Development of high reflectance Cr/V multilayer mirror for water window applications

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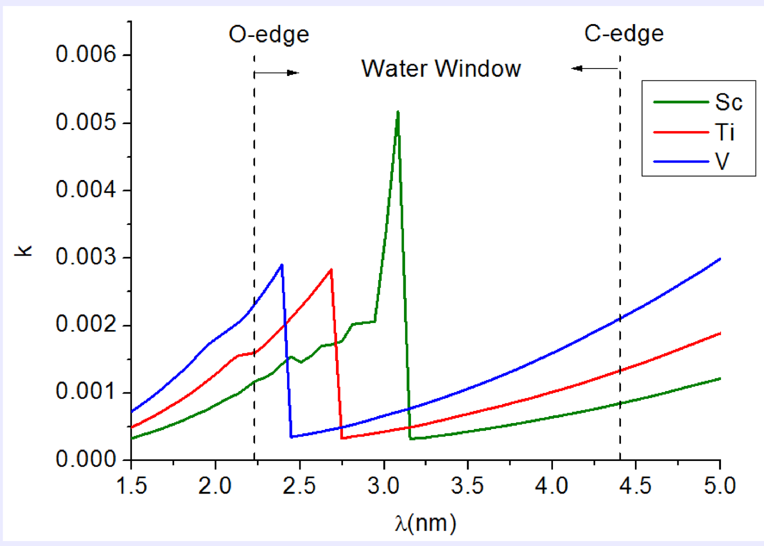
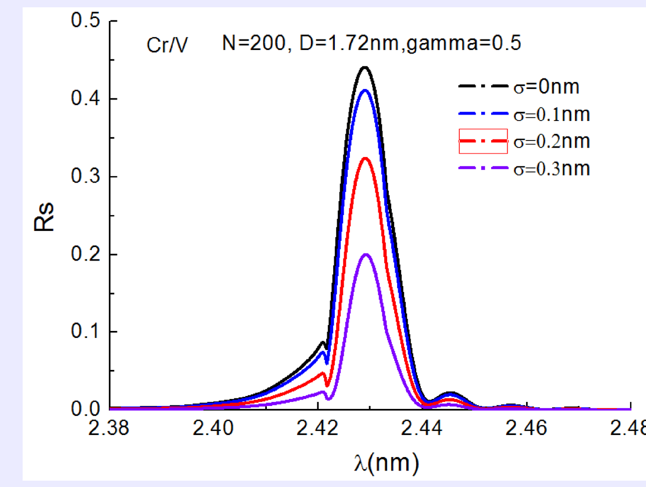
Introduction



Imaging and spectroscopy in the "water window" (λ=2.3-4.4nm) has been long pursued in the fields of biology and material science, driven by the natural contrast between carbon and oxygen, and the high spatial resolution provided by the short wavelength. Besides the high quality sources, multilayer mirror is another key component for the water window microscope. Due to the short working wavelength, the d-spacing of the multilayer is only 1-2nm. This imposes a severe challenge for the fabrication of such multilayer mirrors. Cr/V multilayer is one of the promising candidate working near the V-L edge (λ=2.4nm). This work focus on the development of high reflectance Cr/V multilayer mirror.

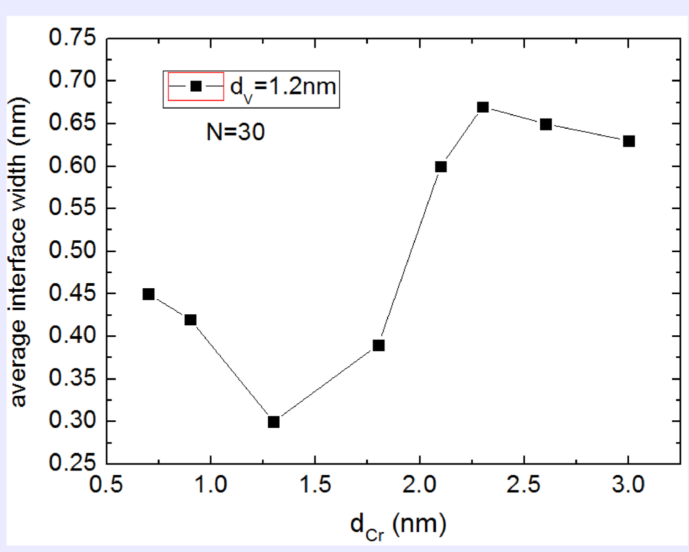


The thoeretical reflectance of Cr/V multilayers with different interface roughness.

Structure evolution of Cr/V multilayers with varied layer thickness

The multilayer structure with different layer thicknesses of Cr and V were first studied to understand the layer growth process.

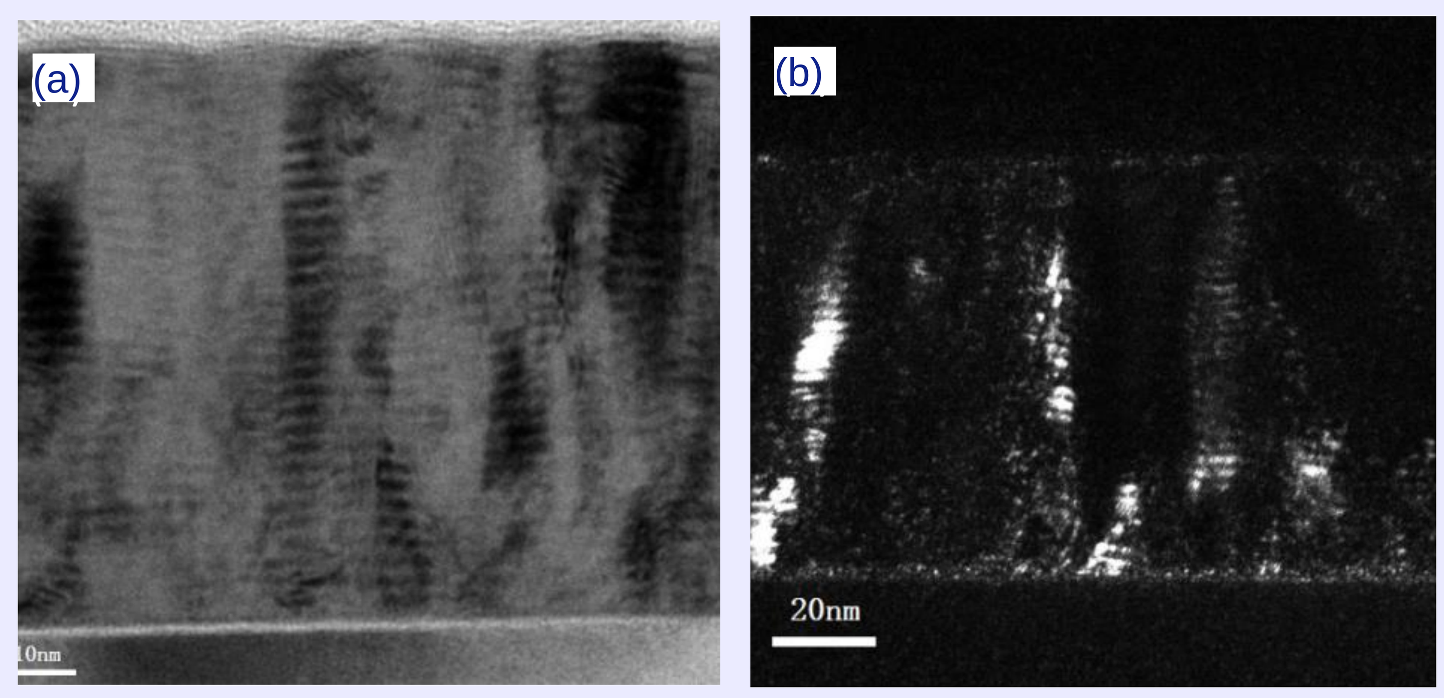
All multilayer samples were fabricated by a direct current magnetron sputtering system on super-polished silicon wafers. The deposition rate of Cr and V is 0.46 Å /s and 0.18 Å /s respectively.



The interface width plotted as the function of Cr layer thickness, V layer thickness is kept at 1.2nm.

d_{Cr}=1.3nm – smallest σ
d_{Cr}>2.0nm - σ further increase.

1.2 nm V layer thickness, 1.3 nm Cr

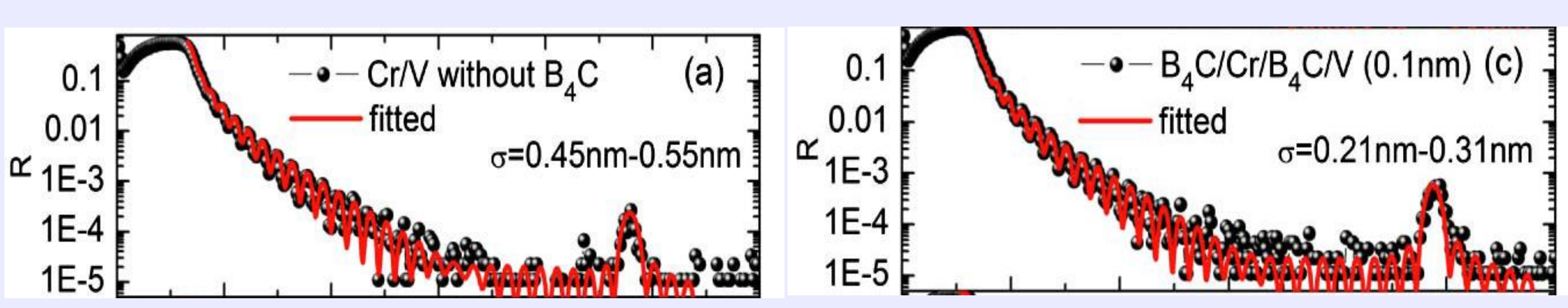


BF DF

The layers start to crystalize from below 1nm, and the size of the grains increase obviously with the layer thickness, which enlarges the interface widths.

Cr/V multilayers with Barrier layer B_4C

To suppress the cyrstallization and improve the interface structure, atomic scale B_4C "layers" were added at both interfaces. GIXR results show a obvious improvement of the hard X-ray reflectivity of the sample with barrier layers.



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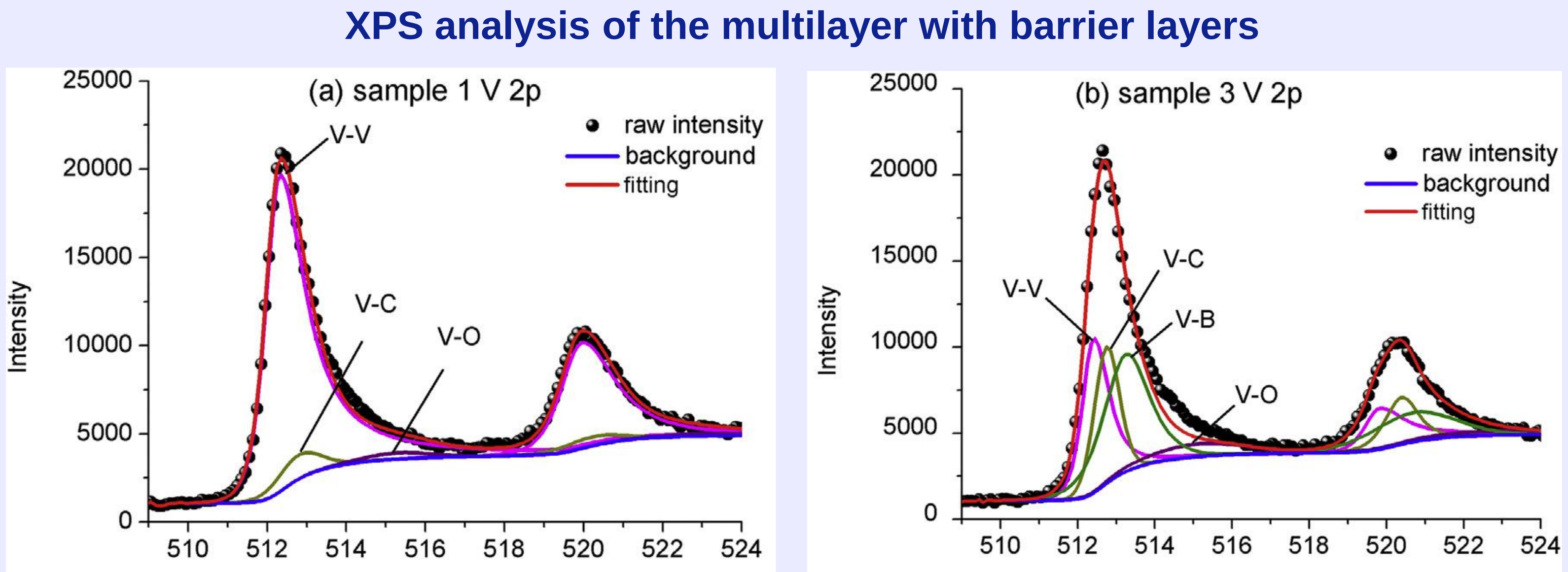
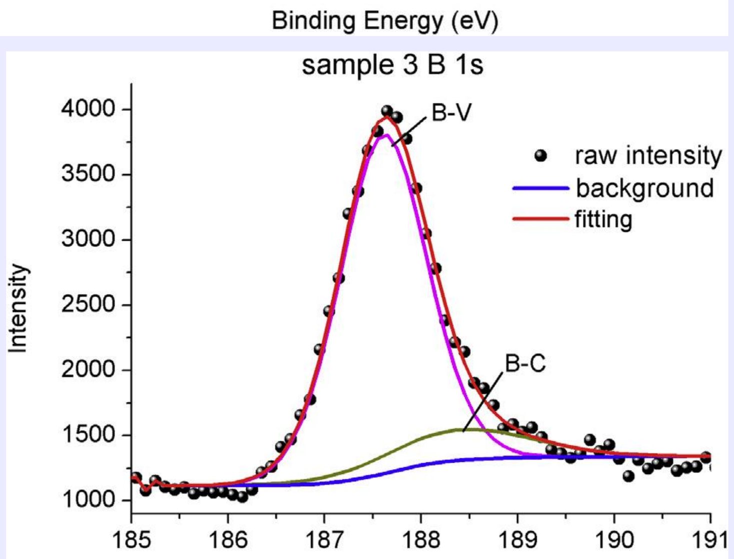
XPS analysis of the multilayer with barrier layers

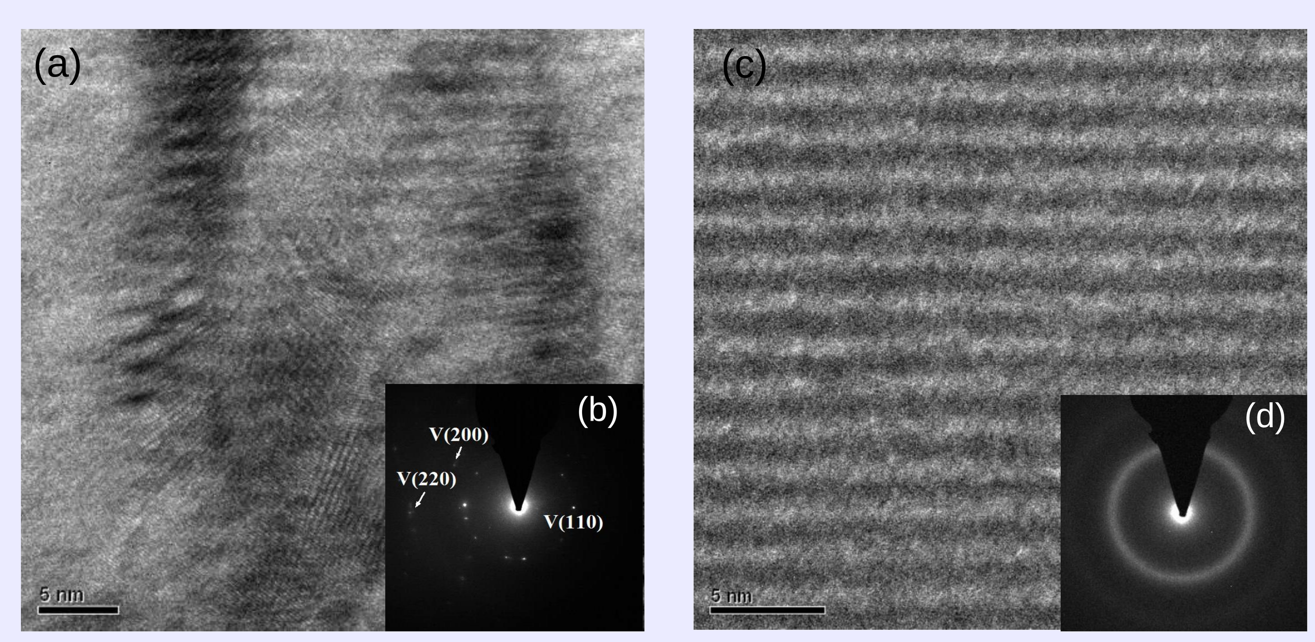




Compound formation of VB_2, VC and residual B4C were found. They help suppress the crystallization & diffusion.

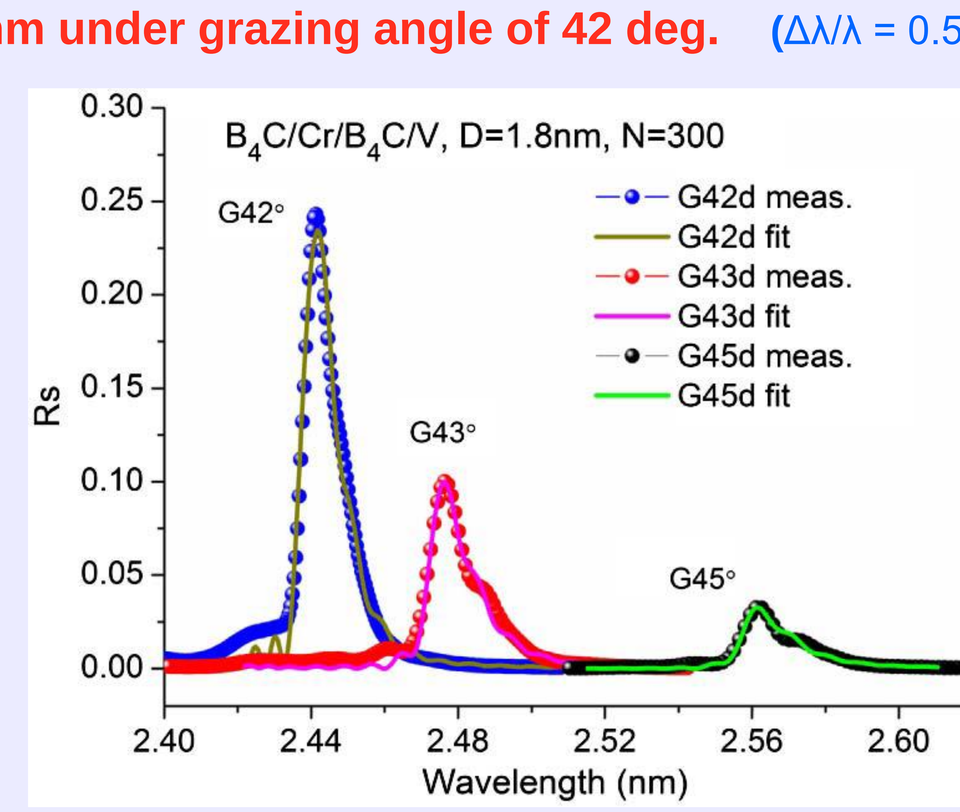
Pin Li, Q. Huang*, et al. Vacuum 128, 85 (2016).

TEM images and SAED patterns of Cr/V multilayers without B4C barrier (a) (b), and with barrier layers (c) (d), respectively.



0.1 nm B_4C significantly suppress the crystallization of the V layers

A high s-polarized reflectance of 24% was measured at λ= 2.44nm under grazing angle of 42 deg. (Δλ/λ = 0.5%)



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Summary

- ❑ The layer growth of Cr/V multilayers with ultrathin thickness is studied and a severe crystallization with large interface widths is found.
- ❑ The Cr/V multilayers with B_4C barrier have smaller interface widths compared to those without B_4C. The measured reflectance at grazing angle 42 deg near V L-edge reaches 24%.