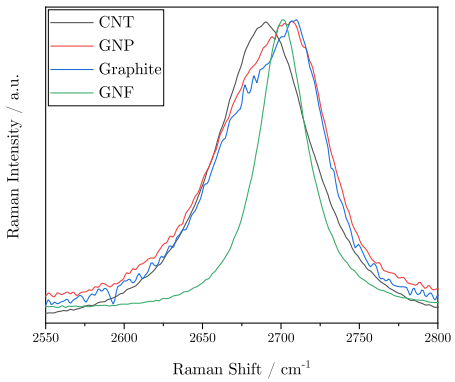

Fig. S3 2D-band of multi-walled CNT, GNP and Graphite compared to the GNFs.

can't be a structure with multiple layers as the 2D band would become asymmetrical, as visible for the GNP and graphite. The production of CNT and GNP is high, with several tons per year, but most of their usage is directed towards applications with unorganized architectures, such as inks, coatings, composites, or catalyst support [40]. In contrast, the GNF from this process are highly oriented and can be manufactured into organized architectures with their anisotropic conductivity, which is beneficial in e.g., Li-ion batteries [2].

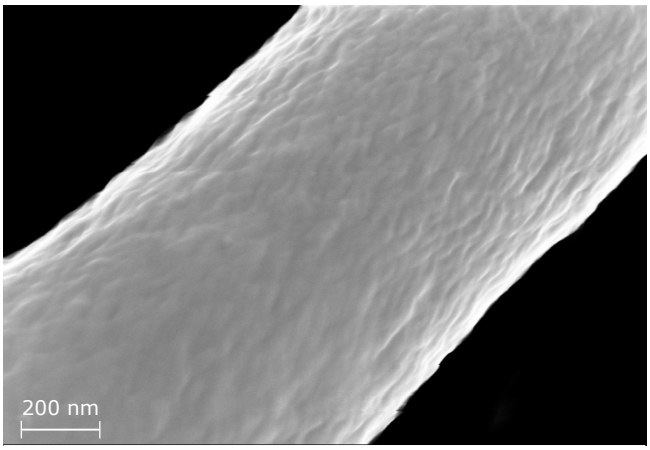

Fig. S4 SEM image of GNF.

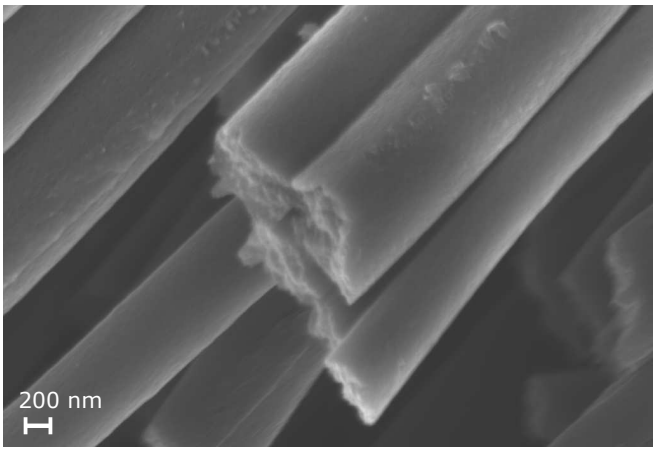

Fig. S5 SEM image of GNF.

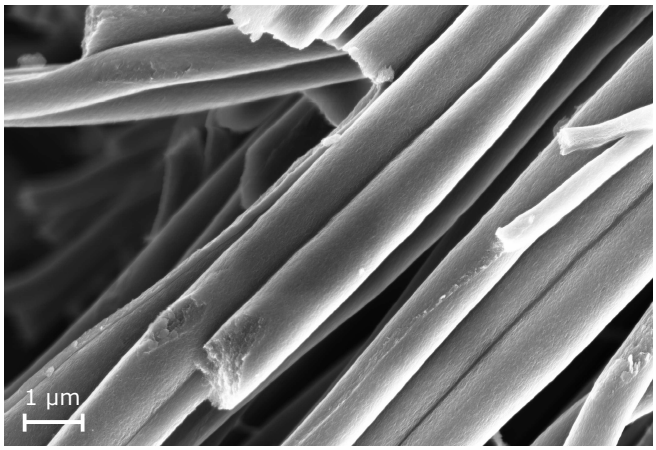

Fig. S6 SEM image of GNF.

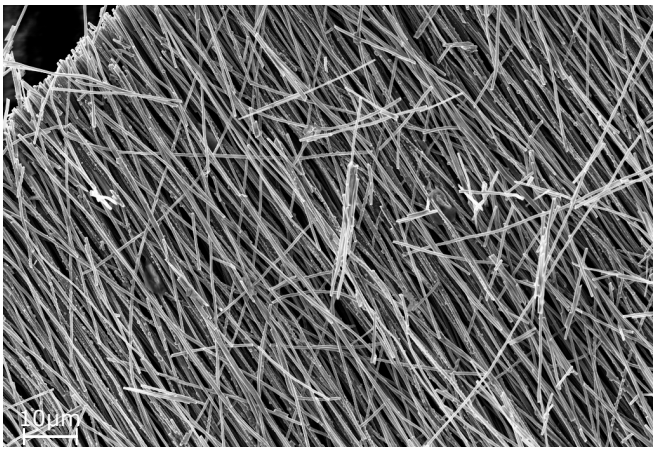

Fig. S7 SEM image of CNF.

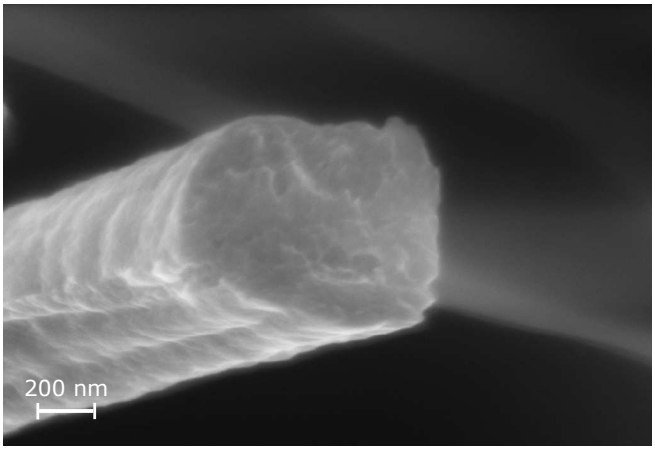

Fig. S8 SEM image of a CNF cross section.