Optimization of Optoelectronic Properties of Electrochemically Exfoliated Graphene by Cascade Centrifugation

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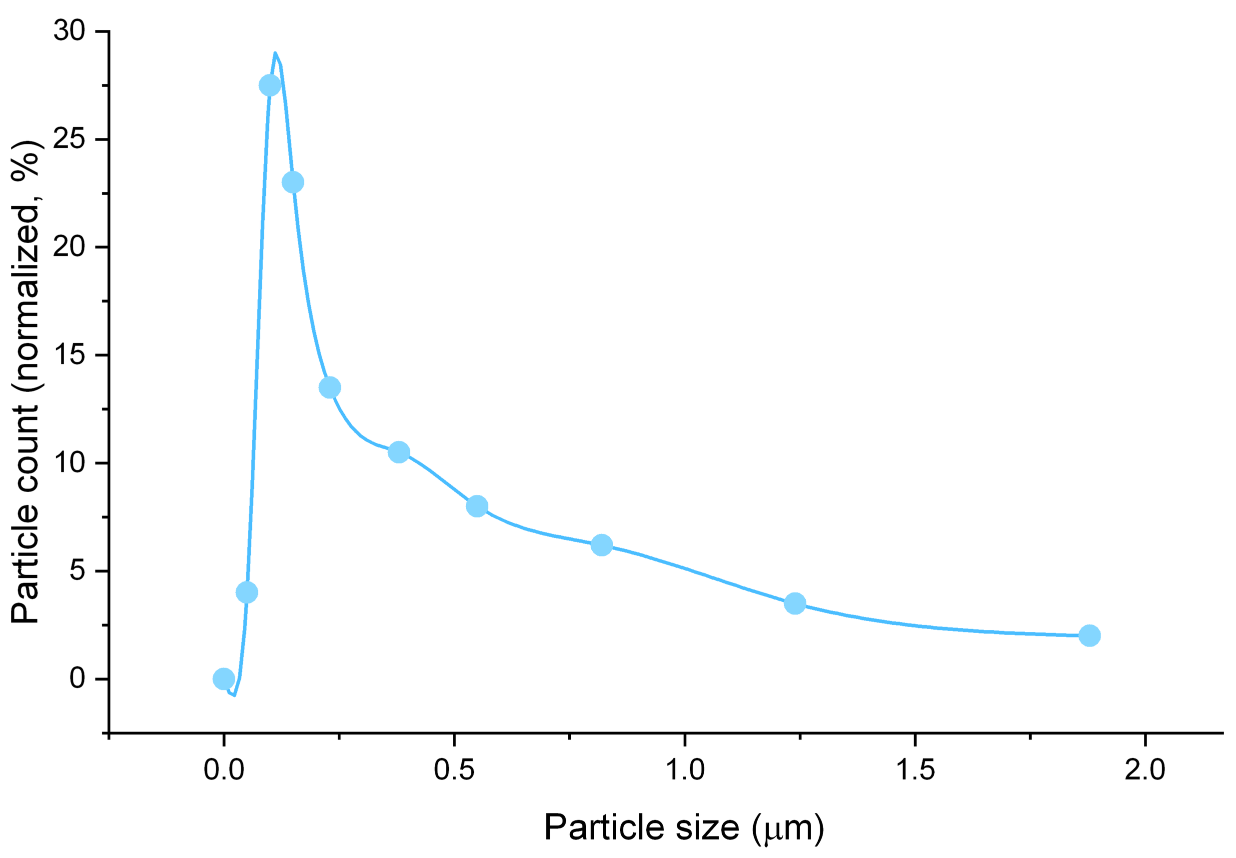
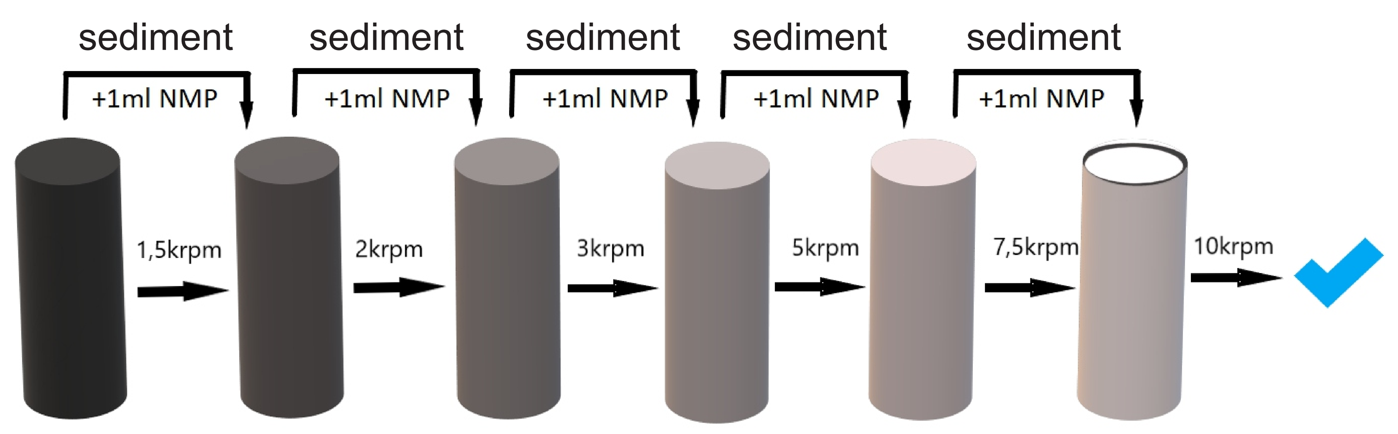
ABSTRACT

Graphene dispersions produced by the process of electrochemical exfoliation were used for preparing multi-layered graphene films for transparent conductor applications. In order to achieve homogeneous films with defined particle sizes from a solution with a wide distribution of initial particle sizes, cascade centrifugation was used. The particle size was selected by low-speed centrifugation, with rate values: 2, 3, 3.5, 4 and 5 krpm. After each step of centrifugation, supernatants were used as initial solutions for the following steps, while the sediments were collected and redispersed by using N-methyl-2-pyrrolidone as a solvent [1]. To study optical properties of produced graphene films, the dispersions were deposited onto glass substrates and UV/VIS spectroscopy was performed. Films with the best optical properties were selected and the same dispersions were deposited onto substrates with electrodes, to examine electronic properties of the films. Films had an optical transparency of ~80% in the visible part of the spectrum, and initial resistances between $8{\cdot}10^3$ and $1.6{\cdot}10^7$ Ohms.

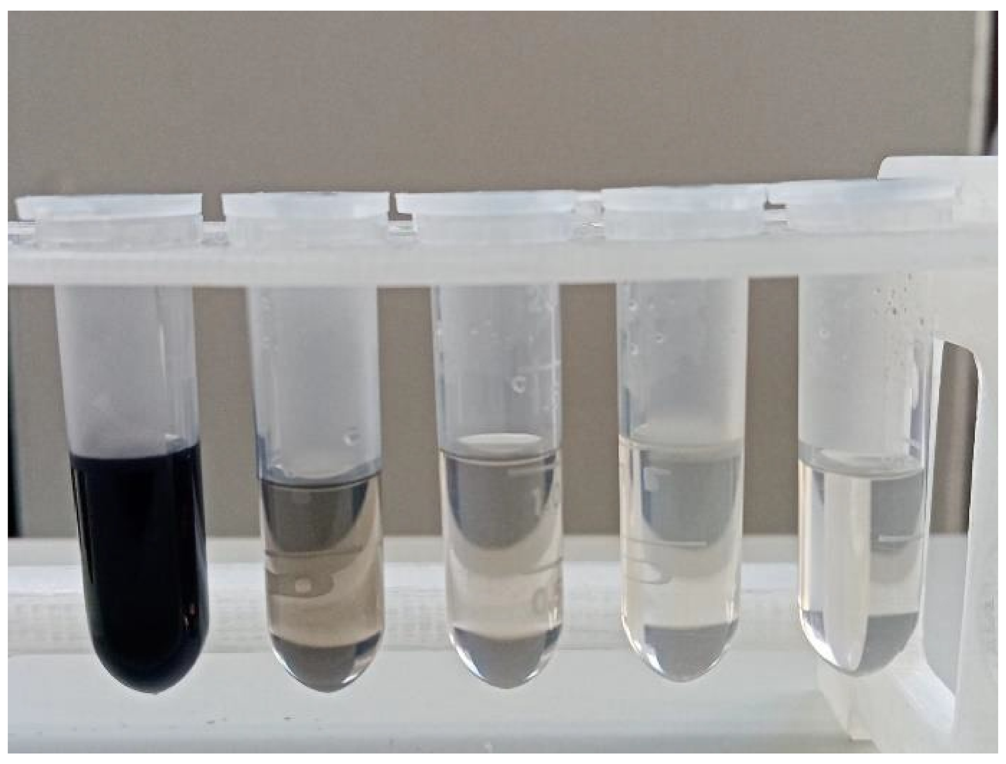
RESULTS

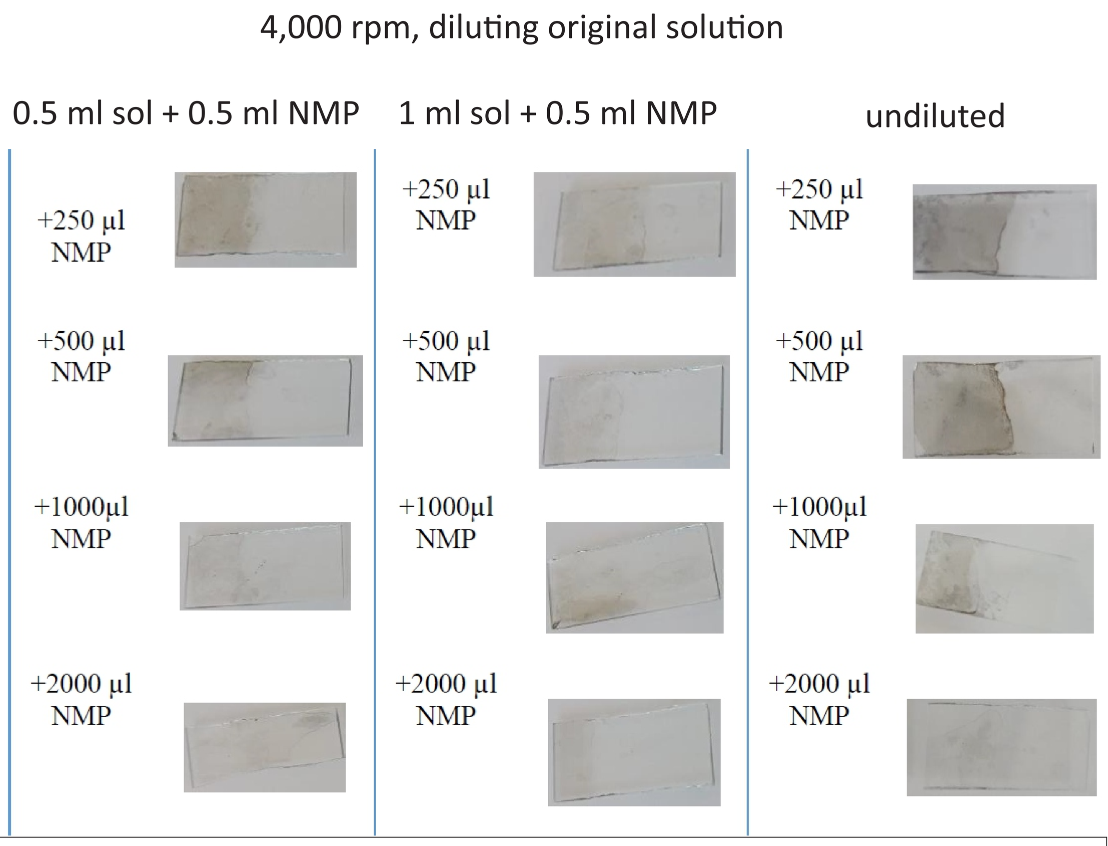


The graphene, as purchased (SixoniaTech GmbH), contains a wide distribution of particle sizes. Films produced from such graphene with Langmuir-Blodgett assembly [2] are thick and optically opaque, which means they cannot be used for applications in transparent conductors. We perform particle size selection by cascade centrifugation [1].



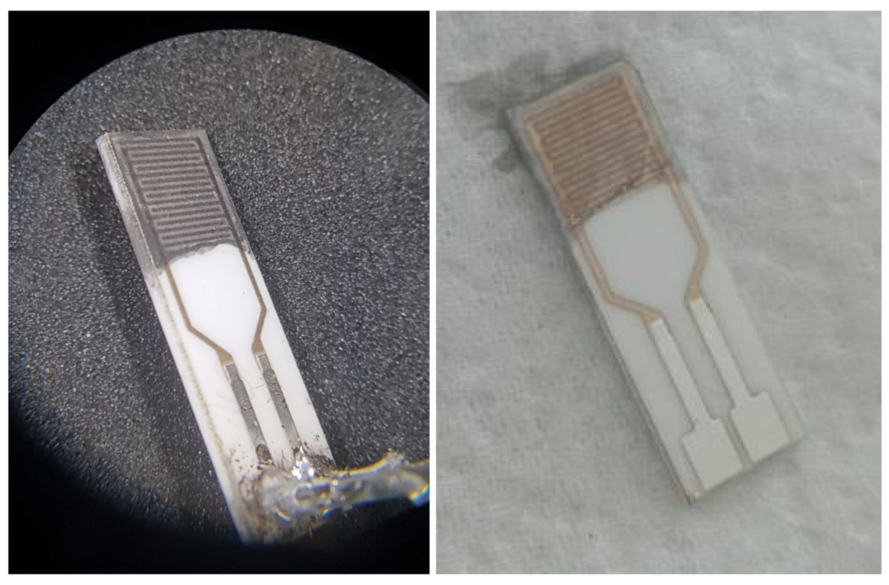
Cascade centrifugation is the process of repeat centrifugation of the graphene dispersion with a stepwise increase in rotation speed. We start from the original solution, undiluted or diluted in NMP. After each centrifugation step, we discard the supernatant and collect the sediment. The sediment is then redispersed in NMP prior to the next centrifugation step.

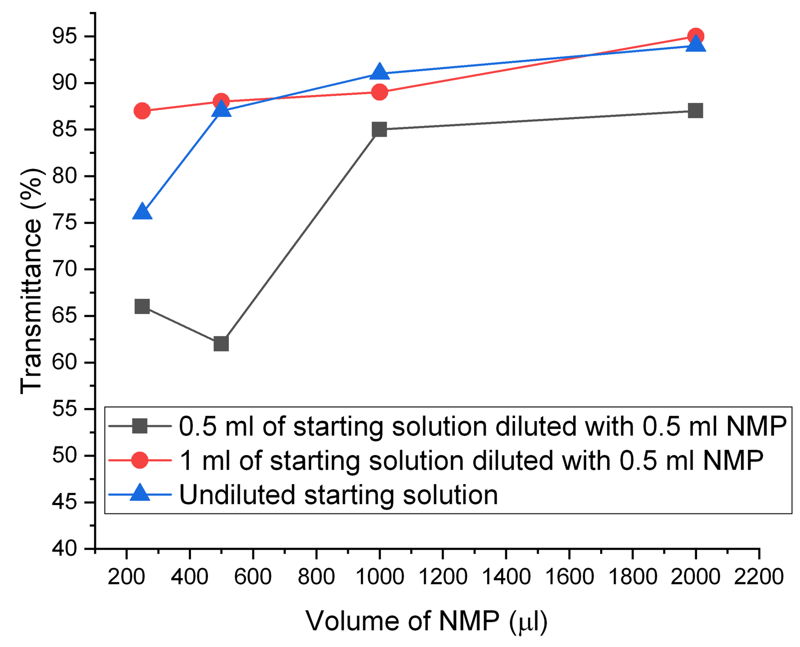




We obtain dispersions with different concentrations of graphene and different particle sizes (left image above). From these dispersions, we can make thin films by Langmuir-Blodgett assembly on a transparent glass substrate (right image above). Depending on the initial dilution of graphene, the final speed of centrifugation, and the dilution ratio in NMP after each centrifugation step, we obtain films of different optical quality.

		0.5 ml starting solution diluted with 0.5 ml NMP	1 ml starting solution diluted with 0.5 ml NMP	Undiluted solution
krpm	**+ V (NMP)**	**Number of layers**		
3	250 μl	17	14	30
	500 μl	11	4	25
	1000 μl	7	3	24
	2000 μl	5	3	24
3.5	250 μl	4	4	10
	500 μl	2	7	15
	1000 μl	0	7	10
	2000 μl	-	-	-
4	250 μl	10	5	15
	500 μl	5	5	16
	1000 μl	3	5	6
	2000 μl	1	0	4
5	250 μl	7	2	3
	500 μl	3	2	0
	1000 μl	1	1	0
	2000 μl	1	0	1





We measure optical transmittance at λ=660 nm for various production parameters and notice a trend in film thickness. Also, initial electrical resistance varies between $8{\cdot}10^3$ and $1.6{\cdot}10^7$ Ohms.

CONCLUSIONS

By varying the initial concentration of graphene in NMP, and the dilution volume of the sediment after each centrifugation step, we obtain films of different optical thickness. The films can be deposited on a substrate with interdigitated contacts, which reveals that also the electrical resistance depends on the thickness. Hence, we can tune the optoelectronic behavior of the commercially obtained electrochemically exfoliated graphene by cascade centrifugation.

REFERENCES

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ACKNOWLEDGEMENTS: We acknowledge support from the Ministry of Science, Education, and Technological Development of the Republic of Serbia, through grant. no. 451-03-9/2021-14/200026. This work has received support from the NATO Science for Peace Program through project SP4LIFE (G5825).