



Grenoble Green
Graphenofluid

GRAPHENE NANOPATELETS SUSPENSIONS





Research institute on geophysical and industrial fluid mechanics

Modeling and Experiments for Geophysics and Environment



Turbulence Modeling and Simulation



Renewable Energies, Hydraulic machinery and cavitation



Two-phase flows and Turbulence



LEGI :

- 4 Research teams;
- 70 Permanent members (Researchers, Academics, Technical & Administrative support);
- 60-65 PhD students;
- 10-15 Postdocs;
- 30-40 Interns and visitors.



Linksium – technology transfer and startup creation in Grenoble Alps

13



Programme d'Investissement d'Avenir

Linksium
57 M€ sur 10 ans



Cumulated figures since 2015
Status 30/04/21



191 PROJETS
technology transfer



346 patents
concerned



44 M€
investis

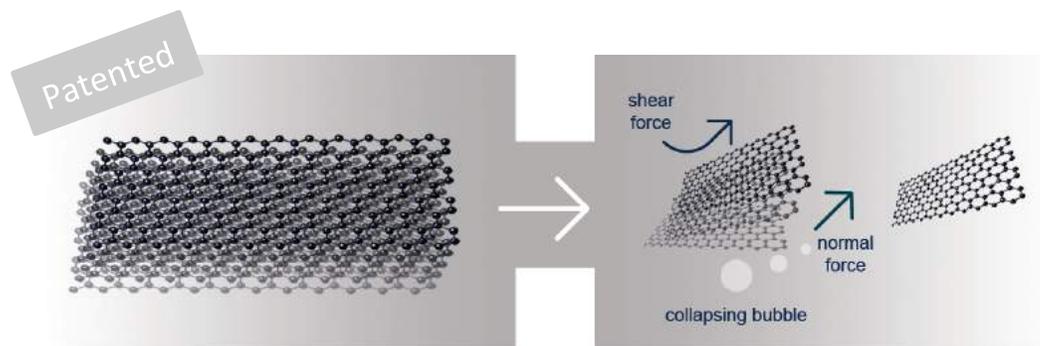


57 STARTUPS
created



503 PEOPLE
involved

→ Microfluidic production process



Liquid Phase Exfoliation

Separation of individual graphene layers by **hydrodynamic cavitation** with a microchannel on a chip

→ Graphene Nanoplatelets Suspension



Typical concentration
1.50 g/L

Graphene platelets thickness
<5 nm

Graphene platelets lateral size
150-200 nm

→ Fundamental Research

2009

Hydrodynamic cavitation
'on a chip'

2015 – 2018

Application to graphite
exfoliation

First installation

Production : 1 L/week

- PhD X. Qiu 2018
- Patent registered



→ Upscaling at labscale

2019 – 2020

Installing production
capacity at labscale
Production : 1 L/day
First application testing

R&D Engineering
Dr. S. Ponomareva

- Validation TRL 5
- Patent extended



→ Next steps

2021 – 2022

Tests for **applications**
(corrosion, lubrication,
electrophoresis, base
fluid)

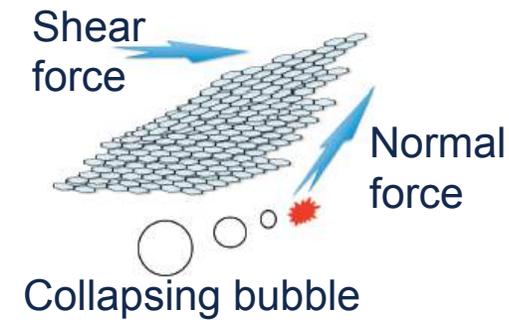
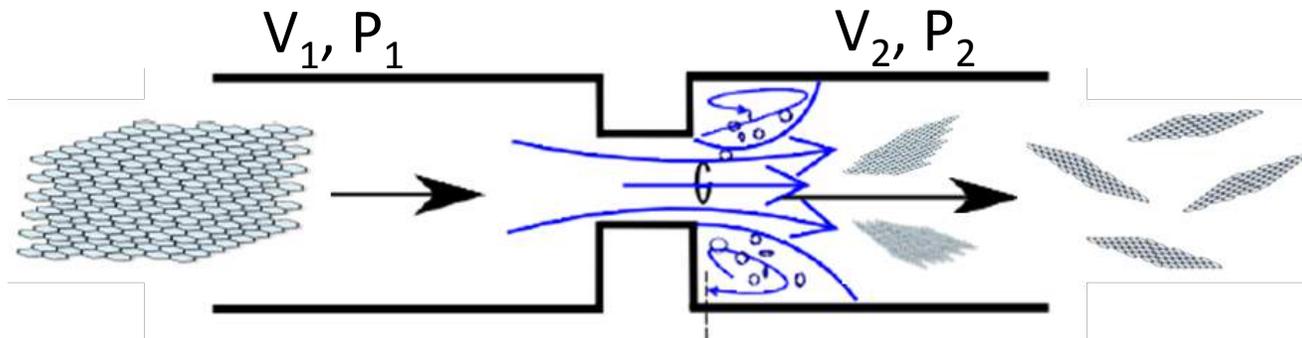
Business license

R&D activity (vacuum
filtration, conductive inks,
cooling liquids, green
solvent)

Dr. A. Mohanty



→ Graphene nanosheets are exfoliated from graphite particles by an innovative microfluidic process using *hydrodynamic cavitation* 'on a chip'

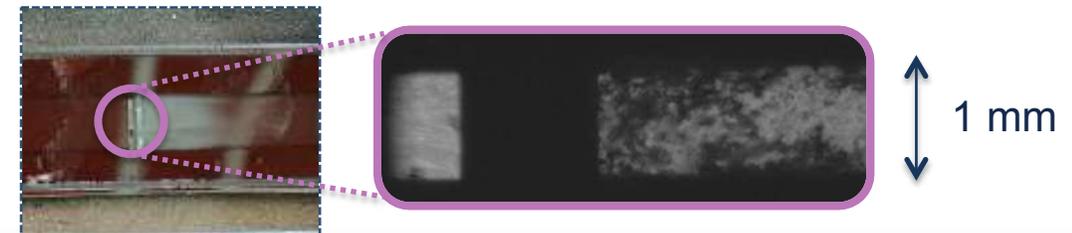


System on a chip

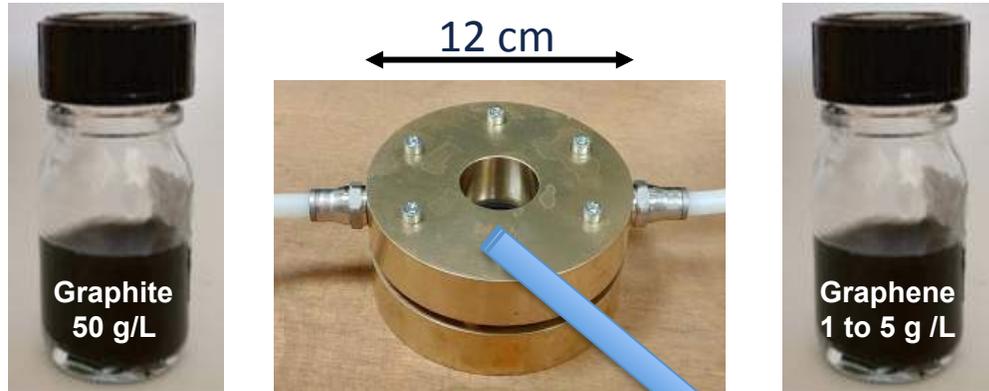


Prototype of the microfluidic system

Inside the system



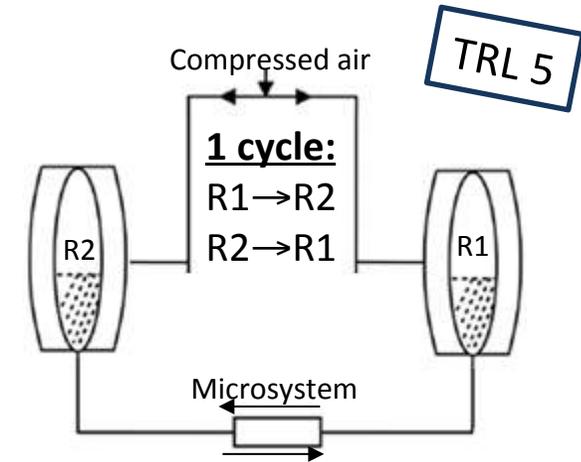
→ High Flow Rate Microsystem



- Integrated microfluidic system
- Exfoliation in water with surfactant
- 5 microchannels in parallel
- **3% nanoplatelets** exfoliation mass efficiency
- Flow Rate : **1 L per day**



→ Compact installation



- Production capacity: **5.5 g** per week
- Energy consumption: **2.2 kW.h** per week
- Working pressure: **<10 bar**
- Size of the **mobile** installation: **2 m³**

→ **GGG exfoliation offers very high quality graphene nanoplatelets in an aqueous suspension**



**Graphenofluid containing
SLG and MLG**

Typical concentration

from 1 g/L to 5 g/L

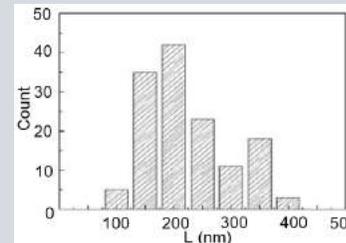
Graphene platelets thickness

$3 \text{ nm} < t < 10 \text{ nm}$

Graphene platelets lateral size

150 - 350 nm

Lateral size
distribution



80% of platelets
< 250 nm

Stability

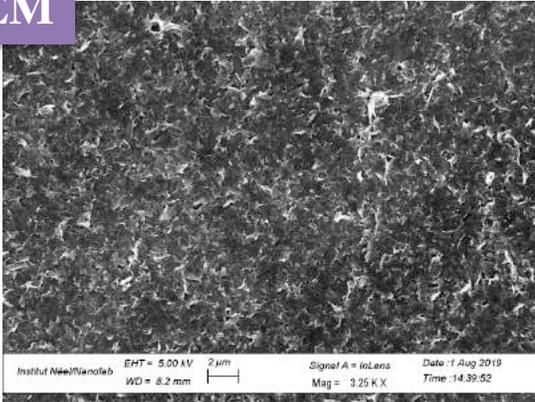
> 12 months without sedimentation

Solvents

Aqueous solution with surfactants;
Development with green solvents in
progress.

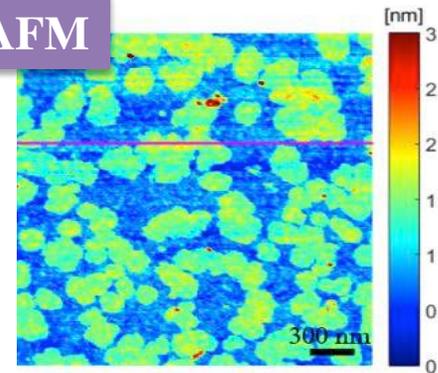
→ Characterisations at the lab proved the platelets to be nano-sized and single layer graphene

SEM



Lateral size distribution below 500 nm

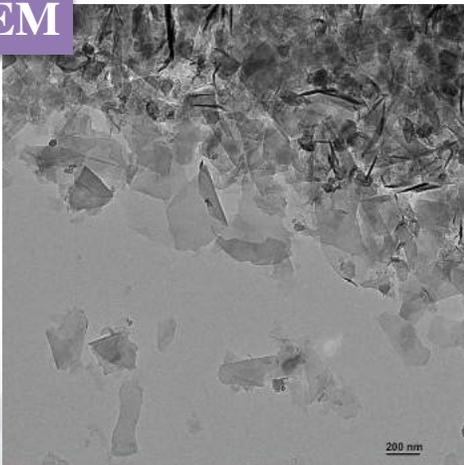
AFM



Nanoplatelets consist of less than 10 graphene layers

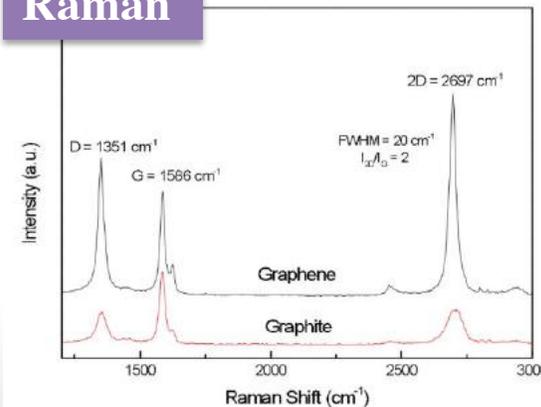
Particles thickness less than 3 nm

TEM



Significant decrease in particles lateral size, between 150 and 350 nm

Raman

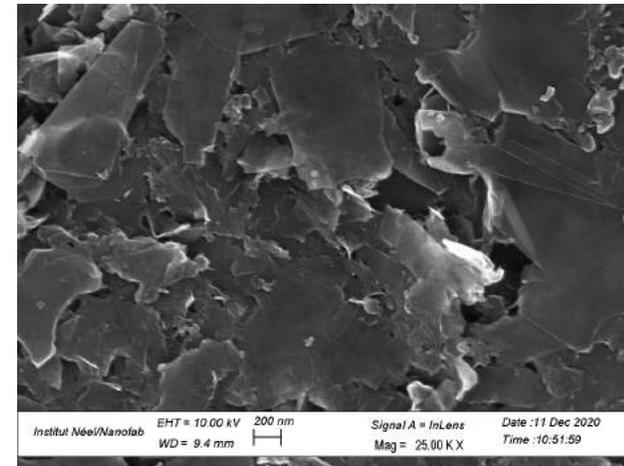
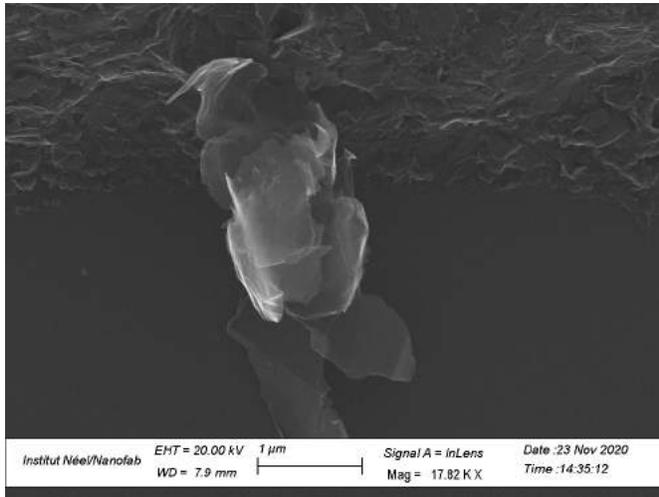


Presence of nanoplatelets with single layer graphene confirmed

→ **GGG : a booklet of snapshots**

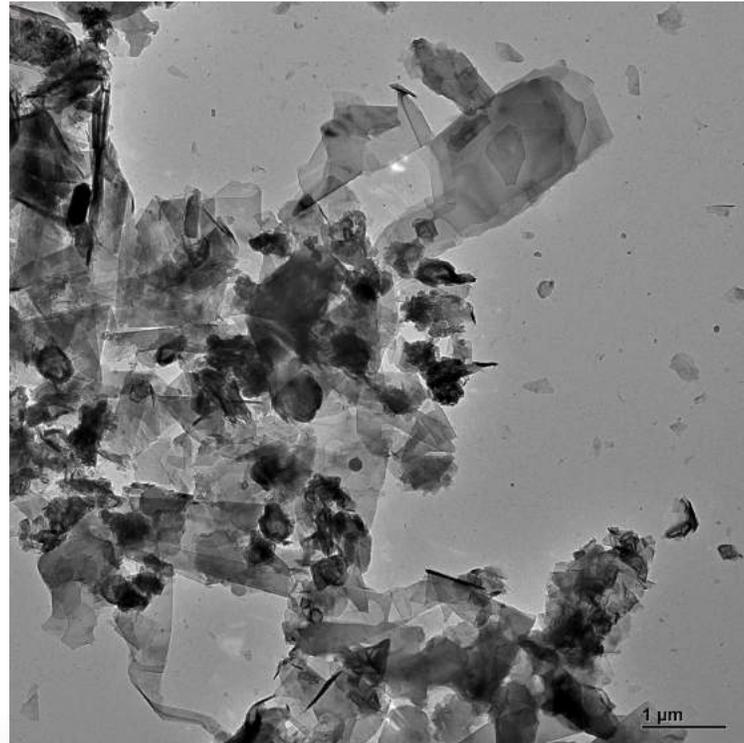
SEM

X 25000



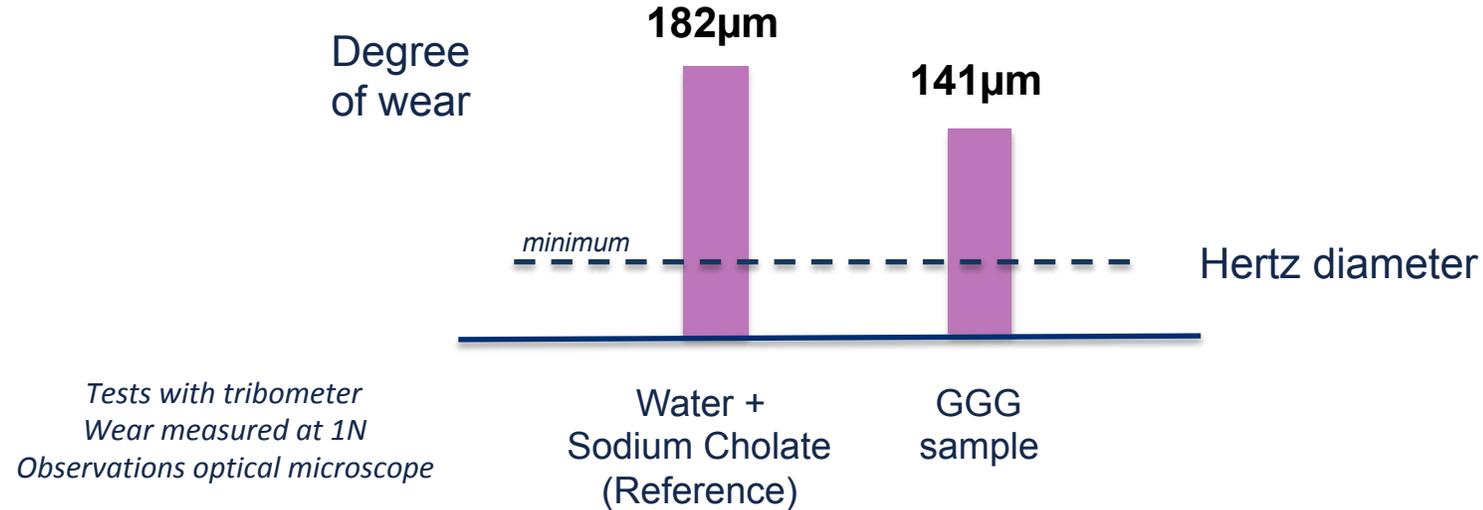
→ **GGG : a booklet of snapshots**

TEM



→ **20% wear reduction observed**

- GGG exhibits stable shear behaviour (F_{\tan} / F_{\parallel}) against water or aqueous suspensions
- Some GGG suspensions have exhibited a 20% decrease of the wear



decrease of wear has been confirmed from electrophoretic deposited thin films, submitted to 600N (\varnothing ball = 5 mm)

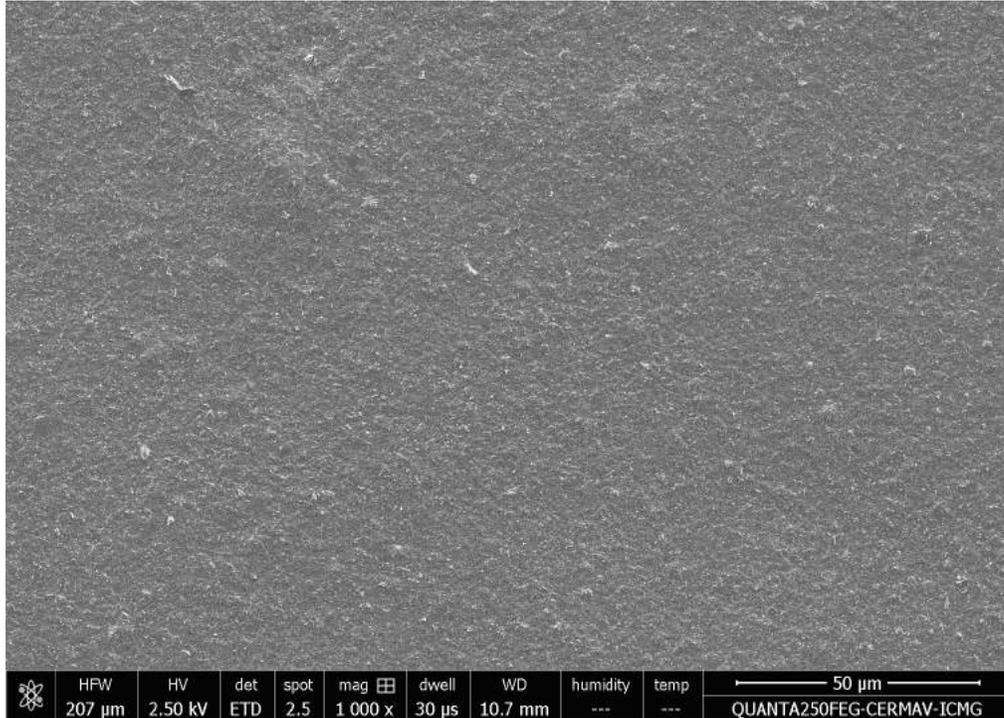
→ No thermal conductivity enhancement observed

- It is well known that the thermal conductivity of a nanofluid is proportionnal to the solid volume concentration Φ
- Graphenofluids with a few g/L solid concentration correspond to $\Phi \approx 0.2 \%$
- The expected relative increase of the thermal conductivity of a graphenofluid is negligible : $\Delta k/k_0 \approx 0.6 \%$
- As expected, the thermal conductivity measurements (hot wire) of GGG was of the same order of magnitude as the thermal conductivity of the base fluid : $0.610 \pm 0.015 \text{ W/m/K}$.

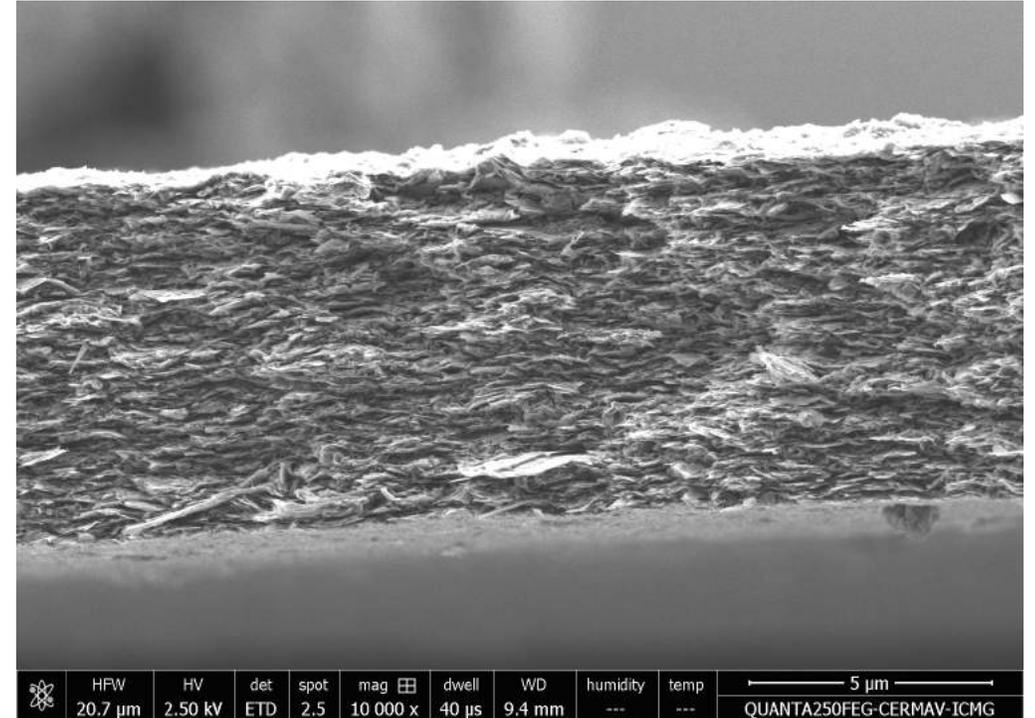


scratch tests in progress

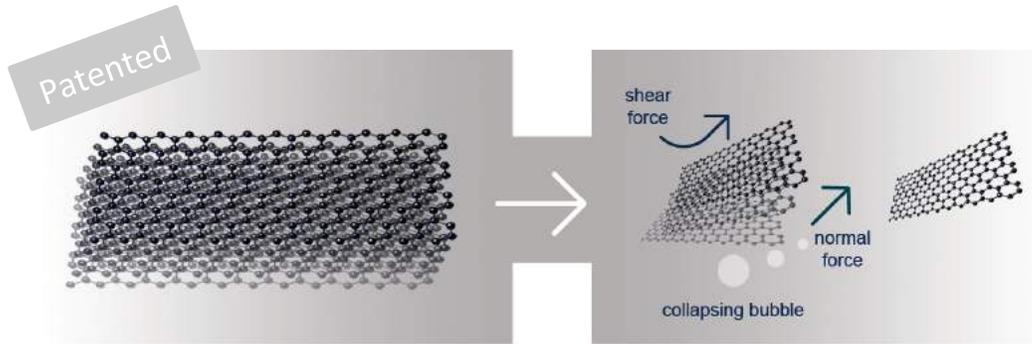
solid thin films from dilute dispersions



Sheet electrical resistance < 10 Ω/sq



→ Microfluidic production process



- Well-defined and **reproducible procedure** confirmed by independent tests;
- Integration of **programmable** logic controller for optimization of exfoliation process;
- Small and **mobile** installation;
- **Low energy** consumption;
- **No hazardous** substances.

→ Graphene Nanoplatelets Suspension



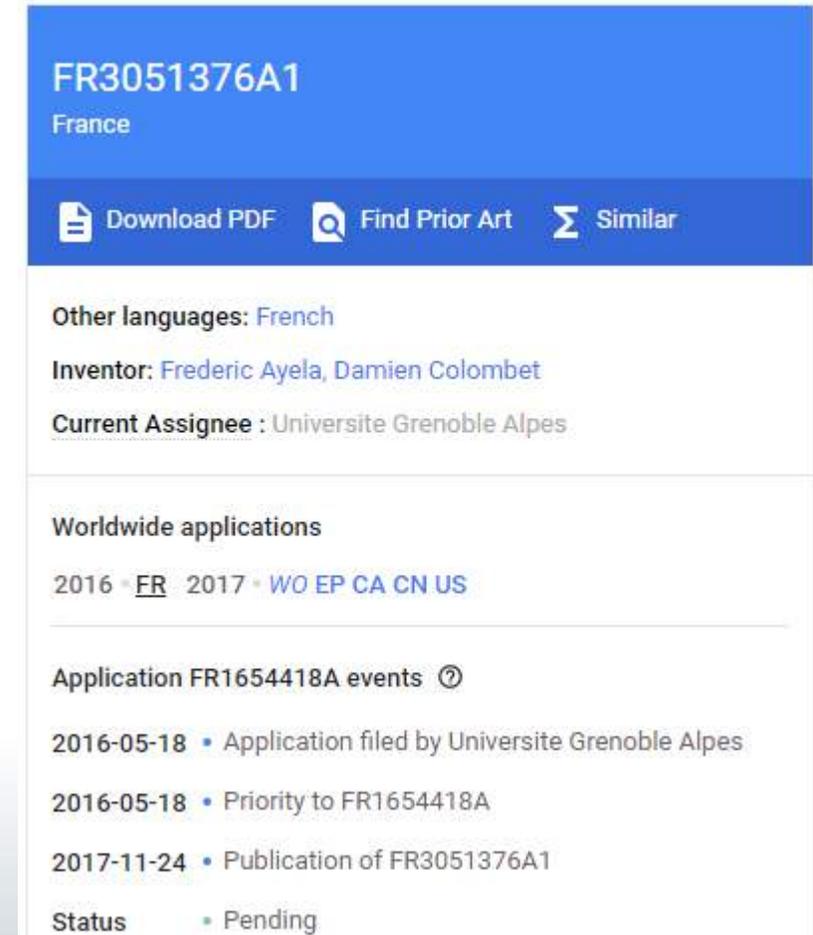
- **Reproducible nanosized platelets** inside the exfoliated and centrifuged solution;
- Confirmed by **strict characterization** and independent tests.

→ A patented process

- The GGG process is a patented solution
- Covering the method of exfoliating the particles
- The research lab owns specific know-how associated with the production process

- Extensions are valid in Europe, USA, Canada and China

→ Available for technology transfer



FR3051376A1
France

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Other languages: [French](#)

Inventor: [Frederic Ayela, Damien Colombet](#)

Current Assignee : [Universite Grenoble Alpes](#)

Worldwide applications

2016 - [FR](#) 2017 - [WO EP CA CN US](#)

Application FR1654418A events 

2016-05-18 • Application filed by Universite Grenoble Alpes

2016-05-18 • Priority to FR1654418A

2017-11-24 • Publication of FR3051376A1

Status • Pending

→ Looking for industrial partners for application testing

- The proof of concept has enabled to validate the **production of graphene nanosheets** in a liquid solution (graphenofluid).
- The scale-up of the microfluidic system has been performed in the laboratory.
- Current exfoliation capacity at high flow rate microfluidic system is **5.5 g of graphene per week**.
- Looking for an **industrial partner** to carry out proof of concept for a first application (lubrication, coating, etc.).
- Looking for an industrial partner for **technology transfer** of the graphene production.



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