Akimitsu Narita[1]
Yunbin Hu,[1] Zongping Chen,[1] Ashok Keerthi,[1] Tim Dumslaff,[1] Xuelin Yao,[1] Xinliang Feng,[2] Klaus Müllen[1]
[1]Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany
[2]Center for Advancing Electronics Dresden (CFAED) & Department of Chemistry and Food Chemistry, Dresden University of Technology, Walther-Hempel-Bau Mommsenstrasse 4, 01062 Dresden, Germany
narita@mpip-mainz.mpg.de

Bottom-up Chemical Synthesis of Atomically Precise Graphene Nanoribbons and Their Potentials

In contrast to zero-bandgap graphene, structurally confined graphene nanoribbons (GNRs) have open bandgaps due to the quantum confinement effect, making them interesting as next-generation carbon-based semiconductor materials.[1] The electronic and optical properties of GNRs critically depend on their chemical structures, in particular the width and edge structure, but conventional top-down methods like "cutting" of graphene sheets and "unzipping" of carbon nanotubes have failed to achieve the required precision. To this end, bottom-up chemical synthesis can provide narrow (~1–2 nm) GNRs with atomically precise structures.[1,2] In this talk, I will introduce our recent progresses in the synthesis of GNRs in solution and on surface and discuss their potentials. By the solution synthesis we can obtain long (>600 nm) GNRs that are dispersible in organic solvents and can be processed from the liquid phase.[3] The GNR edges can be functionalized with different substituents. For example, GNRs functionalized with extended aromatic units demonstrated unique rectangular self-assembly behavior[4] and introduction of organic radicals induced magnetic edge state through spin injection, interesting for spintronic and quantum computing applications.[5] On-surface synthesis of GNRs is typically performed under ultrahigh vacuum (UHV), but also possible under low vacuum to ambient pressure with an industry viable setup of chemical vapor deposition (CVD), producing high-quality, large-area GNR films.[6] We have for example achieved fabrication of low-bandgap $N = 5$ armchair GNRs (5-AGNRs) and their integration into field-effect transistor devices. Lateral fusion of 5-AGNRs into wider $N = 10$ and 15 armchair GNRs could be demonstrated upon annealing at higher temperatures, showing optical absorption over 2000 nm, which could be interesting for infrared sending applications.

References

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Figures

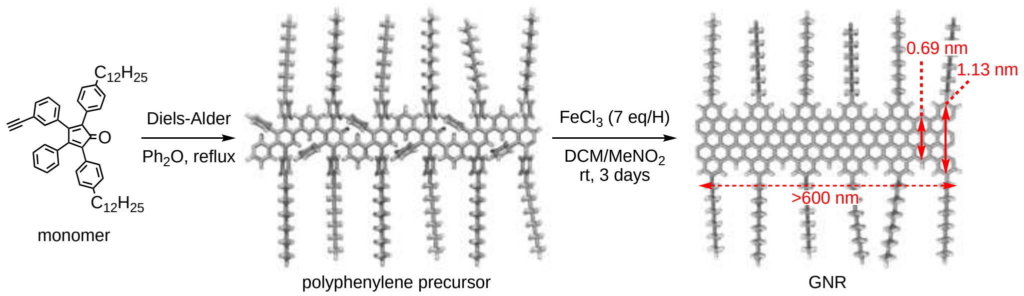

Figure 1: An example for bottom-up solution synthesis of graphene nanoribbons.[3]