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# Graphene-based dispersions for touch sensor fabrication

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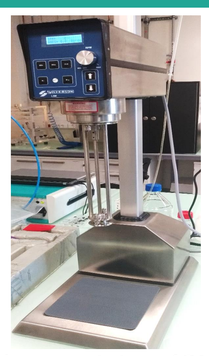
## Introduction

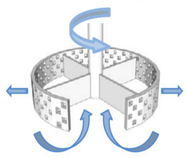
Graphene-based and two-dimensional materials are approaching the industrial production stage with a sustained pace [1]. These materials can be processed in solution and deposited by several techniques to make components for many technologies, such as flexible electronics [2, 3]. However, graphene-based dispersions are currently rather expensive and face some issues, such as a limited compatibility with substrates or the need for post-processing treatments. Here, we propose an approach to produce graphene-based dispersions with high yield and control on the material properties. Our approach is based on the use of a combination of two solution-processing techniques (i.e., shear mixing and ultra-sonication) for the efficient exfoliation of natural graphite into graphene flakes.

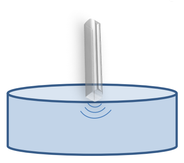
## Methods

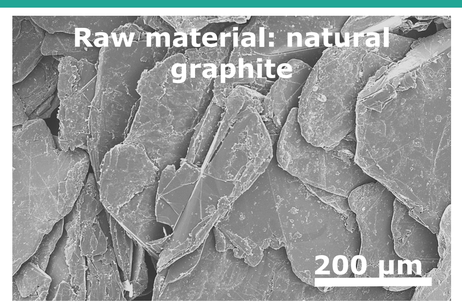


Shear mixing (SM)

Ultrasonication (US)





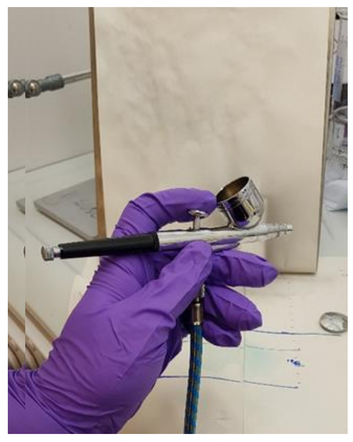



Liquid phase exfoliation (LPE) was used to exfoliate graphite and leave the graphene flakes in suspension.
LPE can be done by several methods, *e.g.*, ultrasonication, shear mixing, and ball milling.

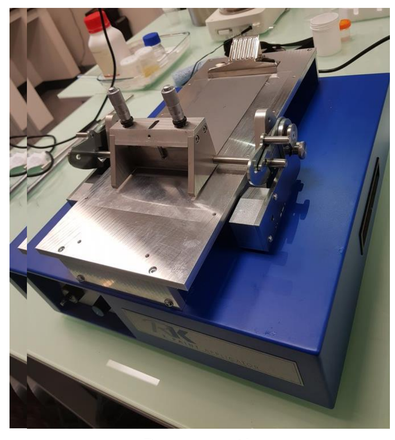
## LPE via ultrasonication and shear mixing

The dispersions were deposited by several techniques (*i.e.*, spray coating, inkjet and screen-printing) on various substrates to fabricate films with desired levels of transparency and conductivity.


Graphene dispersion



Spray coating



Blade coating

Size-selected graphene flakes were used to make inks and pastes with suitable fluidic properties, to be deposited by spray and blade coating.

By using the two LPE processes we produced highly concentrated graphene dispersions that were further optimized to prepare:

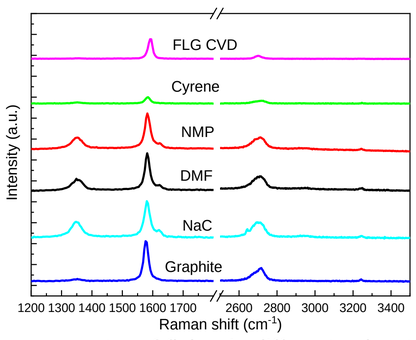
- Highly conductive paste - The viscosity was adjusted with binders, such as CMC sodium salt.
- Conductive ink - PEDOT:PSS was added as a stabilizer agent, overall improving uniformity, adhesion and electrical conductivity of the sprayed films.

## Resuls: grafene-based dispersions and devices

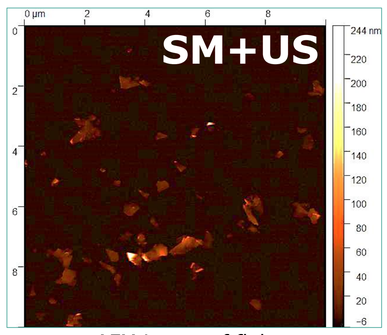
A combination of ultrasonication (US) and shear-mixing (SM) with tuned parameters allowed a high degree of control on the lateral size and thickness of the graphene flakes, and on the concentration of the dispersions.

| Process | Conditions | Concentration (g/ L) | | Lateral size (nm) | |
|---|---|---|---|---|---|
| Ultrasonication | 11 h | 0.29 | - | <1000 | - |
| Shear mixing | 10 h | 0.44 | 0.49 | <1000 | <25 |
| SM + US | 10 h + 6h | 2 | 2.77 | <500 | <20 |
| Solvent: | | NMP | Cyrene | NMP | Cyrene |

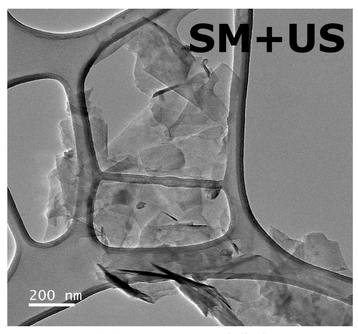
The graphene dispersions in different solvents were characterized by Raman spectroscopy, atomic force and transmission electron microscopy.



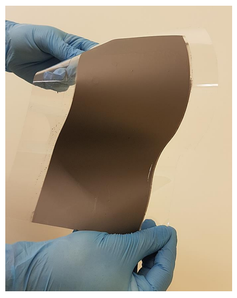

Raman spectra of flakes in different solvents



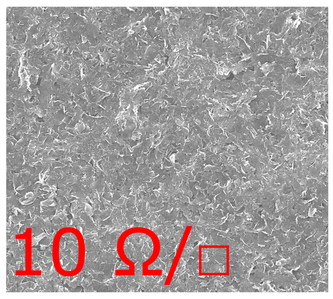

AFM image of flakes




TEM image of flakes



Graphene on flexible polypropylene film



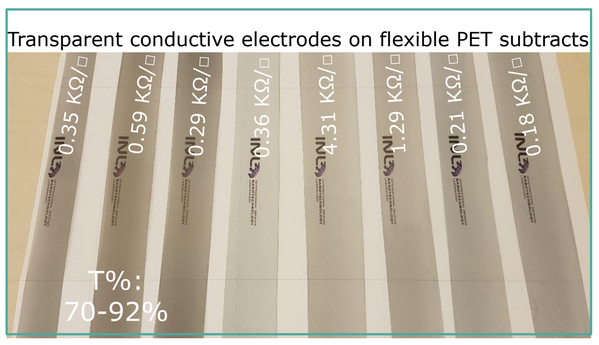

SEM image of the graphene film

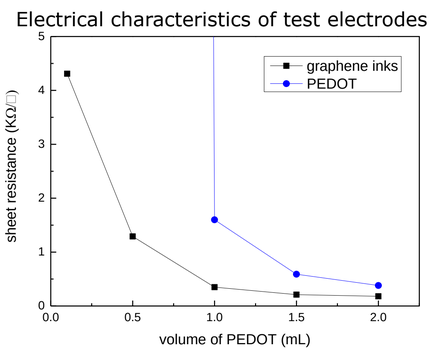
We deposited a highly conductive electrode on flexible polypropylene by blade coating the graphene-based paste. The device serves for electromagnetic interference shielding.

Our paste demonstrated:

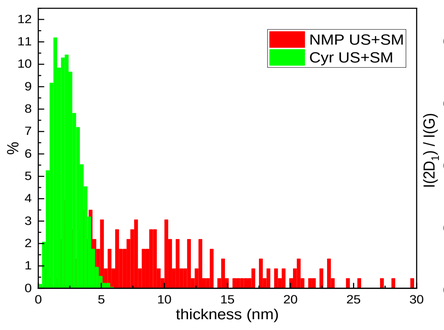
- High adhesion to the substrate
- Possibility to use in screen-printing

We prepared graphene-based electrodes with various characteristics by spray coating.

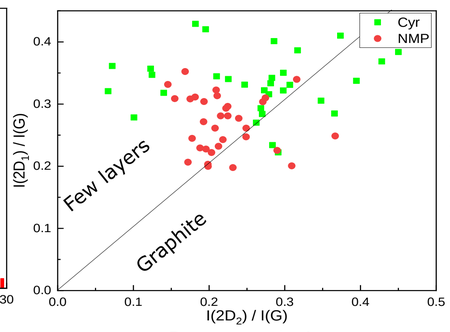


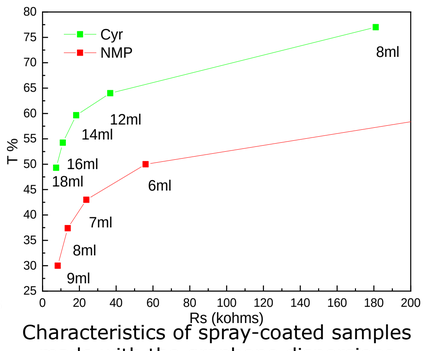

Finally, we fabricated a 10x10 $cm^2$ graphene-based capacitive touch sensor by spray coating.



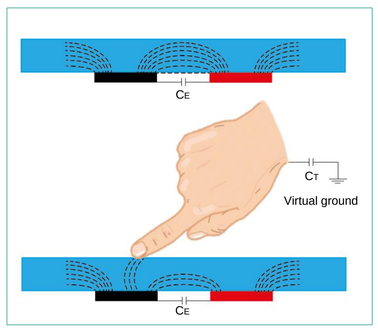

Thickness histogram by AFM



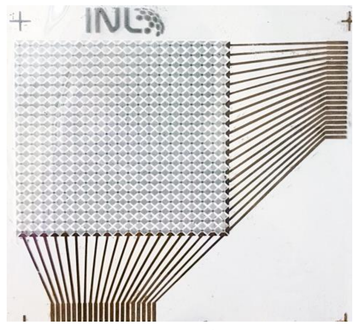

Raman analysis



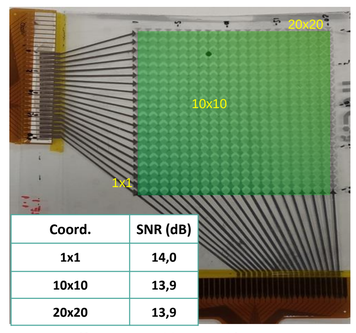

Characteristics of spray-coated samples made with the graphene dispersions




Working principle



Graphene touch sensor




| Coord. | SNR (dB) |
|---|---|
| 1x1 | 14,0 |
| 10x10 | 13,9 |
| 20x20 | 13,9 |

Sensor attenuation map

- We exploited different processes and solvents (NMP and cyrene) to obtain high yield and tune the size and thickness of the graphene flakes.

The sensor showed high signal-to-noise ratio and featured multi touch detection.

## Conclusion

- LPE dispersions of graphene flakes with controlled morphology can be used to prepare functional inks and pastes
- A highly concentrated ink in cyrene (green solvent) was made by a combination of ultrasonication and shear mixing
- Our approach allows large-area coverage and an extensive compatibility with several flexible substrates (such as polymers)
- Our graphene-based touch sensor showed a suitable ratio of transmittance/conductivity, and a constant low attenuation level

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## Contacts

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## References

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[3] A. Capasso et al., "Ink-jet printing of graphene for flexible electronics: An environmentally-friendly approach". Solid State Communications. 224 (2015) 53-63.