Carbon nanoparticles from local biomass for tribological applications First results

Yoan Debaud, T. Cesaire, P. Thomas, Y. Bercion

Carbon microspheres from local biomass for tribological applications. First results

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Summary

Friction and wear phenomena are the main causes of the decrease in performances and durability of mechanical systems. Manufacturing techniques for metal parts must meet the growing economic demands of the market, such as improved material durability or reduced maintenance costs and energy consumption. The use of tribology is essential and constitutes an important economic issue.
Pure lubricating bases (mineral or synthetic oil) cannot provide all protective functions, so that additives are added to improve their reducing properties of friction and wear. New lubrication strategies use dispersed colloidal particles in lubricants. The approach is to supply the sliding contact with solid particles, which can instantly form the tribological film. This study focuses on the development of new friction reducing additives derived from Guadeloupe local biomass.

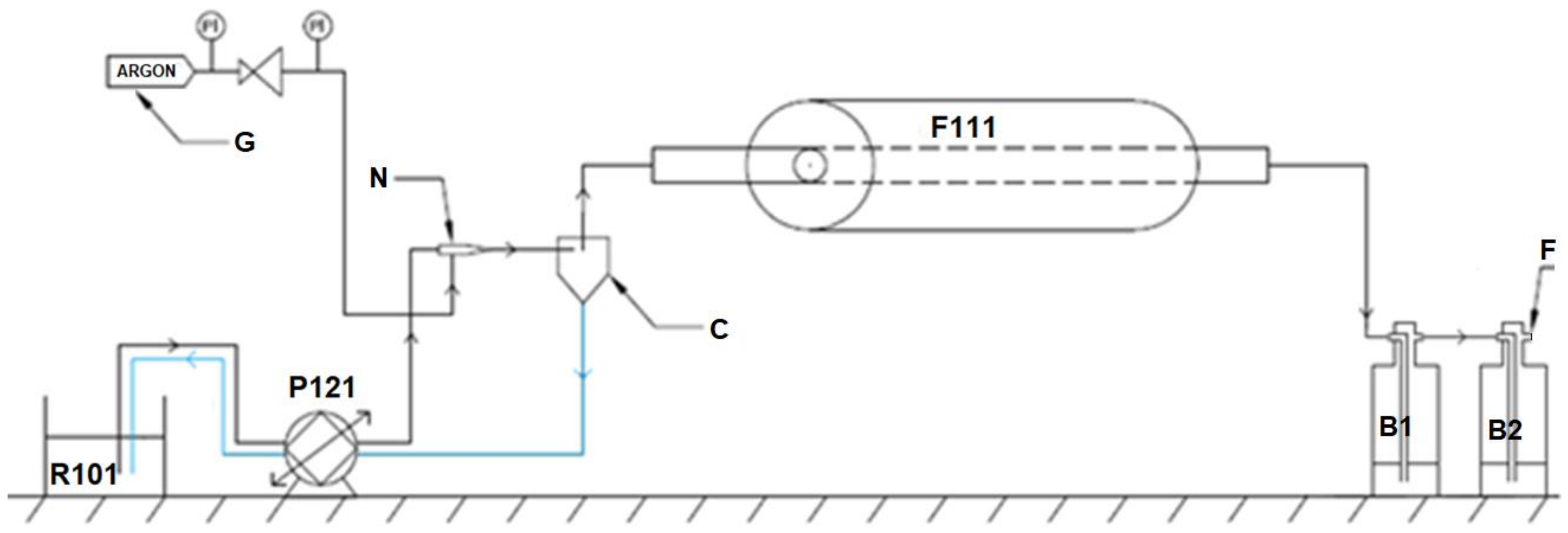
Materials

Starting material : sugarcane from Guadeloupe (sugarcane crystals length: 0,1 mm to 2 mm) + porogen agent (sodium bicarbonate)

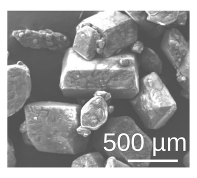

Cane plantation in Guadeloupe


Sugarcane

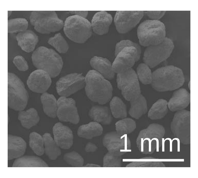

Sodium bicarbonate



Spray pyrolysis[1] : laboratory set up

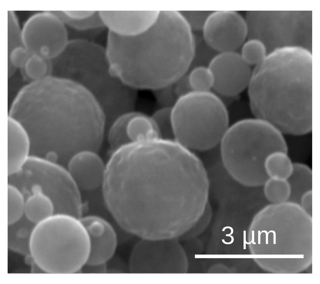


Sugarcane



$NaHCO_3$

R101: Sucrose solution* C: Cyclonic chamber
P121: Peristaltic pump F111: Tubular furnace
N: Nebulizer B1,B2: Water bubblers
G: Gas F: Filter

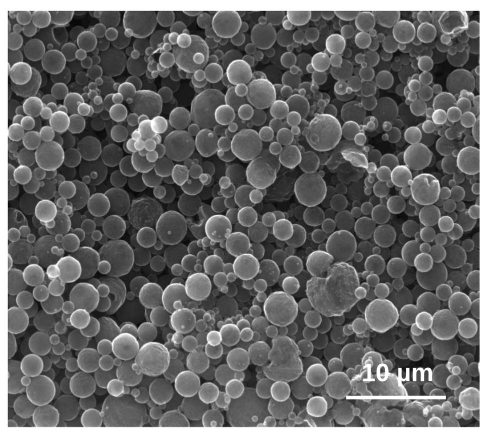


Carbon microspheres

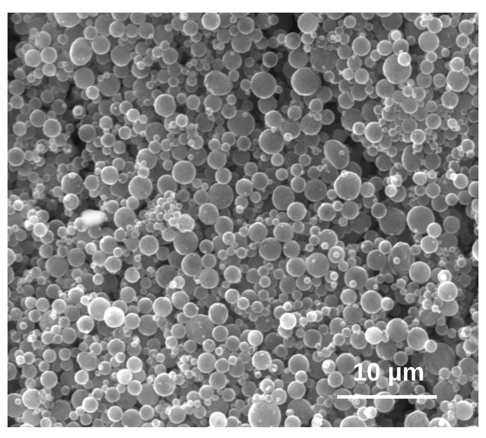
*Sucrose solution: 0,5 mol/L $C_{12}H_{22}O_{11}$ + 1,0 mol/L $NaHCO_3$ in distilled water

SEM and STEM investigations

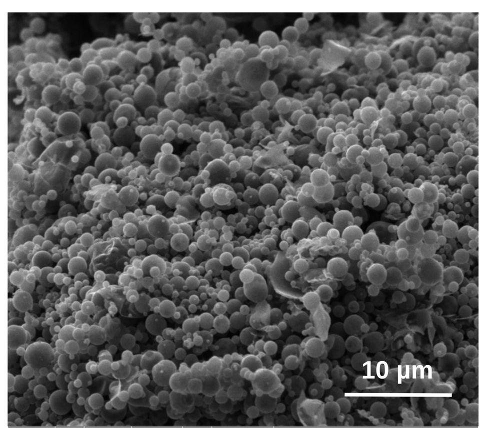
A preliminary work consisted in varying the pyrolysis parameters and observe the products with scanning electron microscopy. We have first seen that by increasing the argon pressure between 1 bar and 3 bar, we get more spherical particles at high pressure.



800 °C - 20 min - B1

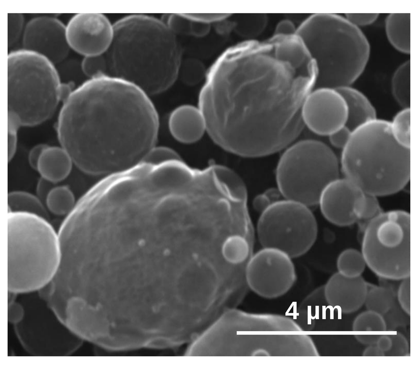


800 °C - 20 min - B2

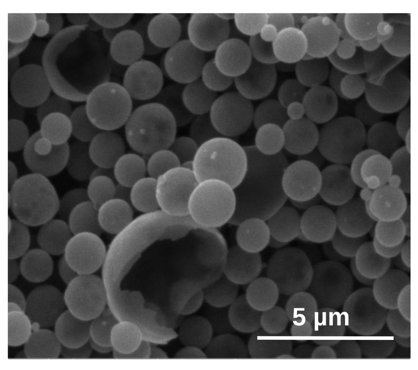


800 °C - 90 min - B2

- Comparing type of bubbler, smaller particles, which are also more volatile, reach the bubbler 2 more easily
- Comparing duration of pyrolysis, particles are more agglomerated for the longest synthesis times



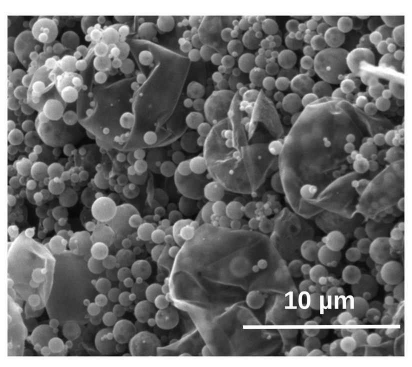
800 °C - 20 min



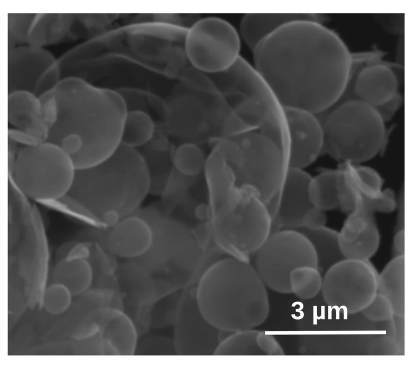
800 °C - 90 min

- Some of the biggest particles are aggregates of smaller particles
- Different shapes (spheres, films, envelopes)
- Different surface aspects (more or less smooth)

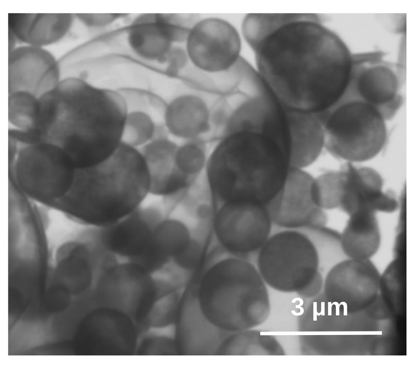
- Visually in the bubblers, there are less particles collected at 1 000°C than at 800°C



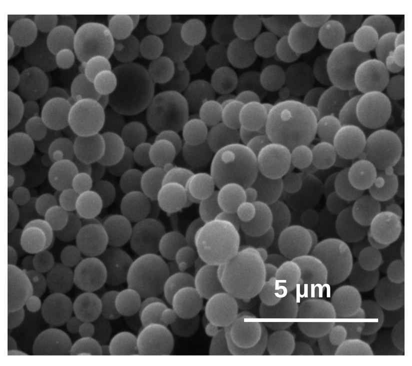
1 000 °C - 90 min



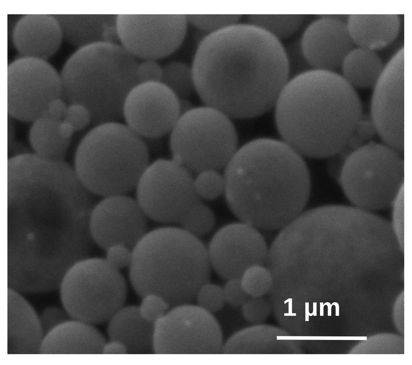
800 °C - 20 min - SEM



800 °C - 20 min - STEM



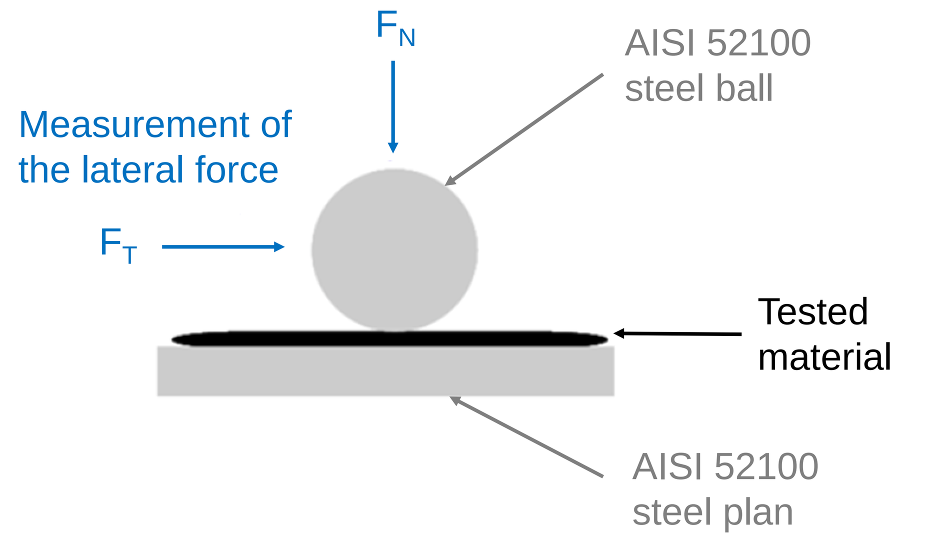
800 °C - 90 min - Filter



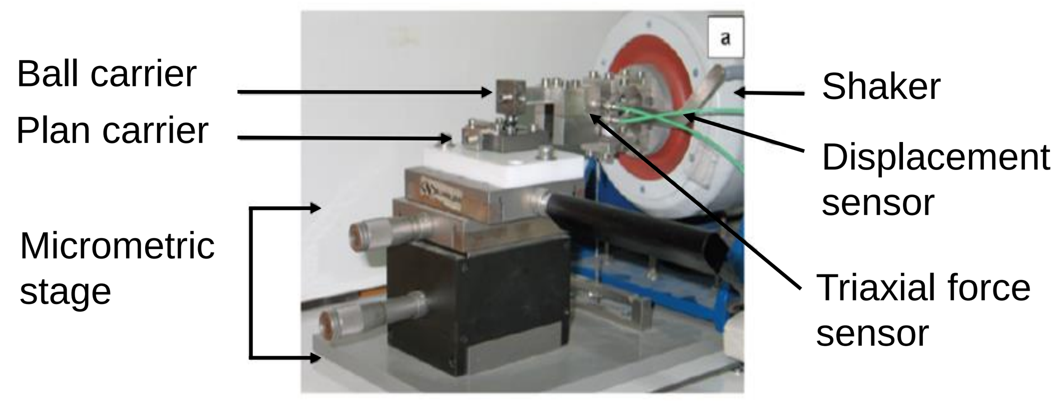
800 °C - 90 min - Filter

- To avoid overpressure, a filter is placed at the exit of bubbler 2
- Particles collected on the filter seem smaller than in the bubblers
- There are more particles on the filter for pyrolysis at 800 °C than at 1 000°C

Determination of the tribological parameters



Experimental conditions**:**
- Normal load : 10 N
- Contact area : 140 µm
- Mean contact pressure : 0,8 GPa
- Sliding speed : 4 mm/s

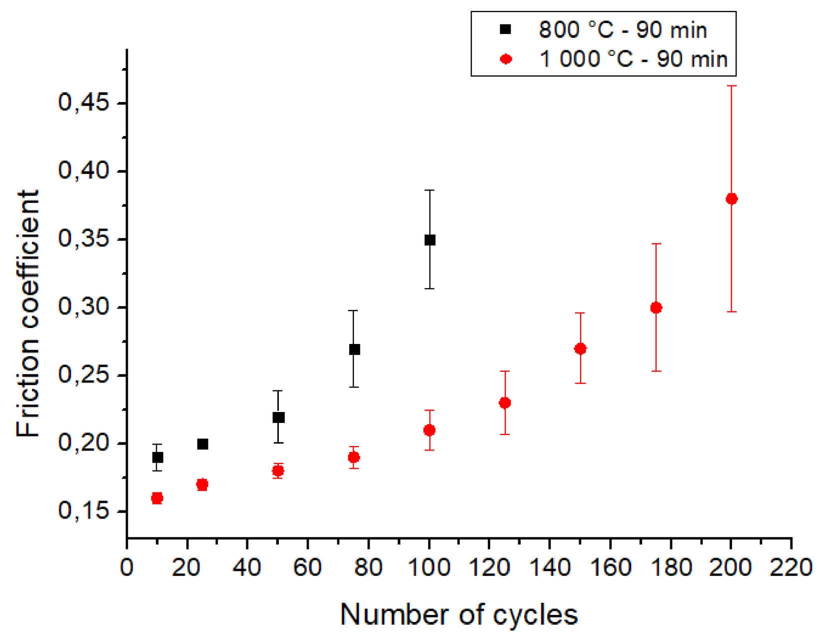


Tribometer, GTSI

Friction coefficient

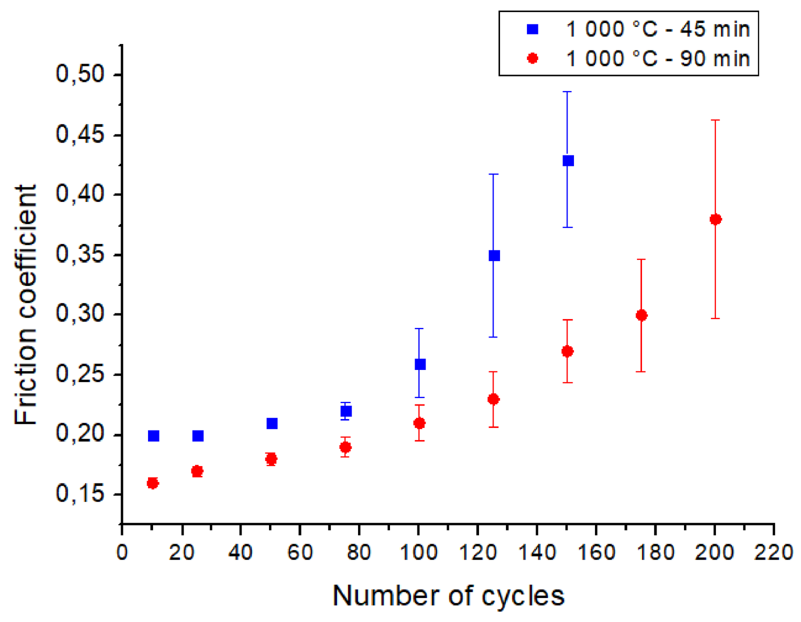
$$\mu = \frac{\text{Lateral force } F_T}{\text{Normal Load } F_N}$$

Tribological properties, first results



- By increasing the temperature of the tubular furnace from 800 °C to 1 000 °C for a pyrolysis duration of 90 min, the microspheres tribological properties are improved. The friction coefficient is lower for particles heated at 1 000C° than at 800 °C

- For a tubular furnace heated at 1 000 °C, the microspheres are more efficient as lubricants with a longer pyrolysis time



- In both cases, the tribofilm resists better for the particles pyrolysed at the highest temperature (1 000°C) and for the longest synthesis time (90 min)

Discussion and perspectives

The first investigations have shown some of the effects of the pyrolysis parameters on the surface aspect of microspheres. For example we get more spherical particles at high pressure (3 bar). Then, the higher the temperature is, the less visible the particles are in the bubblers, it seems that they are smaller and therefore more volatile.
Moreover, we observed different shapes around the microspheres with electron microscopy, like envelopes and films, suggesting that some of the biggest particles are aggregates of smaller particles, which is confirmed when we use scanning transmission electron microscopy.
At this moment, we did not had the possibility to measure the particles size. Only few measurements were made with the SEM software.
More analyses will be carried out to characterize the physico-chemical properties of our carbon microspheres, such as NMR spectroscopy, laser particle size, FTIR, specific surface area.
The particles have a lubricant effect, particularly those heated at 1 000 °C during 90 min. Furthermore, the tribological properties of the microspheres could be improved with fluorination. Indeed, this functionalization step has proved itself on other type of materials, like carbon nanodiscs and nanocones, carbon black or carbon nanofibers.[2,3]

[1] M. E. Fortunato, M. Rost-Abadi, K. Suslick - Nanostructured Carbons Prepared by Ultrasonic Spray Pyrolysis - Chem. Mater. 2010
[2] P. Thomas, K. Delbé, D. Himmel, J.L.Mansot, F. Cadoré, K. Guérin, M. Dubois, C. Delabarre, A. Hamwi: Tribological properties of low-temperature graphite fluorides. Influence of the structure on the lubricating performances. J. Phys. Chem. Solids 67, 1095–1099 (2006).
[3] P. Thomas, D. Himmel, J. L. Mansot, W. Zhang, M. Dubois, K. Guérin, A. Hamwi, Friction Properties of Fluorinated Carbon Nanodiscs and Nanocones, Tribol Lett (2011) 41:353–362

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