

Supporting Information

Atomic Layer Deposition-Assisted Synthesis of Embedded Vanadia Catalysts

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Surface Spectroscopic Characterization of Graphene Oxide

When the method for synthesizing Graphene Oxide (GO) described in the experimental section is applied, various carbon-oxygen surface species are obtained. For the spectroscopic identification of these groups FTIR and XP spectroscopy were employed (see Figure S1).

The IR transmission spectrum in Figure S1 a) shows bands at 1730, 1625, 1225, 1065, and 985 cm^{-1} . The bands at 1730 and 1625 cm^{-1} can be assigned to C=O stretching vibrations of carbonyl and carboxyl groups, as found in esters and lactones, and C=C vibrations originating from the sp^2 carbon framework of the GO, respectively.^{1,2,3-5} Explicit assignment of the bands at wavenumbers below 1500 cm^{-1} is more complex since in this region stretching and deformational vibrations of hydroxyl, carbonyl, carboxyl, ether, and epoxy groups overlap.^{1,2,3-5} The sharp feature at 1384 cm^{-1} may arise from traces of KNO_3 in the KBr used to record the background spectrum.^{6,7}

As shown in Figure S1 b), C 1s photoemissions were observed at binding energies between 284 and 290 eV. A detailed peak-fit analysis reveals contributions at binding energies of 284, 286, 288, and 290 eV, which can be assigned to carbon originating from aliphatic sp^2 , hydroxyl, carbonyl, and carboxyl species, respectively.^{1,2} An atomic ratio O:C of 0.4 was derived from the peak areas, considering the relative sensitivity factors given in Table 2. Besides, traces of sulfur (1.2 at.-%) and nitrogen (1.8 at.-%) were detected.

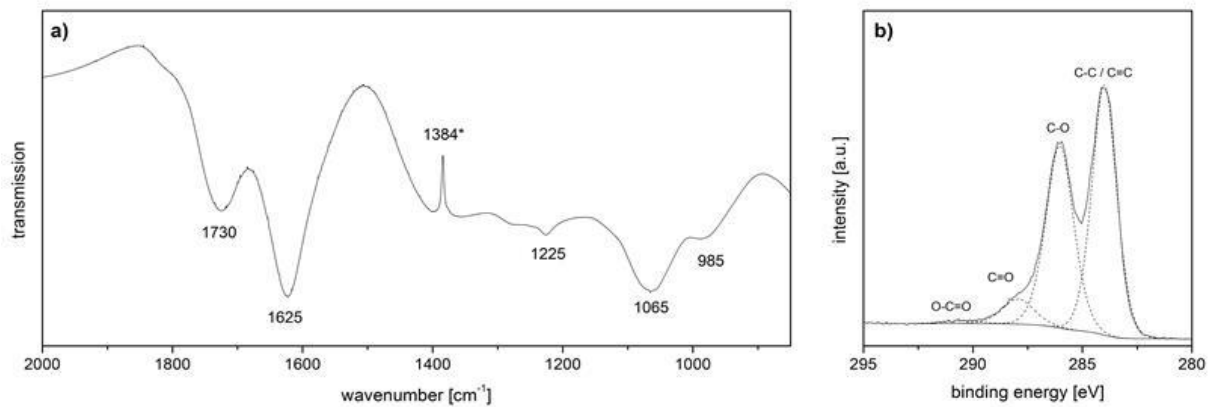


Figure S1. Spectroscopic characterization of carbon-oxygen species serving as functional groups on the surface of multilayered GO using a) FTIR and b) XPS. In b) the results of a peak-fit analysis are also shown. For details see text.

References

- 1 Chen, J.; Li, Y. R.; Huang, L.; Li, C.; Shi, G. Q., High-Yield Preparation of Graphene Oxide From Small Graphite Flakes via an Improved Hummers Method With a Simple Purification Process. *Carbon* **2015**, *81*, 826-834.
- 2 Marcano, D. C.; Kosynkin, D. V.; Berlin, J. M.; Sinitskii, A.; Sun, Z. Z.; Slesarev, A.; Alemany, L. B.; Lu, W.; Tour, J. M., Improved Synthesis of Graphene Oxide. *ACS Nano* **2010**, *4*, 4806-4814.
- 3 Gao, X. T.; Wachs, I. E., Molecular engineering of supported vanadium oxide catalysts through support modification. *Top. Catal.* **2002**, *18*, 243-250.
- 4 Acik, M.; Lee, G.; Mattevi, C.; Pirkle, A.; Wallace, R. M.; Chhowalla, M.; Cho, K.; Chabal, Y., The Role of Oxygen During Thermal Reduction of Graphene Oxide Studied by Infrared Absorption Spectroscopy. *J. Phys. Chem. C* **2011**, *115*, 19761-19781.
- 5 Masteri-Farahani, M.; Modarres, M., Clicked Graphene Oxide as New Support for the Immobilization of Peroxophosphotungstate: Efficient Catalysts for the Epoxidation of Olefins. *Coll. Surf. A* **2017**, *529*, 886-892.
- 6 Shen, J. F.; Hu, Y. Z.; Shi, M.; Li, N.; Ma, H. W.; Ye, M. X., One Step Synthesis of Graphene Oxide-Magnetic Nanoparticle Composite. *J. Phys. Chem. C* **2010**, *114*, 1498-1503.
- 7 Miller, F. A.; Wilkins, C. H., Infrared Spectra and Characteristic Frequencies of Inorganic Ions - Their Use in Qualitative Analysis. *Anal. Chem.* **1952**, *24*, 1253-1294.