A Universal Length-Dependent Vibrational Mode in Graphene Nanoribbons

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Graphene nanoribbons (GNRs) have attracted considerable interest, as their atomically tunable structure makes them promising candidates for future electronic devices. However, obtaining detailed information about the length of GNRs has been challenging and typically relies on low-temperature scanning tunneling microscopy. Such methods are ill-suited for practical device application and characterization. In contrast, Raman spectroscopy is a sensitive method for the characterization of GNRs, in particular for investigating their width and structure. Here, we report on a length-dependent, Raman-active low-energy vibrational mode that is present in atomically precise, bottom-up-synthesized armchair graphene nanoribbons (AGNRs). Our Raman study demonstrates that this mode is present in all families of AGNRs and provides information on their length. Our spectroscopic findings are corroborated by scanning tunneling microscopy images and supported by first-principles calculations that allow us to attribute this mode to a longitudinal acoustic phonon. Finally, we show that this mode is a sensitive probe for the overall structural integrity of the ribbons and their interaction with technologically relevant substrates.
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