doi:10.1017/S1431927622009357
Microsc. Microanal. 28 (Suppl 1), 2022

TEM Analysis and Mechanical Properties of Ternary $M_{n+1}AX_n$ and Binary MXene for Applications in Nanocoating Technology

Filip Mamon[1,2], Snejana Bakardjieva[1,2], Jakub Mares[1,2], Stefan Michna[1], Jiri Vacik[3], Pavel Horak[3], Ceccio Giovanni[3], Jiri Nemecek[4]

[1]Faculty of Mechanical Engineering, J. E. Purkyne University in Usti nad Labem, Pasteurova 3334/7, Usti nad Labem, Czech Republic,
[2]Institute of Inorganic Chemistry of the Czech Academy of Sciences, Husinec-Rez, Czech Republic,
[3]Institute of Nuclear Physics of the Czech Academy of Sciences, Husinec-Rez, Czech Republic,
[4]Czech Technical University in Prague, Faculty of Civil Engineering, Prague, Czech Republic
* Corresponding author: snejana@iic.cas.cz

MAX phases are hybrid nanolaminates with a hexagonal structure, composed of three elements, called M, A, and X, which were discovered in the 1960s. Due to their unique properties, MAX phases are now the subject of intensive research, especially for their mechanical and thermal properties. MAX phases are considered as a bridge between metal and ceramic, combining the properties of both of these materials .

This work is focused on the development and characterization of advanced hybrid nanolaminates based on ternary $M_{n+1}AX_n$, (where M = Hf, Zr, Sc; A = In; X = C and n = 1) and binary MXene, (where M = Ti and X = C) in the form of thin films . Thin films were prepared using a LEIF technique and further were irradiated with 35 keV Ar^+ with a fluctuation of 10^{15} cm^{-2} [2]. Characterization of all thin films was performed to describe the physical, chemical, and mechanical properties, and their structure. HRTEM studied the microstructure and SAED analysis confirmed the formation of M_2AX (Hf_2InC, Zr_2InC a Sc_2InC) and M_2X (Ti_2C) phases. Nuclear RBS analysis was applied to determine the stoichiometry of samples. The values of Young's modulus of elasticity and microhardness were found by nanoindentation.

HRTEM/SAED analysis showed the formation of M_2AX phases: Hf_2InC, Zr_2InC and Sc_2InC (Fig. 1a-f) and Ti_2C (MXene) (Fig. 2a-c). The formation of nanograins within the Hf_2InC and Zr_2InC films Hf_2InC was observed. They are destroyed and damaged by radiation with an Ar+ ion beam with high fluences. Nanoindentation has shown that the modulus of elasticity and microhardness of Hf_2InC and Zr_2InC thin films is comparable to the MAX phases known so far. The Sc_2InC phase has these lower values. Ion bombardment of Hf_2InC thin films leads to a gradual decrease in the values of the modulus of elasticity and microhardness, while after a high dose of irradiation there is a large decrease in these properties due to increased radiation damage and degradation of the MAX crystalline structure.

Nanoindentation of the Ti_2C phase shows excellent mechanical properties. These even exceed the values measured for MAX phase thin films. HRTEM analysis of the studied Ti_2C thin film showed an amorphous structure along with the crystalline TiC particles at the edge of the sample plane before irradiation. The probability of the formation of the Ti_2C phase is also confirmed by the RBS (NRA) spectrum, where it was found that the stoichiometry of the elements corresponds to $Ti_{2.2}C$.

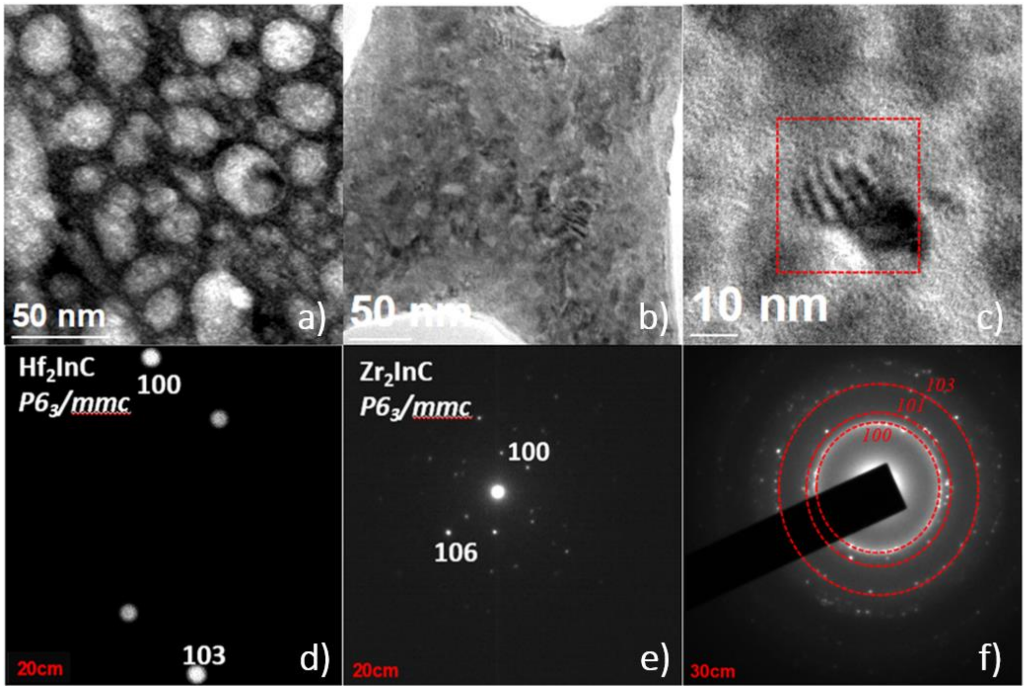

Figure 1. HRTEM/SAED analysis of (a) Hf_2InC, (b) Zr_2InC, (c) Sc_2InC and their corresponding electron diffraction (d) Hf_2InC, (e) Zr_2InC and (f) Sc_2InC.

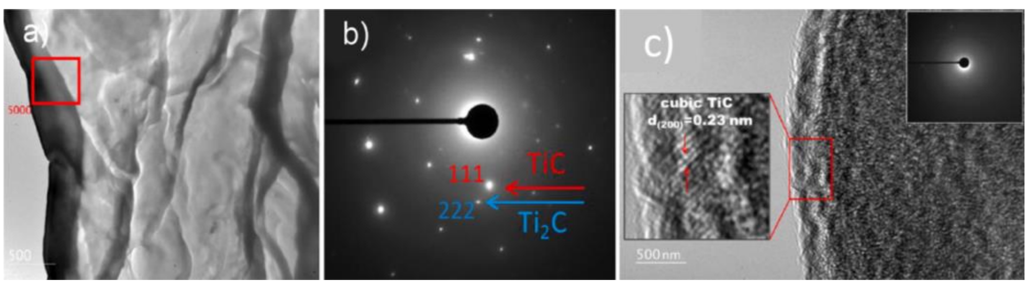

Figure 2. HRTEM analysis of (a) Ti_2C, (b) SAED of Ti_2C and (c) cubic TiC.

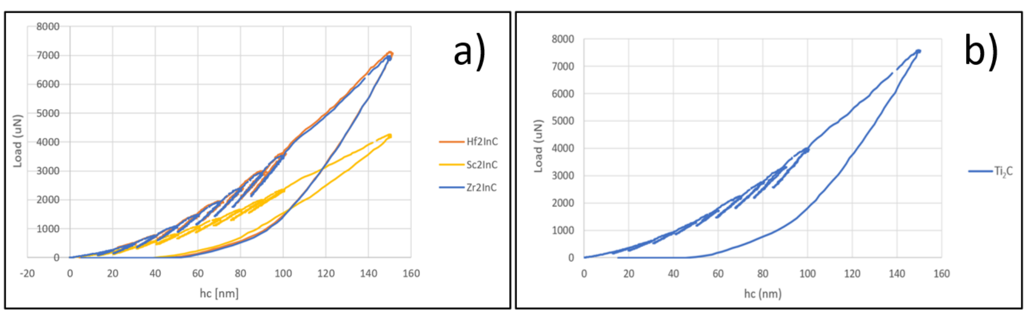

Figure 3. Nanoindentation results of (a) MAX phases Hf_2InC, Zr_2InC and Sc_2InC and (b) MXene phase Ti_2C.

https://doi.org/10.1017/S1431927622009357 Published online by Cambridge University Press

References:

[1] M. Radovic and M. Barsoum, Amer. Ceram. Soc. Bull. **92** (2013) p.333
[2] P. Horak, S. Bakardjieva and al., Nucl. Inst. Meth. Phys. Res. **55** (2020) p. 49.

[3] Authors acknowledge funding from the Czech Science Foundation GACR/18-21677S and NANOTHECH ITI (CZ.02.1.01/0.0/0.0/18_069/0010045) with EU support.

https://doi.org/10.1017/S1431927622009357 Published online by Cambridge University Press