The Controlled Production of Graphene Using Automated Mechanical Exfoliation

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Graphene, the monolayer form of graphite, is an atomically-thin material with unique physical and electrical properties, and a wide range of applications from stronger composite materials to transparent, flexible electronics. Much of current research focuses on discovering graphene's novel properties; this is most effective in pristine samples, necessitating the consistent production of high-quality graphene. Manual mechanical exfoliation, using Scotch tape to peel layers from graphite to produce monolayers, has traditionally been used to produce the highest-quality graphene of any other method. However, it produces low yields of small-sized flakes, and the presence of human variability prevents controlled, consistent graphene production. In this study, a novel motorized 3-roller device was used to automate exfoliation in order to achieve controlled graphene production. The roller method had two steps: exfoliation, where all three rollers were wrapped in adhesive tape in order to cleave graphite; and transfer, where the middle roller was replaced by another roller with holders for SiO_2 substrates. The roller was used to control and determine the effects of five variables. Through this controlled study, it was determined that a combination of highly oriented pyrolytic graphite, Nitto brand tape, 120s O_2 plasma treatment, moderate inter-roller pressure, and higher temperature produced significantly greater quantities of larger graphene flakes ($p<.05$, $p<.01$, $p<.001$). In the future, design changes should be made to the roller to optimize graphene production, and the device should be used to exfoliate other atomically-thin materials with different properties and applications, such as the semiconducting WS_2 and the insulating hBN.