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Surface and Interface Properties of Carbon-Based Materials for Future Nanotechnologies

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Abstract – Reactions on solid surfaces on an atomic scale are of interest in many nanotechnological fields. With the development of surface sensitive analytical techniques, enormous advances have been made in the understanding of surface reactions at the atomic and/or molecular level. In this talk, relevant carbon-based systems such as silicon carbide, nanocrystalline diamond, graphene, etc. are presented in a surface science context with a nanotechnological perspective. In addition, PEM fuel cells and nanopositioning machines are discussed as typical applications of such systems. The relevance of a variety of surface modifications will be presented and promising future directions will be discussed.

Carbon-based materials such as graphene, silicon carbide, nanocrystalline diamond and diamond-like carbon are promising materials for nanotechnological applications in fields such as electronics, catalysis, electrochemistry, tribology and materials processing. Since nanostructures have a high surface area, it is vital to understand their surface as well as interface properties.

Graphene is a prominent example. This material has gained intense attention due to its exceptional properties. There is considerable interest to grow and characterize graphene on a larger scale than currently possible with the exfoliation method. Possible routes are to grow large area graphene on nickel or by thermal treatment of silicon carbide surfaces. Phonon dispersion curves (Fig. 1) measured using high resolution electron energy loss spectroscopy (HREELS) in the Γ-K direction support single as well as few layer graphene formation. The development route can be ascertained using HREELS and X-ray photoelectron spectroscopy (XPS) while the structure can be examined using scanning tunneling microscopy (STM). Nanocrystalline diamond is a carbon-based material with considerable interest for bioelectronic and sensor systems. Here, the surface interaction of gas molecules such as hydrogen is important. HREELS and XPS (Fig. 2) experiments as a function of annealing treatments in UHV reveal the occurrence of core-level shifts due to hydrogen desorption and subsequent graphitization at grain boundaries. The changes from the sp^3 to sp^2 phases can be precisely tracked by corresponding HREELS measurements.

Application examples of carbon-based materials are native polymers which when pyrolyzed transform to graphite for use as cost effective bipolar plates in PEM fuel cells (Fig. 3) and tribological coatings for stable and controlled friction in a nanopositioning system. In the latter case the characteristics of the transfer layer structures are seen to define the ultimate tribological performance (Fig. 4).

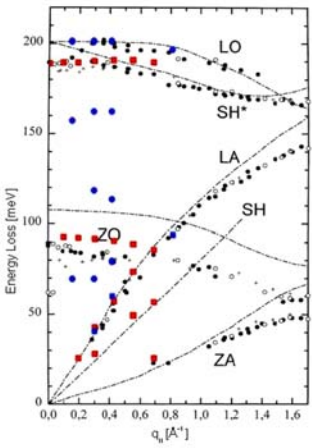

Figure 1: Phonon dispersion curves of graphene on 6H-SiC(0001) (blue solid circles) and on Ni(111) (red squares).

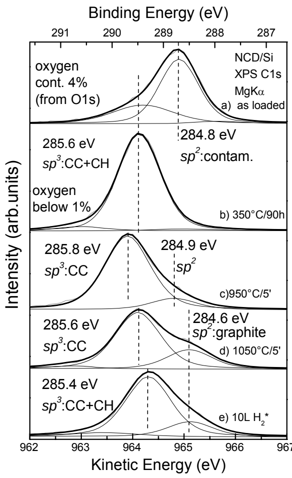

Figure 2: XPS spectra as a function of thermal treatments in UHV and hydrogen dosing.

Figure 3: Using native based polymers as bipolar plates in PEM fuel cells after pyrolysis.

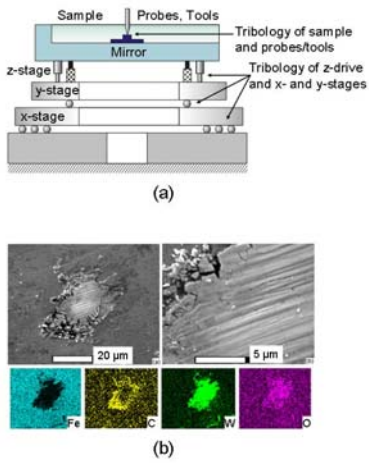

Figure 4: (a) Schematic of a nanopositioning machine and (b) SEM images and EDX mapping of a transfer layer on a WC-C coating.