HOCHSCHULE SCHMALKALDEN
UNIVERSITY OF APPLIED SCIENCES

Lignin-based binder for high performance carbon electrode

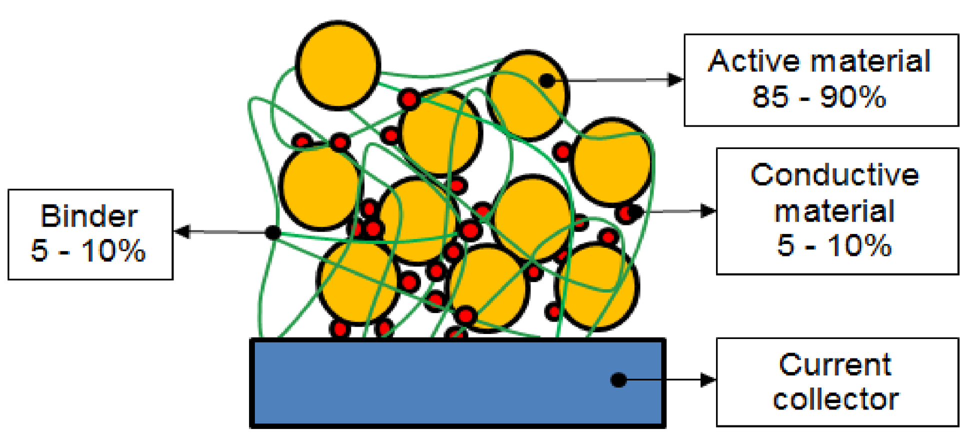
Nur Batrisyia binti Tajuddin[a], Annett Dorner-Reisel[a], Viola Matner[a], Stefan Svoboda[b], Horst Schäfer[b]

a) University of Applied Sciences Schmalkalden, Faculty of Mechanical Engineering, 98574 Schmalkalden, GERMANY
b) University of Applied Sciences Schmalkalden, Faculty of Electrical Engineering, 98574 Schmalkalden, GERMANY

Concept of lignin-binders

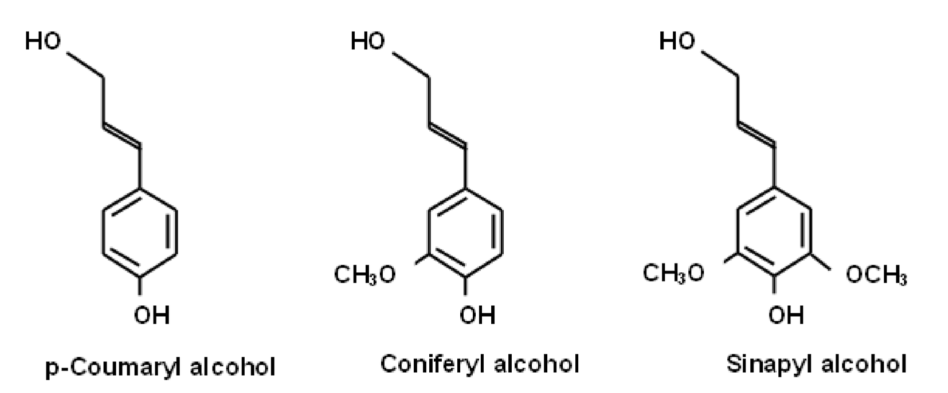
Polyvinylidene fluoride (PVDF) is the most conventional binder used in commercial Li-ion electrodes. However, PVDF binder is expensive, not easily to recycle and it involves the usage of volatile organic compounds for its processing. In addition, the reaction between PVDF with Li is an exothermal, which can cause self-heating and thermal runaway.

Therefore, Lignin-based binder is studied as an alternative binders that are more environmentally friendly. Lignin has emerged as an interesting raw material for the carbon materials in an electrode due to its low price and resistance to heat. Besides that, it can modify the electrode due to the formation of electroactive quinone functionalities which can oxidize and reduce during cycling.



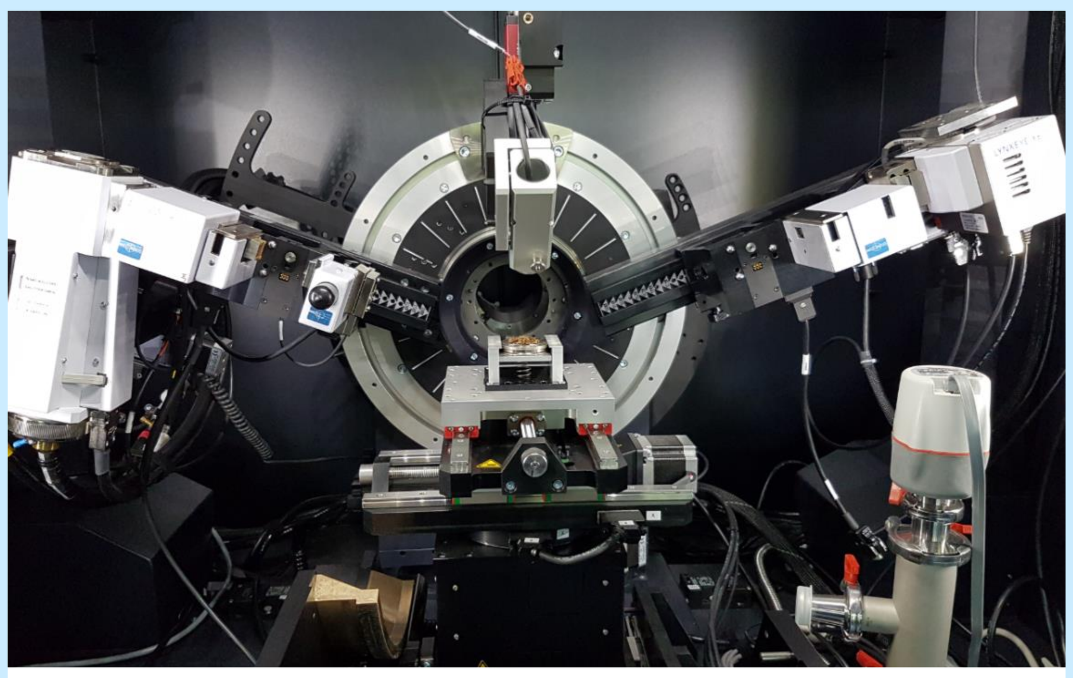
Schematic of conventional positive electrode for lithium ion battery

Structure of three phenyl propane monomers in lignin.



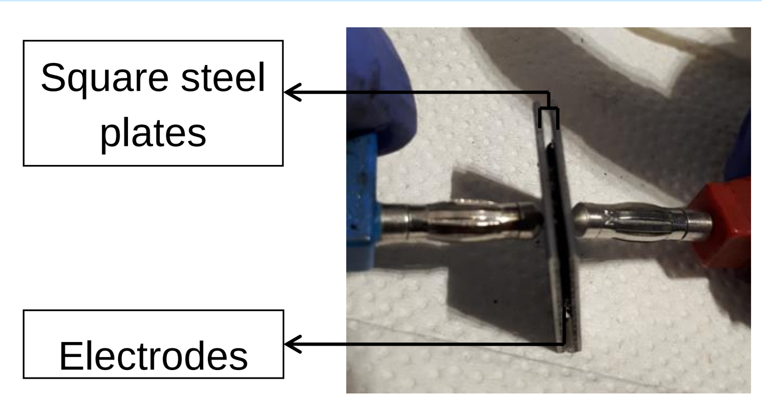
Experiment Methods

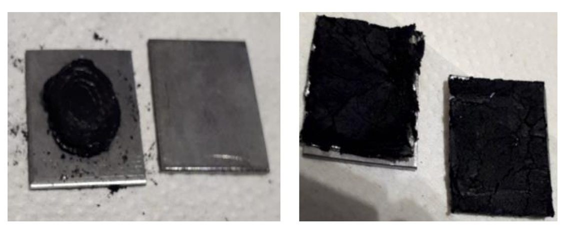
a) Stereomicroscope
b) Scanning electron microscope (SEM)
c) X-Ray diffraction (XRD) measurement



Source: Dorner-Reisel. A.: Examination report XRD for wheat straw lignins of PFI e.V. Hochschule Schmalkalden. 31.08.2017

d) Raman spectroscopy
e) Resistivity of electrodes

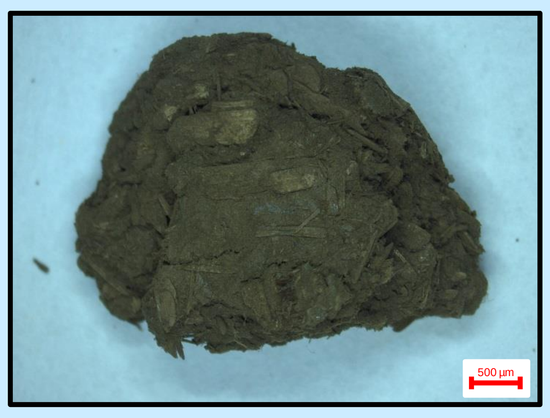




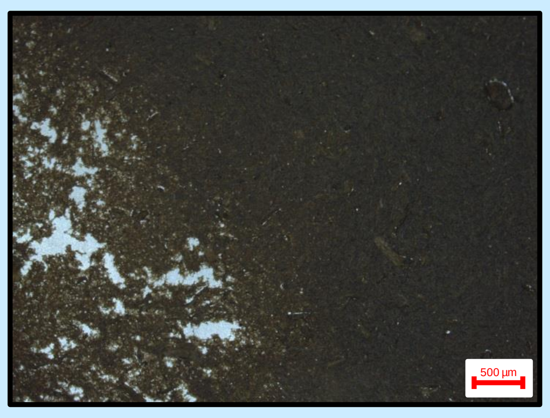
Arrangement of electrodes on the square steel plates

Results

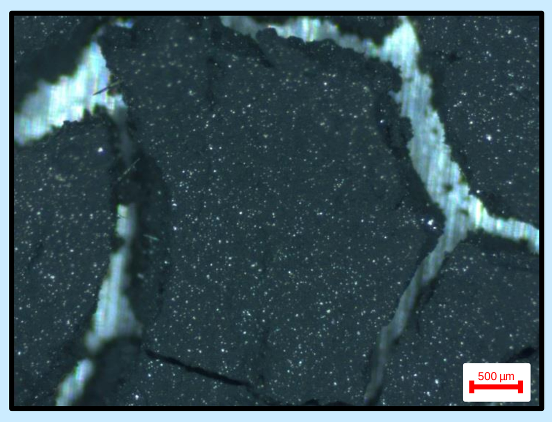
1. Stereomicroscope images



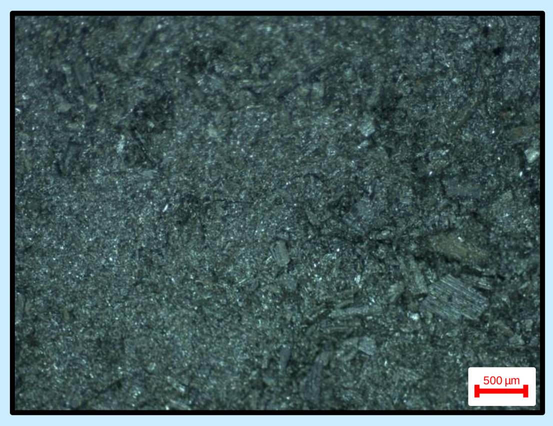
Enzymatic hydrolysed wheat straw



Lignin reacted with the solvent

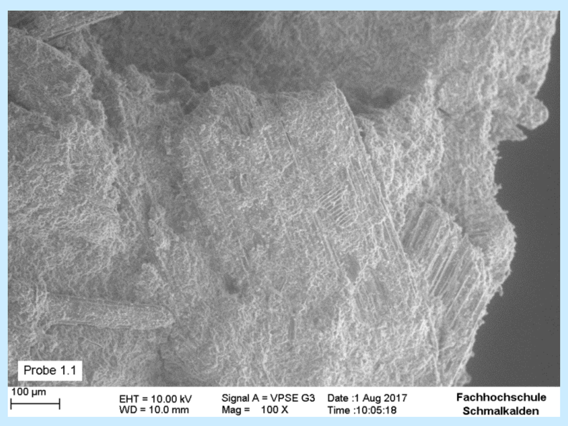


Acetylene carbon black as active material

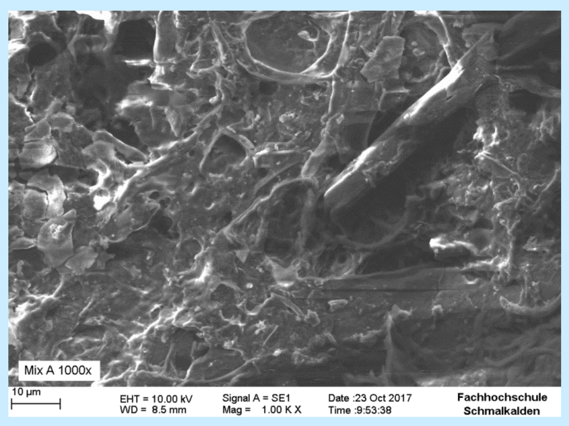


Untreated carbon from 600°C pyrolysis as active material

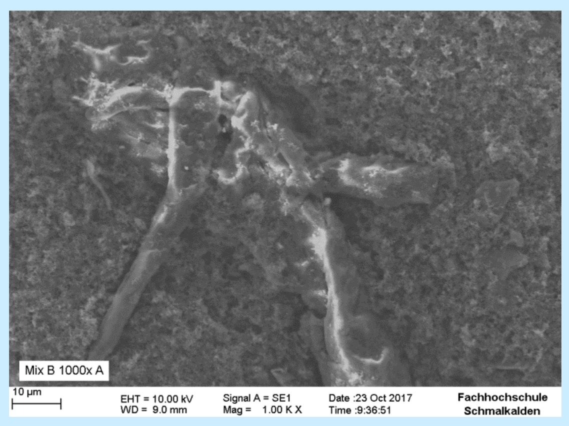
2. SEM images



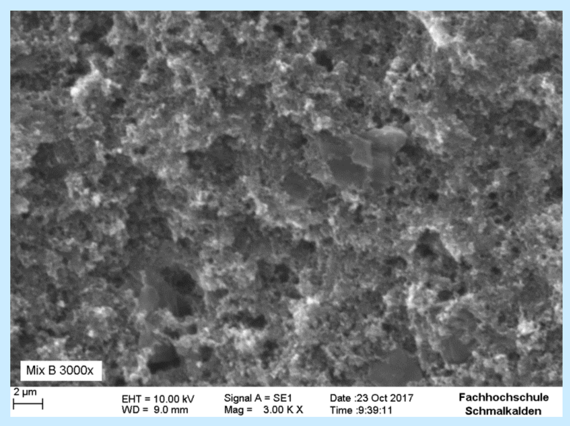
Extensive lamellar structure and major destruction of fibers



High degree of surface flacking and rupturing



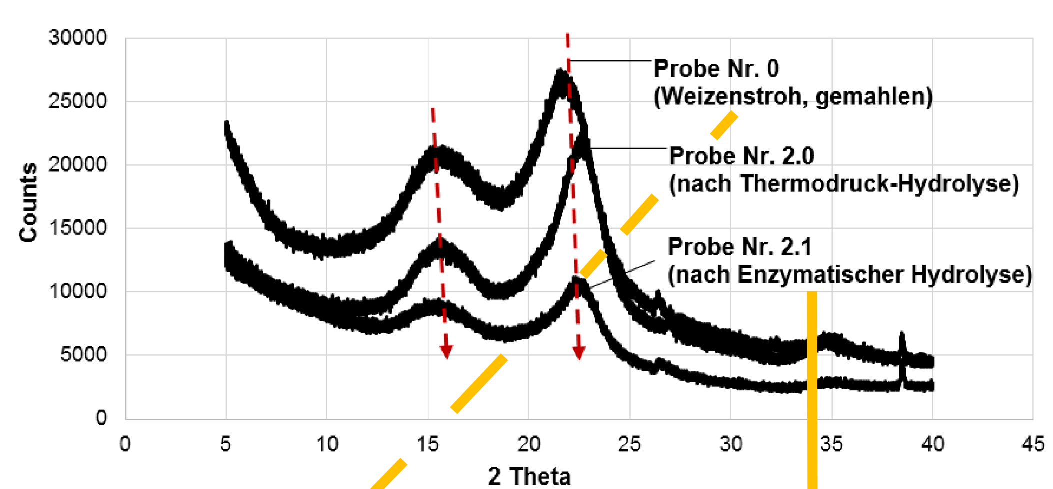
Fiber - fiber fusion in lignin based carbon fiber mats



Electrode exhibits a complex and porous structure.

3. XRD Analysis

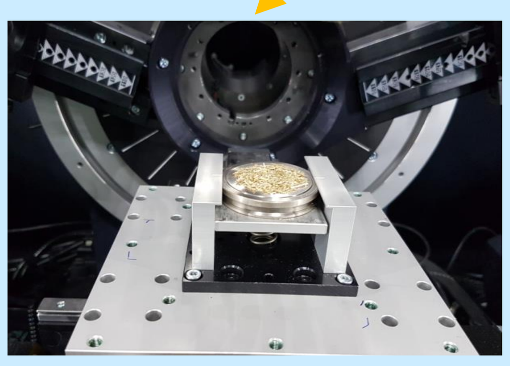
Source: Dorner-Reisel. A.: Examination report XRD for wheat straw lignins of PFI e.V. Hochschule Schmalkalden. 31.08.2017

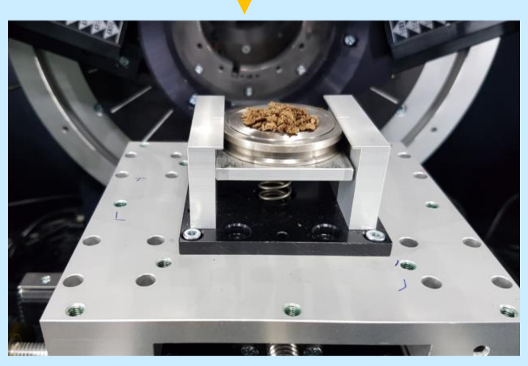


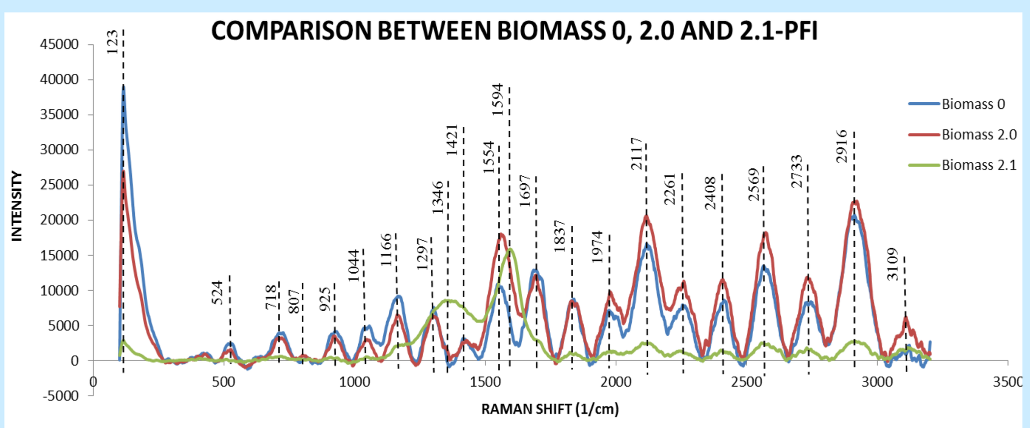
CrI value increased after undergo thermal pressure hydrolysis.
Reason: Removal of non-cellulosic amorphous polysaccharides and less ordered surface cellulose chains in the matrix.

CrI value decreases after enzymatic hydrolysis.
Reason: Breaking down of the cellulose molecular chain into sugar, which gradually decrease the degree of polymerization in cellulose.

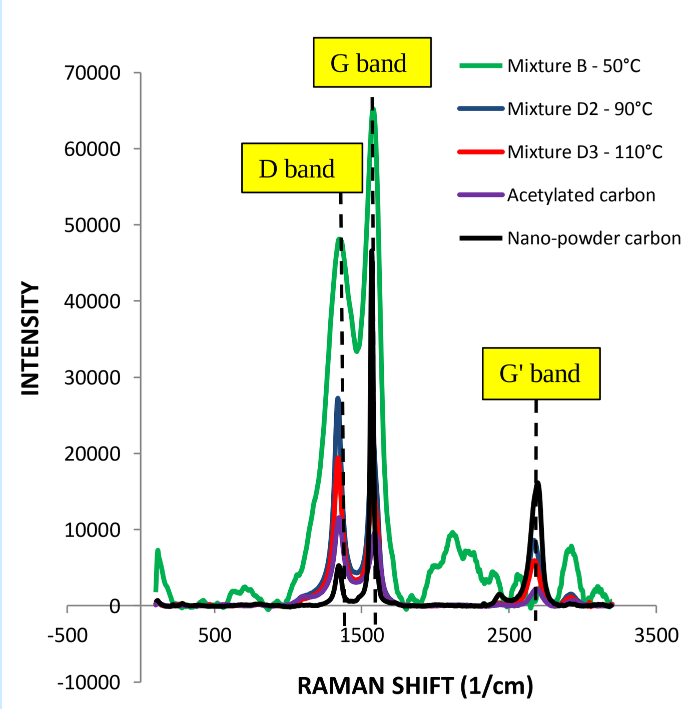
Shifting (~ 0.50° to 1.00°) towards higher 2θ
Reason: Crystals dilation.





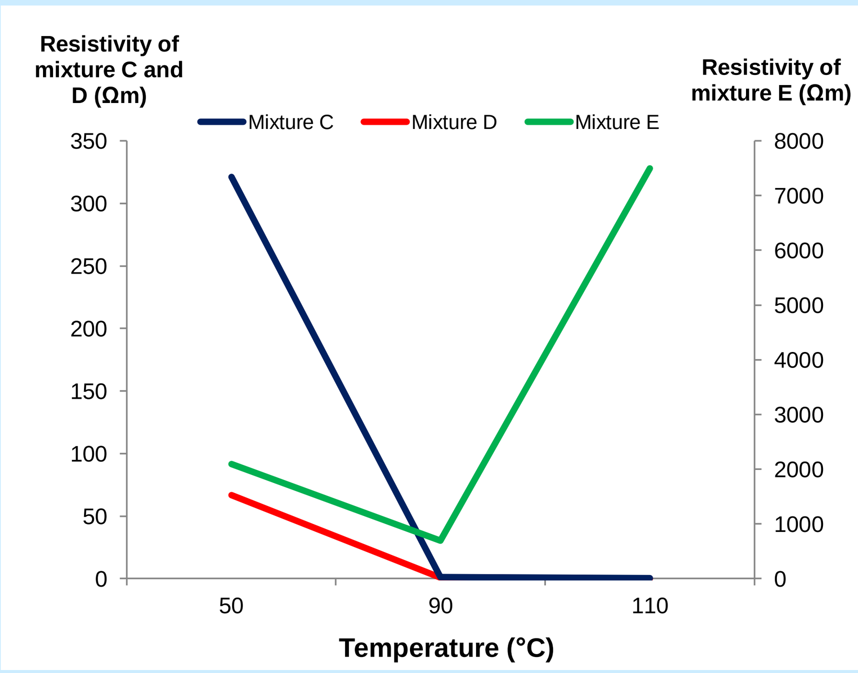


4. Raman Analysis



Comparison between the electrodes, that use acetylene carbon black as active material.
As temperature gets higher, the intensity gets lower.
Reason :
- Dispersing of graphene by NMP and Acetone.
- The bundles formed were more loosely bundled at high temperature.
- Reduction in the degree of intermolecular association occuring within the lignin.

5. Resistivity of electrodes



Mixture E (Untreated carbon from 600°C pyrolysis as active material) has highest resistance.
Reason :
- Low crystallinity of the 600°C pyrolysis
- High percentage of defects on the graphene surfaces
- Low contact between the carbon particles

Resistance of mixture C, which contain lignin and solvent, decreases as temperature increases.
Reason :
- Reducing of the glass transition temperature, T_g. Lignin are converted into a rubber-like state and it is more elastic

References

i. Hanny F. Sangian, Arief Widjaja: Effect of Pre-treatment Method on Structural Changes of Coconut Coir Dust. In: Sangian et al. / BioResources 12(4) (2017) 8030-8046.
ii. Ludovic Dumée, Kallista Sears, Jürg Schütz, Niall Finn, Mikel Duke, Stephen Gray: Influence of the Sonication Temperature on the Debundling Kinetics of Carbon Nanotubes in Propan-2-ol. In: Nanomaterials (Basel) 3(1) (2013) 70–85.
iii. Nada AMA, Yousef HA, El-Gohary S.: Thermal degradation of hydrolyzed and oxidized lignins. In: J. Therm Anal Calorim. 68(1) (2002) 265-273.

Acknowledgement

The project BUNT „Biogene Hochleistungskarbone", no. 2015 - 0012 is financed by the Thuringia Ministry TMWWDG. The authors acknowledge the support thankfully.