

Insights into the structure of MoS₂/WS₂ nanomaterial catalysts as revealed by aberration corrected STEM

Francis Leonard Deepak*, Rodrigo Esparza**, Carlos Fernando Castro-Guerrero**, Sergio Mejía-Rosales***, Xochitl Lopez-Lozano** and Miguel Jose-Yacaman**

* International Iberian Nanotechnology Laboratory, Av. Mestre José Veiga, Braga 4715-330, Portugal

** Department of Physics and Astronomy, University of Texas at San Antonio, One UTSA Circle, San Antonio, Texas, 78249, USA

*** Center for Innovation and Research in Engineering and Technology, CICFIM-Facultad de Ciencias Físico-Matemáticas, Universidad Autónoma de Nuevo León, San Nicolás de los Garza, NL, 66450, Mexico

Molybdenum disulfide/Tungsten disulphide (MoS₂/WS₂) is a compound very useful for its properties; it is used as lubricant, catalyst in hydrodesulfuration, in hydrogen fuel storage, etc. As part of the 2nd Joint Congress of the Portuguese and Spanish Microscopy Societies the present work reports about the different types of MoS₂/WS₂ nanomaterials which have been investigated by using aberration corrected STEM namely: (1) MoS₂ nanotubes (2) MoS₂ hexagonal nanoplates, (3) rippled or helical MoS₂ nanowires, (4) Co-doped MoS₂/WS₂ nanowires and (5) fullerene-like WS₂ nanoparticles [1-6].

Aberration-corrected electron microscopy (STEM-HAADF) has been used to understand the capping, nature and structure of the MoS₂ nanotubes. Thus the 3R rhombohedral stacking sequence was identified in this study [1]. In another study MoS₂ nanoplates having a size of 20–30 nm were investigated using aberration corrected STEM. Thus detailed insight into the structure of these nanoplates was obtained in great detail in this study and they were subsequently used in catalysis: namely the hydrodesulphurization reaction of dibenzothiophene [2]. The structure of MoS₂ nanowire catalysts (supported on Al₂O₃ substrates) was investigated to provide detailed information of its shape and structure. HAADF (High Angle Annular Dark Field) - STEM images shows very clearly that the catalyst is formed by elongated chains with a twisted and helical structure (Figure 1). Based on the HAADF-STEM images, three atomic models were built to illustrate the different morphologies found in the MoS₂ catalyst [3]. A very significant increase in their activity can be achieved by adding Co or Ni as a promoter. Thus aberration corrected STEM (scanning transmission electron microscopy) has been used to characterize Co doped MoS₂/WS₂ nanowire catalysts (supported on Al₂O₃ substrates). The high-resolution imaging reveals clearly the location of Co in the individual nanowire catalysts (Figure 2). Based on the HAADF-STEM images, two models for the Co-Mo-S and Co-W-S catalysts were built to illustrate the different morphologies found in the catalysts [4,5]. In addition IF-WS₂ nanoparticles have been investigated by using aberration corrected scanning transmission electron microscopy (C_s-STEM) whereby the new 1T type of stacking, common in MoS₂ but never seen before in the case of the IF-WS₂ nanoparticles was identified [6].

References

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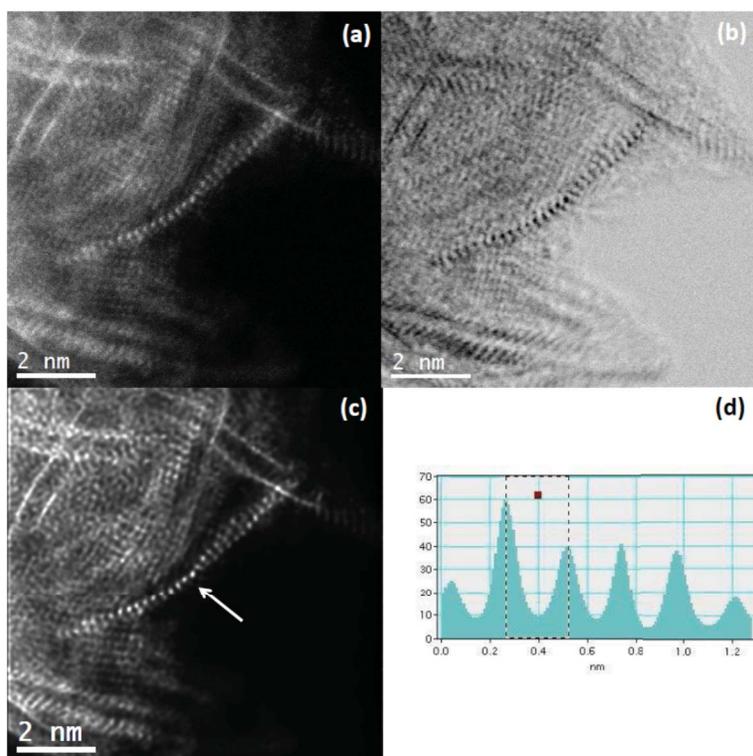


Figure 1. MoS₂ catalysts supported on Al₂O₃: a) HAADF-STEM image and b) BF-STEM image of the MoS₂ catalysts, c) Filtered HAADF-STEM image of the MoS₂ catalyst, d) The line profile corresponding to the interatomic distances of the Mo–Mo atoms (bright atom contrast), distances of 2.7 Å between the atoms. The white arrow shows the S atoms that make up the S–Mo–S chevron.

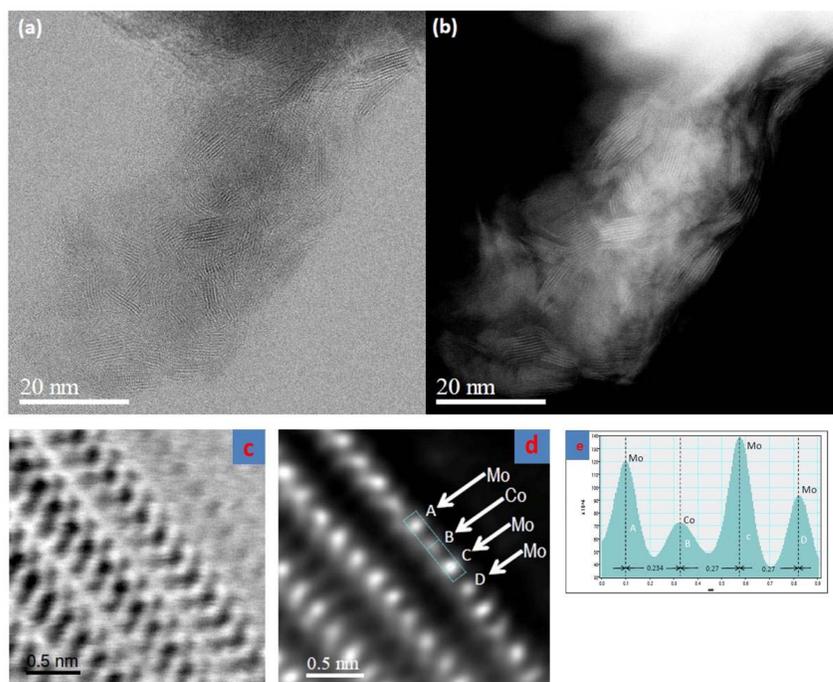


Figure 2. (a) and (b) show the low magnification BF-STEM and HAADF-STEM images of the Co-doped MoS₂ nanowire catalysts, (c) and (d), Ultra high magnification BF-STEM and HAADF-STEM images of the Co-doped MoS₂ nanowire catalysts (unsupported catalyst), and (e) corresponding line profiles (the spacing between the Mo-Co-Mo-Mo atoms, atoms A-B-C-D). The Co atoms have a lesser intensity in comparison to the Mo atoms as a consequence of the difference in their respective atomic numbers.