

## Electrochemical Exfoliation of 2D Materials for Composite and Energy Applications

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The electrochemical exfoliation of 2D materials can produce flakes with morphologies that are difficult to achieve using other exfoliation techniques [1]. We have exfoliated graphene and TMD flakes using both reductive and oxidative routes, with a range of electrolytes including molten salts, deep eutectic salts, organic and aqueous. Anodic exfoliation of graphite tends to produce material that is more oxidised, but the oxygen content can be reduced using metal salts [2] or by separating the intercalation and oxidation reactions [3]. Whilst cathodic exfoliation produces more “pristine” flakes albeit at slower rates and also gives the opportunity for in-situ functionalisation [4].

Energy storage and composites [5] are both very promising applications for graphene materials and the talk will discuss the design rules for these applications, highlighting how the morphology [6] and hence production route of the material [7] is crucial in obtaining the best properties

### References

- [1] How to Get Between the Sheets: A Review of Recent Works on the Electrochemical Exfoliation of Graphene Materials from Bulk Graphite, A.M. Abdelkader, A.J. Cooper, R.A.W. Dryfe, I.A. Kinloch, *Nanoscale*, 7, 6944-6956, 2015
- [2] On the Role of Transition Metal Salts During Electrochemical Exfoliation of Graphite: Antioxidants or Metal Oxide Decorators for Energy Storage Applications, A. Ejigu, K. Fujisawa, B.F. Spencer, B. Wang, M. Terrones, I.A. Kinloch, R.A.W. Dryfe, *Advanced Functional Materials* 28 (48), 1804357, 2018
- [3] Two-step electrochemical intercalation and oxidation of graphite for the mass production of graphene oxide, J. Cao, P. He, M.A. Mohammed, X. Zhao, R.J. Young, B. Derby, I.A. Kinloch, R.A.W. Dryfe, *Journal of American Chemical Society*, 139(48), 17466-17456, 2017
- [4] Single Stage Simultaneous Electrochemical Exfoliation and Functionalization of Graphene, A. Ejigu, I.A. Kinloch, R.A.W. Dryfe, *ACS Applied Material & Interfaces*, 9 (1), 710-721, 2016
- [5] Composites with carbon nanotubes and graphene: An outlook, I.A. Kinloch, J. Suhr, J. Lou, R.J. Young, P.M. Ajayan, *Science* 362 (6414), 547-553, 2018
- [6] Mechanical properties of graphene and graphene-based nanocomposites, D.G. Papageorgiou, I.A. Kinloch, R.J. Young, *Progress in Materials Science* 90, 75-127, 2017
- [7] Comparison of Two-Dimensional Transition Metal Dichalcogenides for Electrochemical Supercapacitors, M.A. Bissett, S.D. Worrall, I.A. Kinloch, R.A.W. Dryfe, *Electrochimica Acta*, 201, 30-37, 2016.