Spectroscopic ellipsometry signatures of structural evolution in NiMo-C coatings for HER applications

Krzysztof Dorywalski[1,#], Tomasz Suszko[2], Ewa Dobruchowska[2], Witold Gulbiński[2], Jerzy Morgiel[3]

[1] Institute of Experimental Physics, Faculty of Mathematics Physics and Informatics, University of Gdańsk – Gdańsk, Poland
[2] Koszalin University of Technology – Koszalin, Poland
[3] Institute of Metallurgy and Materials Sciences, Polish Academy of Science – Kraków, Poland

Transitioning to sustainable energy systems requires efficient hydrogen production technologies, with the Hydrogen Evolution Reaction (HER) playing a central role. Our recent work has demonstrated that NiMo-C coatings with a carbon content of 20 at. % or higher serve as promising alternatives to noble metal catalysts due to their high corrosion resistance in acidic environments and favorable HER performance.

NiMo-C coatings synthesized by reactive magnetron sputtering exhibit a structural evolution from a dense nanocrystalline phase to an amorphous and nanocolumnar morphology as carbon content increases. This study presents spectroscopic ellipsometry (SE) as a rapid and non-destructive tool to resolve this evolution, identifying specific optical signatures associated with morphological transitions. For coatings with carbon content up to ~23 at. %, a homogeneous isotropic model based on Drude–Lorentz dispersion was applied, effectively capturing the metallic-like behavior of the nanocrystalline structure. For carbon-rich coatings (> 23 at. %), a uniaxial anisotropic model combined with the Bruggeman Effective Medium Approximation (BEMA) was required to account for the heterogeneous nanocolumnar morphology. The detected positive birefringence $n_z > n_{xy}$ serves as a direct optical signature of vertically oriented metallic-rich nanopillars embedded within the carbon matrix.

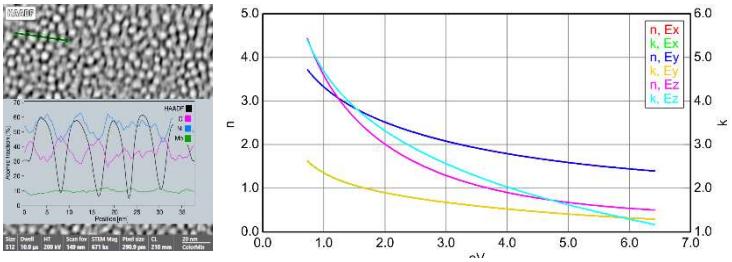

Figure 1. HAADF plan view picture (a) of the NiMoC/a-C:H thin film containing 74 at. % carbon, combined with EDS line scan and complex refractive index (b) derived from ellipsometry

[1] T. Suszko, E. Dobruchowska, W. Gulbiński, et.al. , ACS Appl. Mater. Interfaces 17 (2), 3344-3355 (2025)

krzysztof.dorywalski@ug.edu.pl