Atomically thin carbon and boron nitride films as anti-corrosive coatings

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Materials corrosion and degradation causes a serious problem in many important technological fields of modern society, and therefore the development of new improved anti-corrosive coatings is getting increasingly important. Application of effective anti-corrosive coatings poses considerable technical challenges, in particular when very thin protective coatings are required. For this reason, investigation of chemical resistance of two-dimensional (2D) materials is scientifically and technologically extremely valuable. From a scientific point of view, it allows to test some of the most fundamental processes happening at interfaces of composite materials, while addressing and helping to solve some of the problems in different technological applications.

In this study, we examine corrosion resistance of atomically thick materials, boron nitride (BN), graphene and diamond-like carbon (DLC), in various gaseous and liquid environments. The oxidation behavior of hexagonal BN and graphene nanosheets (1–4 layers) is examined using heating in air [1]. BN films are found to have higher oxidation resistance than graphene, which makes them more preferable for high-temperature applications. Atomic force microscopy and Raman spectroscopy analyses showed that monolayer BN nanosheets can sustain up to 850 °C. The starting temperature of oxygen doping/oxidation of BN nanosheets only slightly increases with an increasing number of layers and strongly depends on the exact heating conditions. The detailed oxidation mechanism of BN has been found different from graphene. Elongated etch lines have been observed on the oxidized monolayer BN nanosheets, indicating that the BN nanosheets are first cut along the chemisorbed oxygen chains and then the oxidative etching occures perpendicularly to these lines.

The main advantage of thin carbon films for anti-corrosive applications lies in their multi-functional properties, such as tunable electrical conductivity, surface chemistry and excellent biological, chemical and corrosion resistance. To fully utilize these unique properties in various nano- and bimomedical applications, it is first important to homogenously deposit atomically thin carbon coatings on different nanostructured materials. We have developed a new plasma-induced coating method that allows effective surface modification of the entire surface of nanoporous materials by homogenous ultrathin (2-5 nm) carbon layers. This method allows fabrication of hybrid carbon-alumina materials with well ordered nanoporous structure and variable pore size. Higher sp^3 content in the deposited carbon layers has been found beneficial for anti-corrosion applications, providing better protection than sp^2-rich carbon layers. Our measurements show that ultrathin DLC coatings on nanoporous alumina templates possess excellent corrosion resistance to all tested harsh chemical (acid/alkaline) environments even at high temperatures (up to 200 °C). These highly resistant amorphous carbon layers could be converted to single, double and multilayer graphene layers respectively by using a low-temperature graphitization process. This process allows integration of graphene with well ordered nanoporous structures and holds promise for the development of novel sensor membrane devices.

References

[1] L. H. Li, J. Cervenka, K. Watanabe, T. Taniguchi and Y. Chen, ACS Nano, Article ASAP
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