How easy is it to produce and characterize carbon-based nanomaterials from waste? Insights and future perspectives

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The widespread availability and the multifaceted characteristics of carbon-rich wastes (e.g. refuse-derived fuels, biomasses) call for a systemic change in the use and recovery of resources in the economy through a clear transition to a regenerative circular economy. Due to the broad variability in terms of structure and chemical–physical characteristics, carbon-based materials have a tremendous potential for a wide range of applications, ranging from energy to automotive and biomedical. Thanks to the easily tunable carbon moieties, nano-sized and/or nanostructured materials can also be produced through the development and implementation of top-down, environmentally friendly, cost-effective and scalable synthesis protocols (whereas wet-chemical approaches are in many cases the most convenient).

After an appropriate thermal conversion and/or thermal post-treatment, it is possible to develop at the nanoscale level randomly arranged or ordered stacked sheets of condensed aromatic ring systems (i.e. graphene layers), which can be further functionalized into versatile, multi-purpose nanomaterials tailored for specific applications (e.g. sensing, CO_2 capture, water remediation). Overall, the development of materials starts from the design of the chemical formulation to the production of objects in a structured form, involving engineering with a multi-scale approach.

Here, we report on the latest developments in the production of carbon-based nanomaterials from carbon-rich wastes, including the state-of-the-art approaches for their chemico-physical characterization. Both carbon-based nanomaterials used in pure form and, more extensively, composite materials in which they act as fillers or are integrated into metal-organic frameworks or coated/impregnated with metal oxides, metal nanoparticles and conducting polymers will be considered. The most appropriate analytical techniques for assessing the main characteristics of these categories of materials are reported, together with their prospects.