Understanding origami in 2-D materials

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One in five mobile phone users in the UK have cracked their screen by dropping the phone in a three year period, according to a YouGov poll. The mobile screens break easily because they are usually made from an oxide material which allows the touch screen to function but breaks easily. In contrast, graphene and other 2-D materials could also function as as efficient mobile touch screens but are highly bendable. These

materials therefore promise to revolutionise flexible electronics with the potential to produce unbreakable mobile phone displays.

Due to material flexibility 2-D materials are already finding application in advanced composite materials used to optimise the performance of sports equipment such as skis or tennis rackets and to reduce the weight of vehicles. Electronics applications could also benefit from new robust 2-D materials such as graphne. The ability to bend and stretch are essential to all these applications, and new research has demonstrated what happens when atomically thin materials are folded like origami.

Writing in *Nature Communications*, researchers at The University of Manchester have been studying the folding of 2-D materials at the level of single atomic sheets. Lead researcher Dr. Aidan Rooney said: "By analysing these folds in such detail we have discovered completely new bending behaviour which is forcing us to look again at how materials deform."

One of the special folds they have observed is called a twin; for which the material is a perfect mirror reflection of itself on either side of the bend. Professor of Materials Characterisation Sarah Haigh says: "While studying material science at Oxford, I learned about the structure of twin bending in graphite from textbook illustrations very early in my course. However, our recent results show that these textbooks need to be corrected. It is not often that as a scientist you get to overturn key assumptions that have been around for over 60 years."

The researchers found that in contrast to previous models, folds in layered materials like graphite and graphene are delocalised over many atoms – not sharp as has always been assumed. Effectively a tiny region of nanotube-like curvature is produced at the centre of the bend. This has a major effect on the materials strength and ability to flex and stretch. Other complex folding features were also observed.

Professor of Polymer Science and Technology, Robert Young commented: "We found that the type of folding can be predicted based on the number of atomic layers and on the angle of the bend – this means that we can more accurately model the behaviour of these materials for different applications to optimise their strength or resistance to failure."

More information: A. P. Rooney et al. Anomalous twin boundaries in two dimensional materials, *Nature Communications* (2018). DOI: 10.1038/s41467-018-06074-8

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