Integration of multifunctional ceramic nanocomposite coatings on irregular surfaces

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Wang's Thin Film Group

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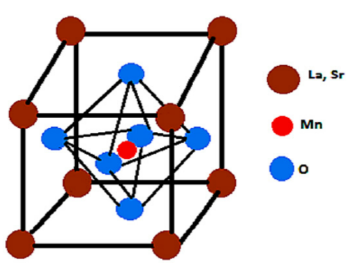
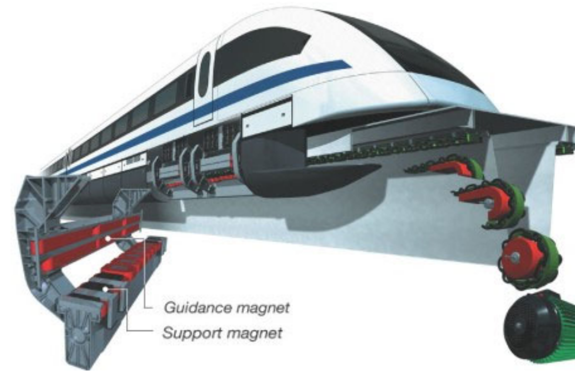
Why multifunctional ceramics?

Data storage devices

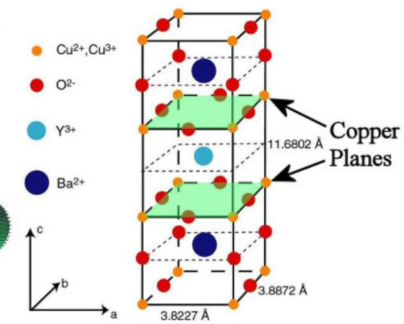
$La_{0.7}Sr_{0.3}MnO_3$



Superconductors

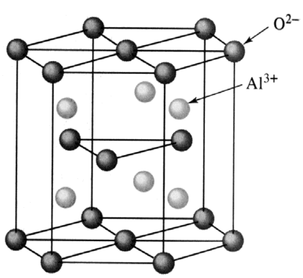


$YBa_2Cu_3O_7$



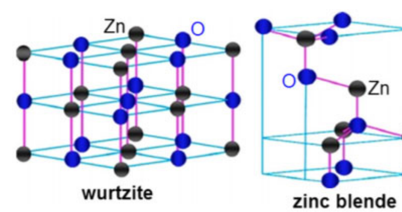
Biomedical applications

Al_2O_3



Solar cells

ZnO



S. Majumdar, et al. J. Phys. D. Appl. Phys., 2014, 47, 34010
http://slideplayer.com/slide/8278025/
G. Modi, et al. *Adv. Nat. Sci. Nanosci. Nanotechnol.. 2015,* 6, 33002
https://chemistry.stackexchange.com/questions/9730/why-dont-molecules-of-ionic-compounds-exist

Why on irregular surfaces?

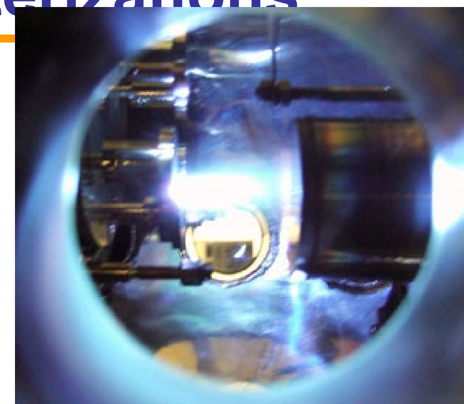

Electronics integrated on glass and flexible substrates for light weight personal devices

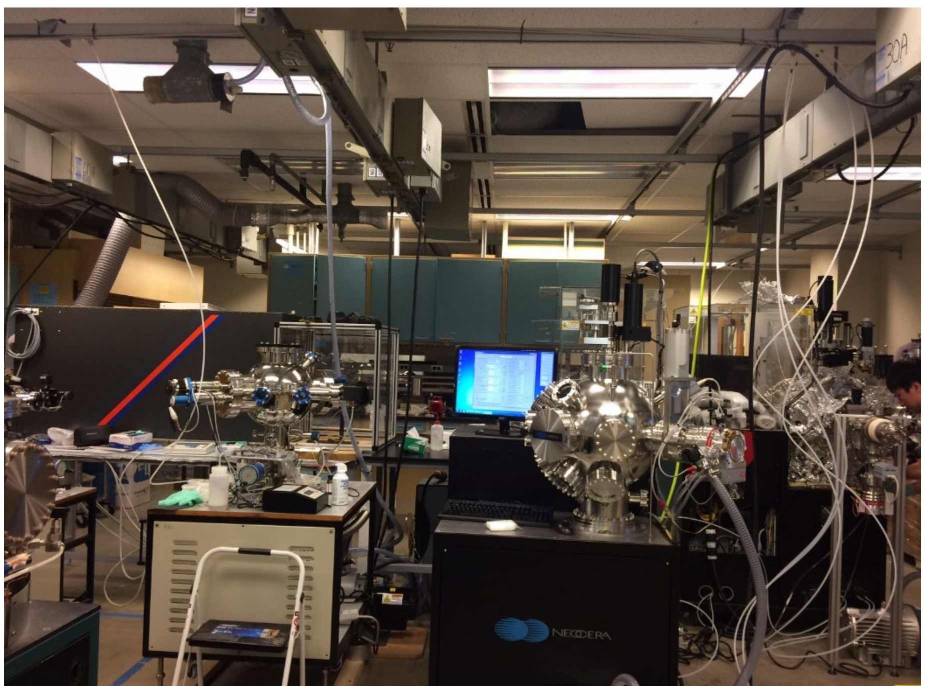

Phase change materials and other functional materials for artificial intelligence and smart windows for light selectivity

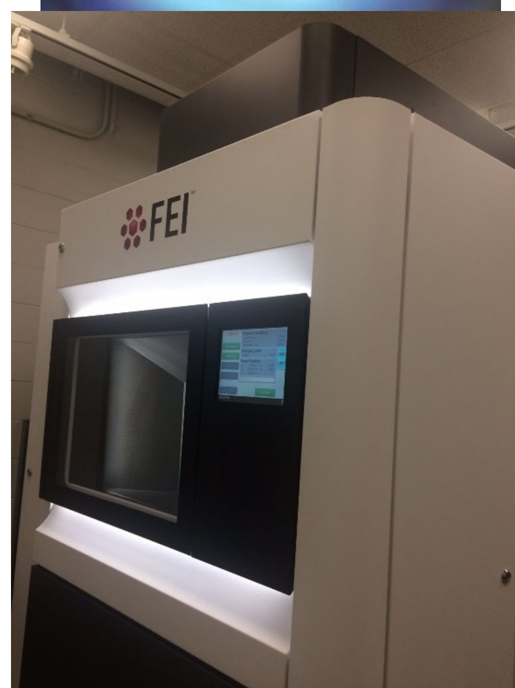
Why our thin film team?

Group Capabilities: Thin Film Growth and Nanoscale TEM Characterizations

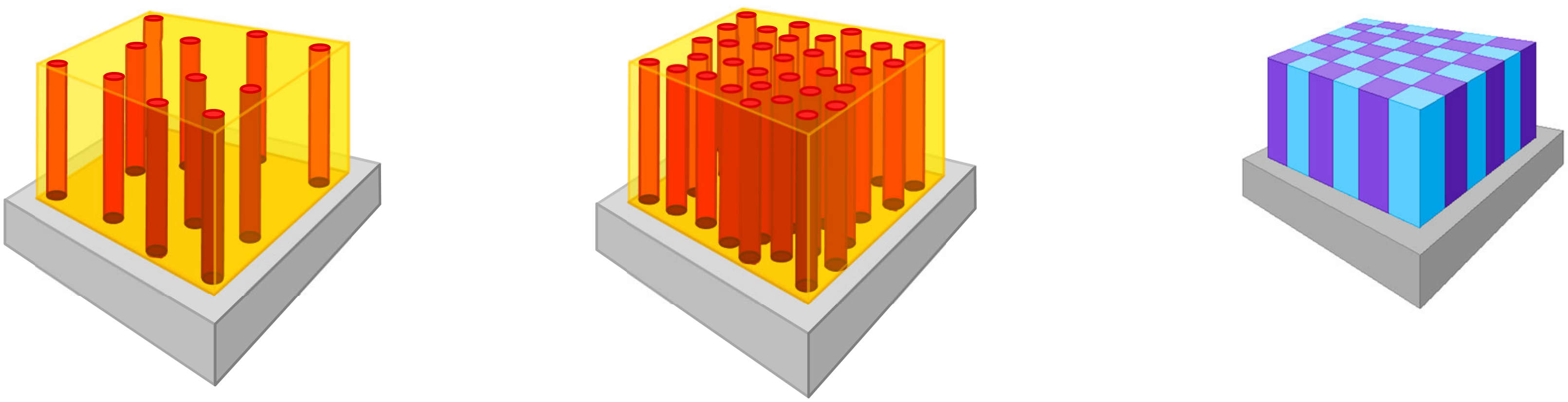
- **Thin Films growth (multiple PLD chambers), bulk synthesis by SPS, powder synthesis;**
- **TEM (FEI TALOS)**
- **XRD (Panalytical Empyrean)**
- **AFM-PFM-MFM**
- **Furnaces and other measurement tools**







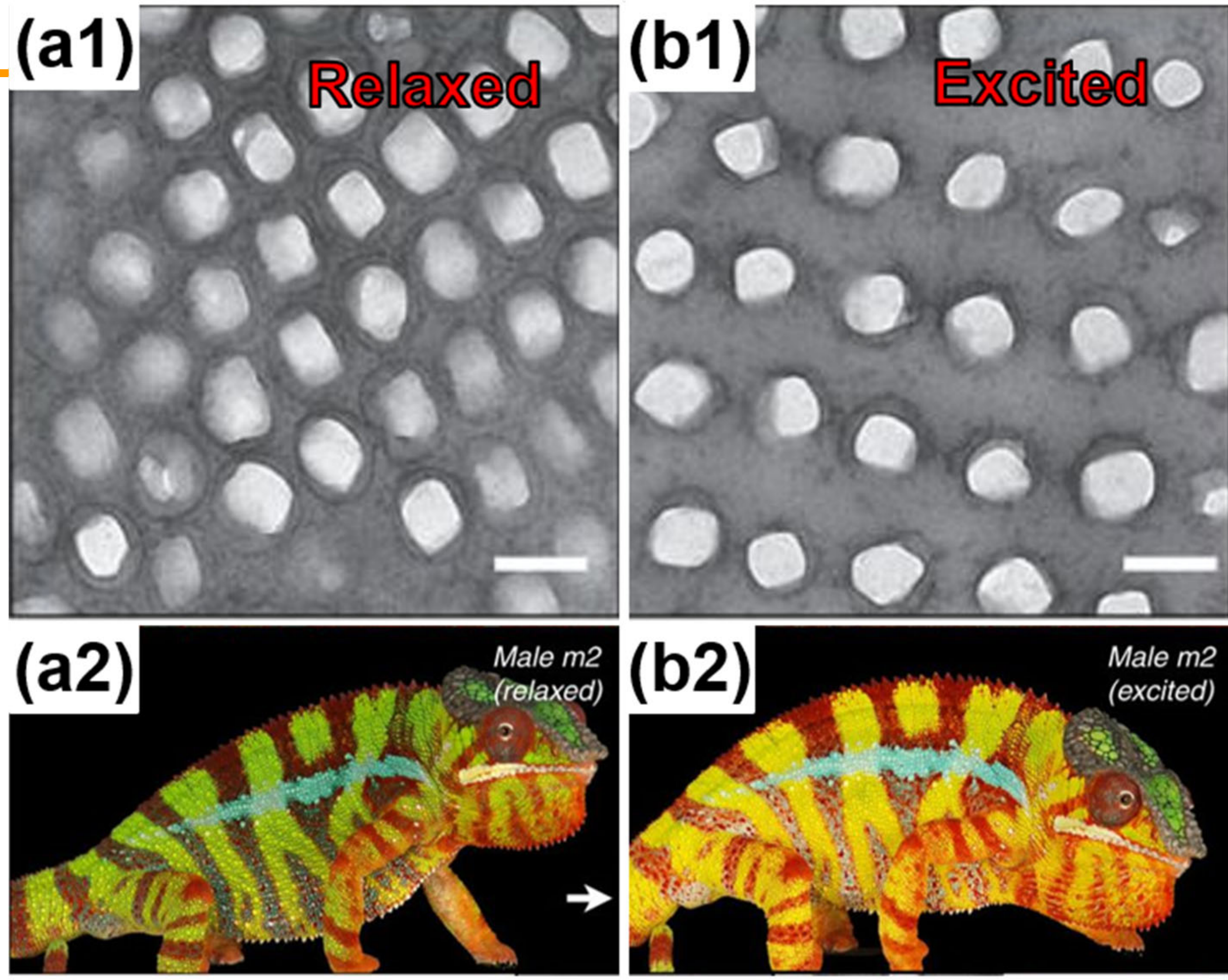
Our Approaches:
Thin Film Based-Hybrid Materials-Nanocomposites



Vertically Aligned Nanocomposites (VAN)

W. Zhang, Q. Jia, H. Wang, et al. *Current Opinion in Solid State & Materials Science*, 18, 6-18, 2014;
W. Zhang, Q. Jia, H. Wang, et al. MRS Bulletin Invited Review, 2015.

Functional Nanocomposites in Nature



Chameleon color change
(scale bar, 200 nm)

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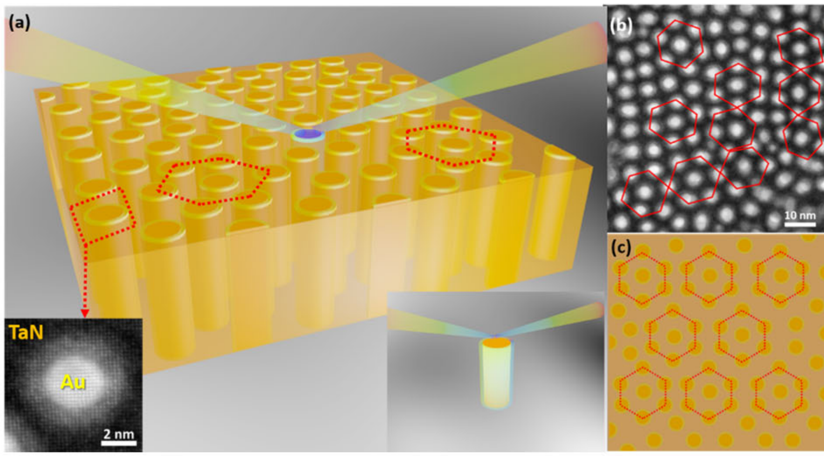
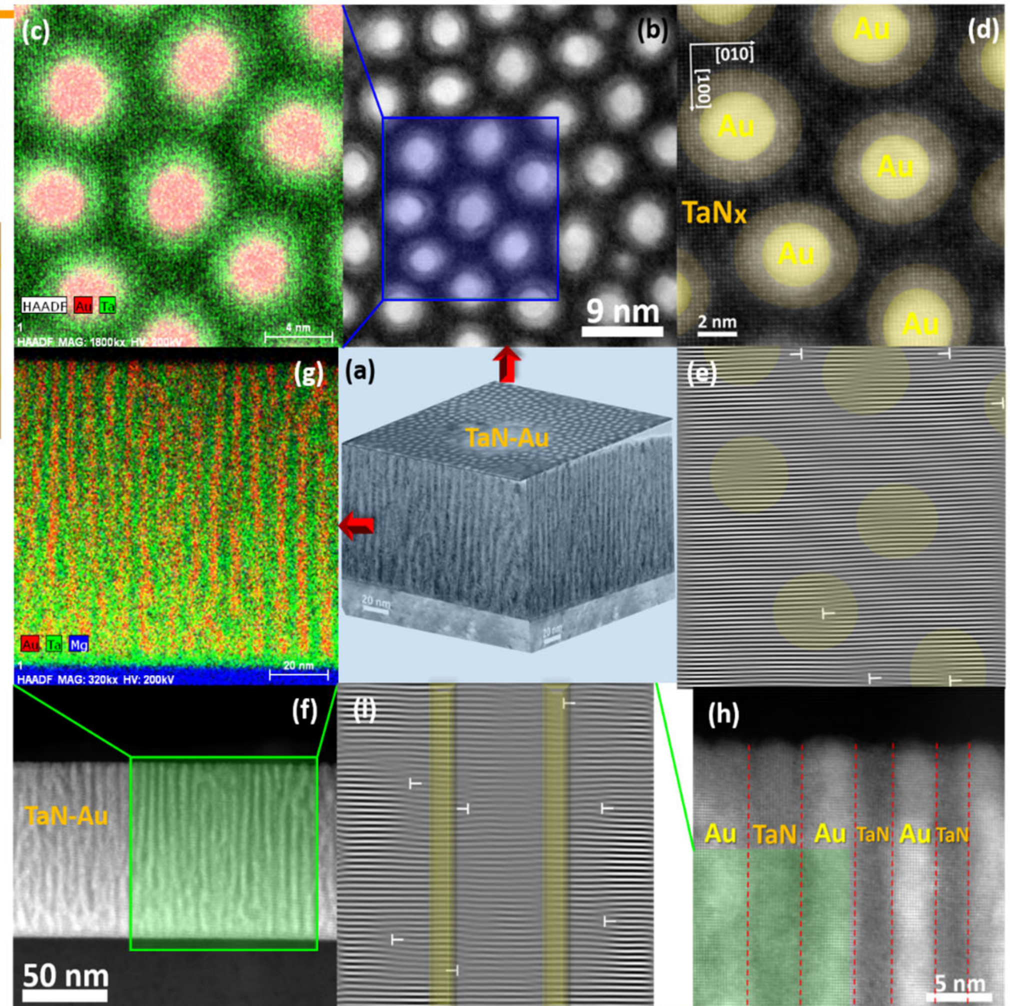
Nanoscale Artificial Plasmonic Lattice in Self-Assembled Vertically Aligned Nitride-Metal Hybrid Metamaterials





- Why nitride? High thermal and mechanical stability; metallic ceramics, plasmonics, and easy to coat on various substrates.
- Why Au? Plasmonic and stable noble metal with strong potential for sensing and photocatalytic applications.
- Why nitride-Au? Hybrid plasmonic lattice for engineered plasmonic resonance wavelength range and optical anisotropy.

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J. Huang, H. Wang, et al., Advanced Sciences, 2018.

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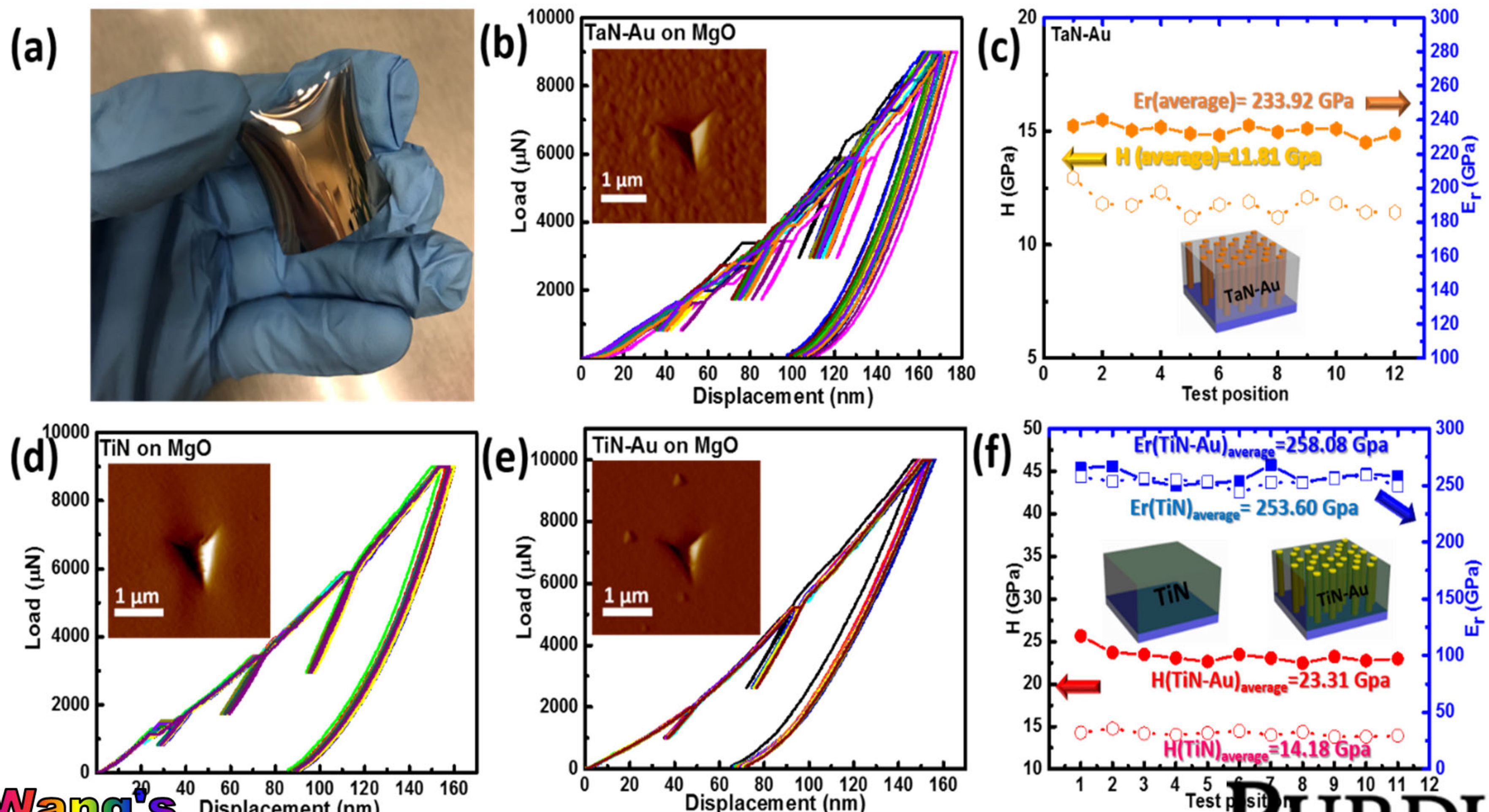
Vertically Aligned Nitride-Metal Hybrid Metamaterials can be coated on irregular substrates with mechanical integrity.



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J. Huang, H. Wang, et al., *Advanced Sciences*, 2018.

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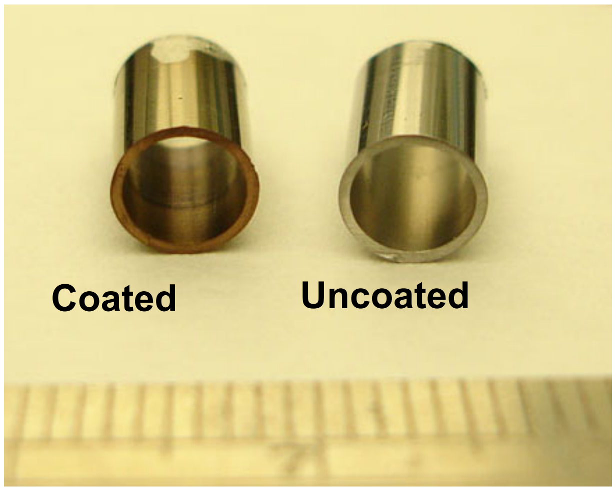
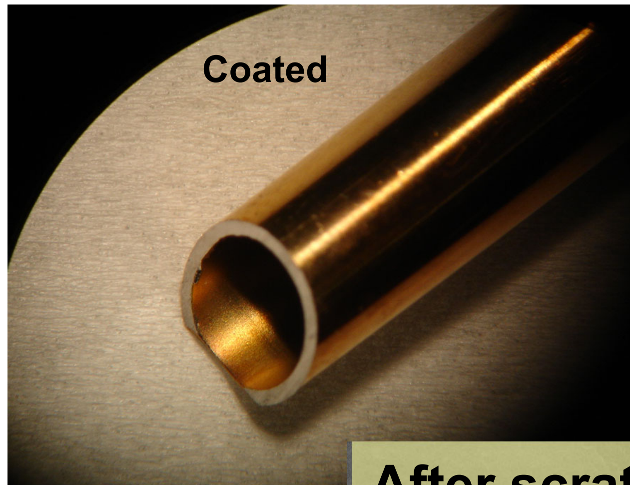
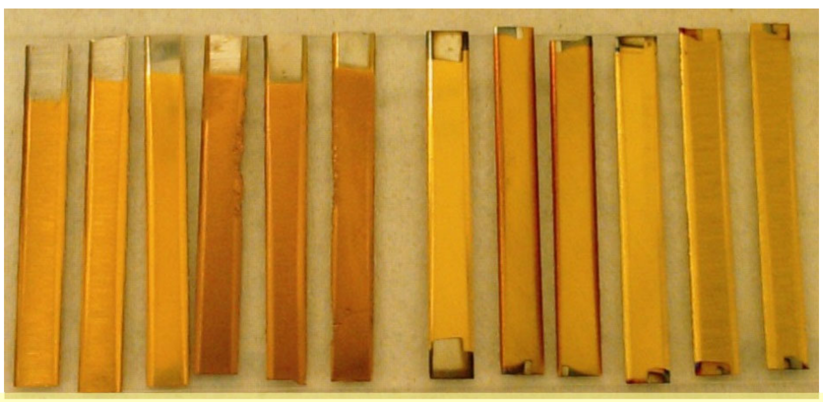
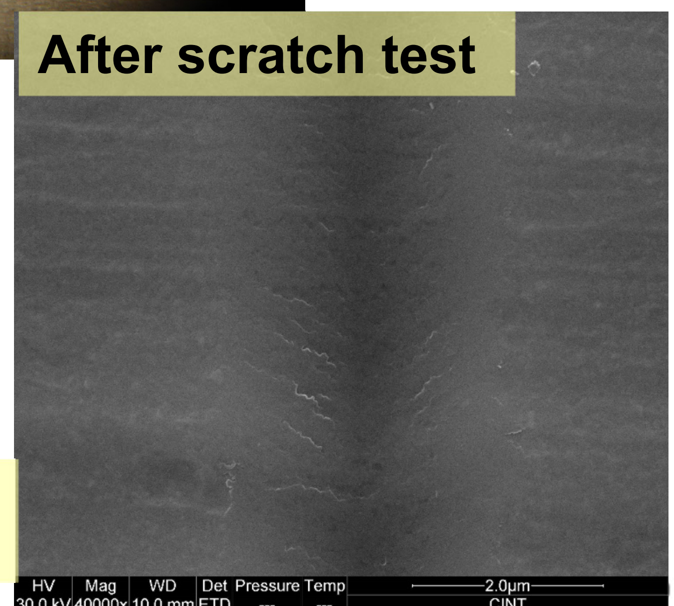
Outer and inner tube deposition of TiN on HT-9 tubes and bars







Thermal cycle testing done on all the HT-9 bars showed excellent adhesion of the coating.



What are we proposing to do

- VO_2 phase change materials on irregular glass surface for smart window applications; color change as a function of temperature;
- Plasmonic nitride coatings for high temperature plasmonic applications on metallic or glass surfaces, for color change or surface plasmonic properties;
- DLC (diamond like carbon) coatings on irregular surfaces for mechanical protections and coatings;
- Nitride nanocomposite coatings on tool surfaces for wear resistance and corrosion resistance.

Why us? Group Capabilities:

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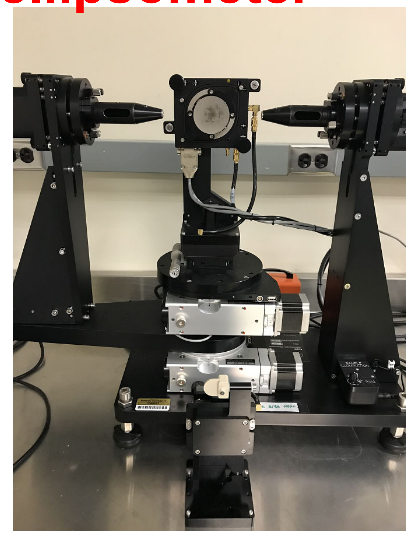
XRD

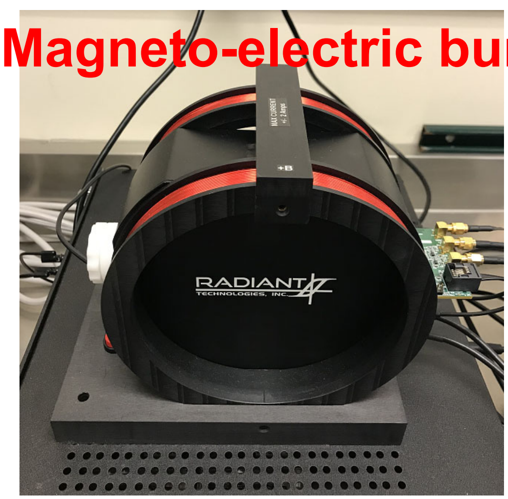
AFM/PFM

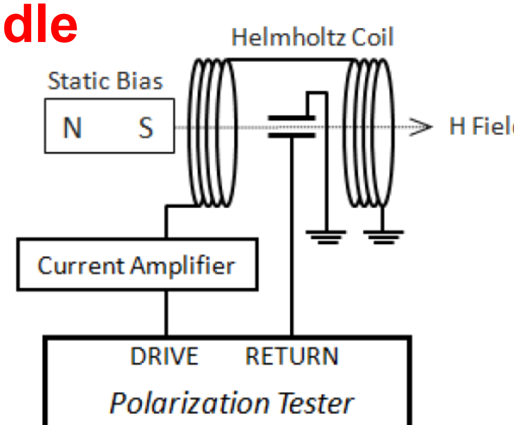
Spectroscopic ellipsometer



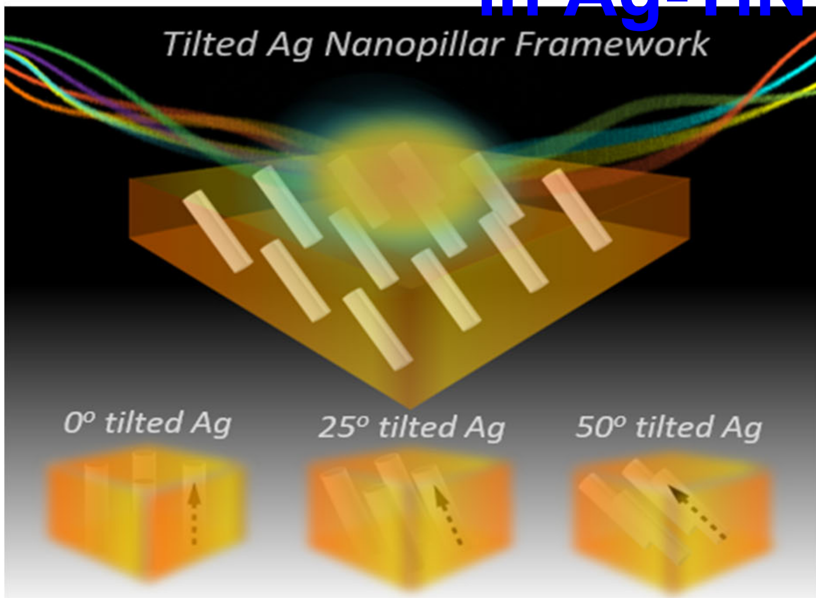
Optical spectrophotometer

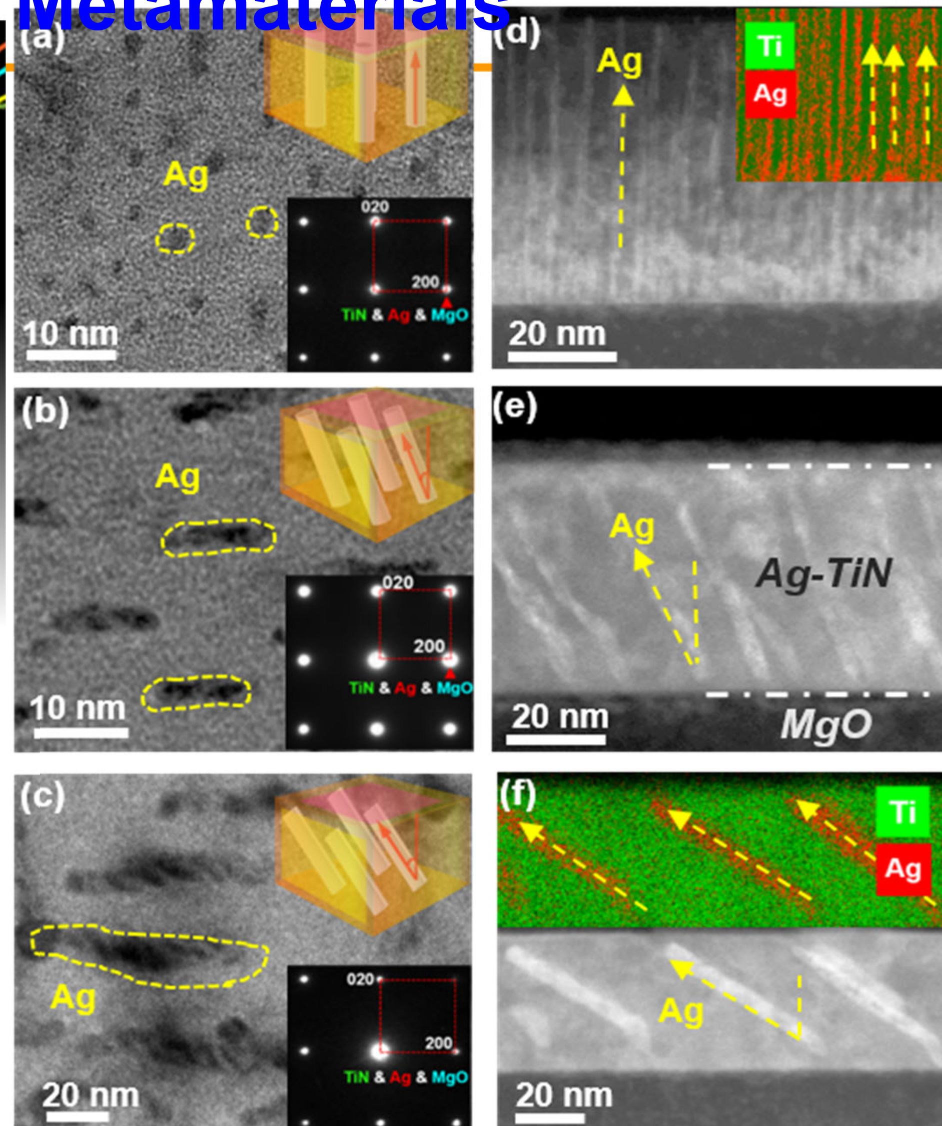
Magneto-electric bundle





Tunable Angular Selectivity-- Tailorable Tilted Nanopillar and Optical Properties in Ag-TiN Metamaterials



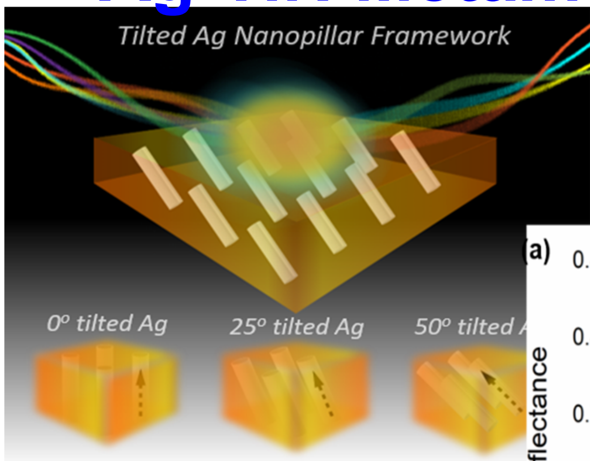


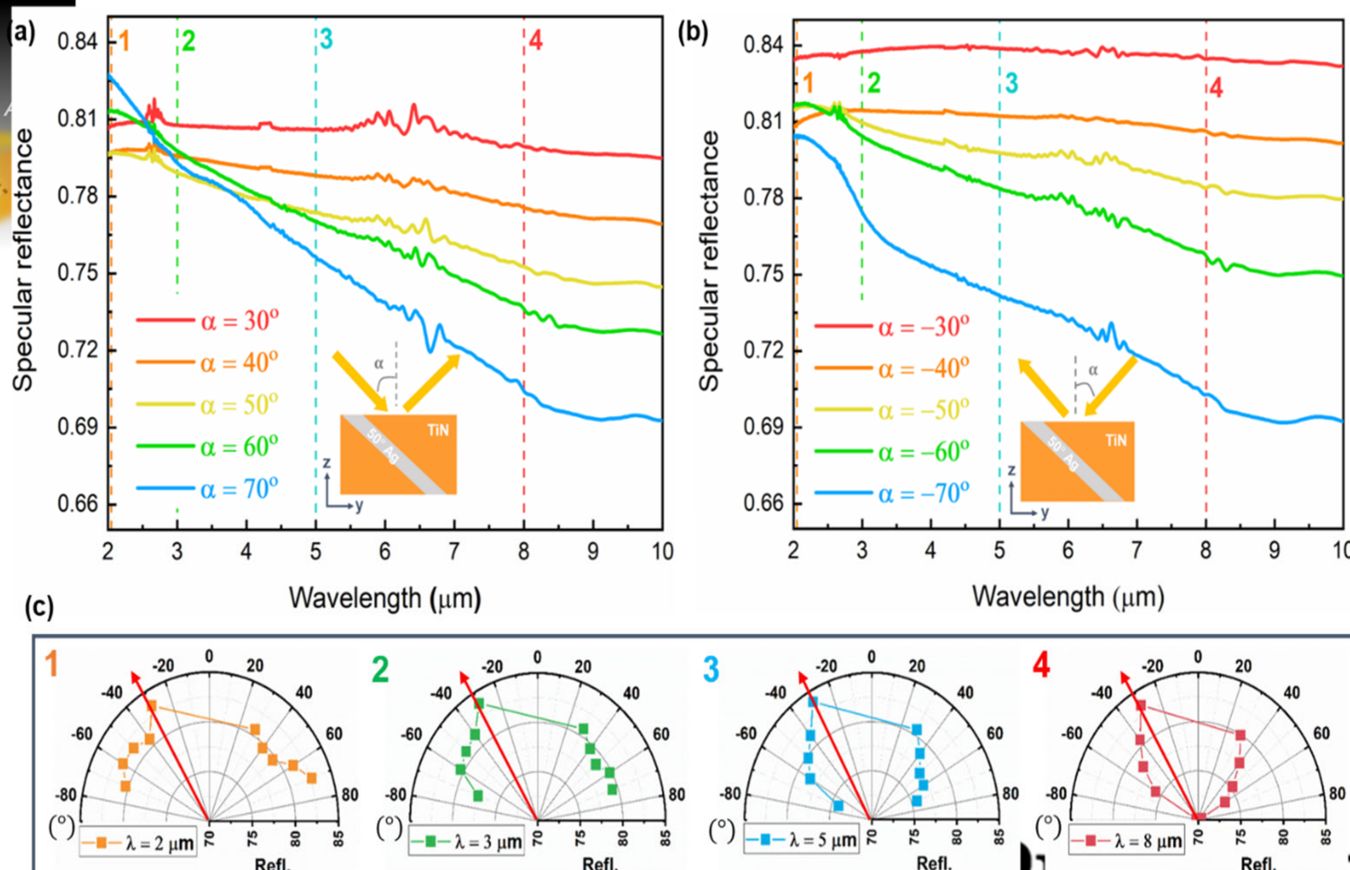
Key Highlights:

- **Self-assembly of Ag-TiN hybrid nanocomposite structure;**
- **High epitaxial quality, no inter-diffusion;**
- **Controllable tilting of nanopillars from 0° ~ 50°** for optical angular selectivity;

X. Wang, H. Wang, et al., Advanced Optical Materials, 2018.

Tunable Angular Selectivity-- Tailorable Tilted Nanopillar and Optical Properties in Ag-TiN Metamaterials

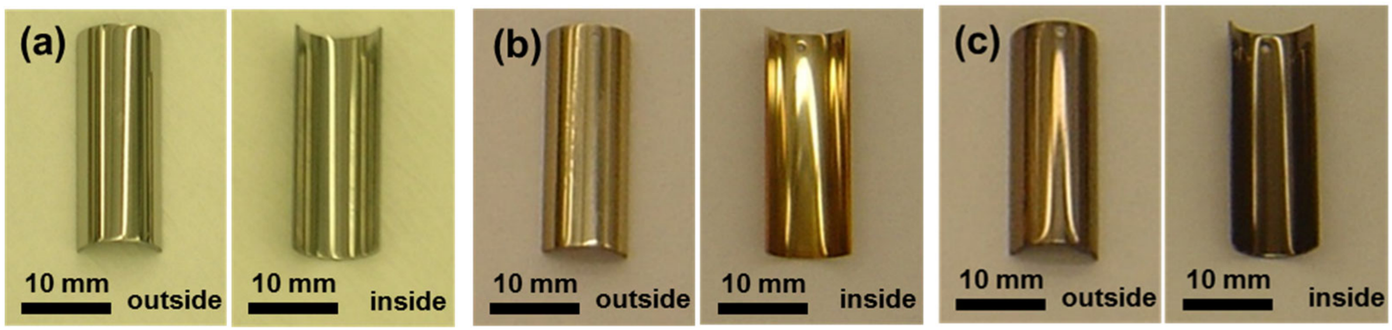




- ❖ Polar plot at 2 μm, 3 μm, 5 μm and 8 μm indicate selective high reflectance at -30° incidence;
- ❖ Selectivity can be improved with enhanced ordering of tilted nanopillars, 75 ~ 80% (current) -> 100% (ideal).

X. Wang, H. Wang, et al., Advanced Optical Materials, 2018.

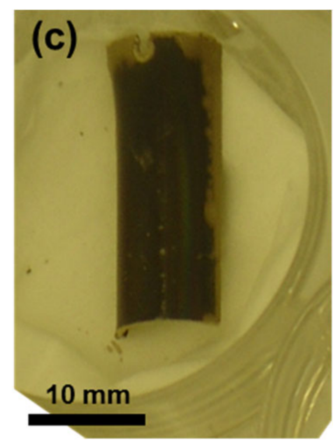
Excellent Corrosion Resistance Properties
All Tube Samples before and after Supercritical Water Test



(a) bare uncoated Zr-4 tube sections, (b) TiN-coated Zr-4 tube sections, and (c) $Ti_{0.35}Al_{0.65}N$-coated Zr-4 tube sections.

(a) bare uncoated,

(b) TiN-coated



(c) $Ti_{0.35}Al_{0.65}N$-coated Zr-4

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Journal of Nuclear Materials, 451, 346-351,.2014.

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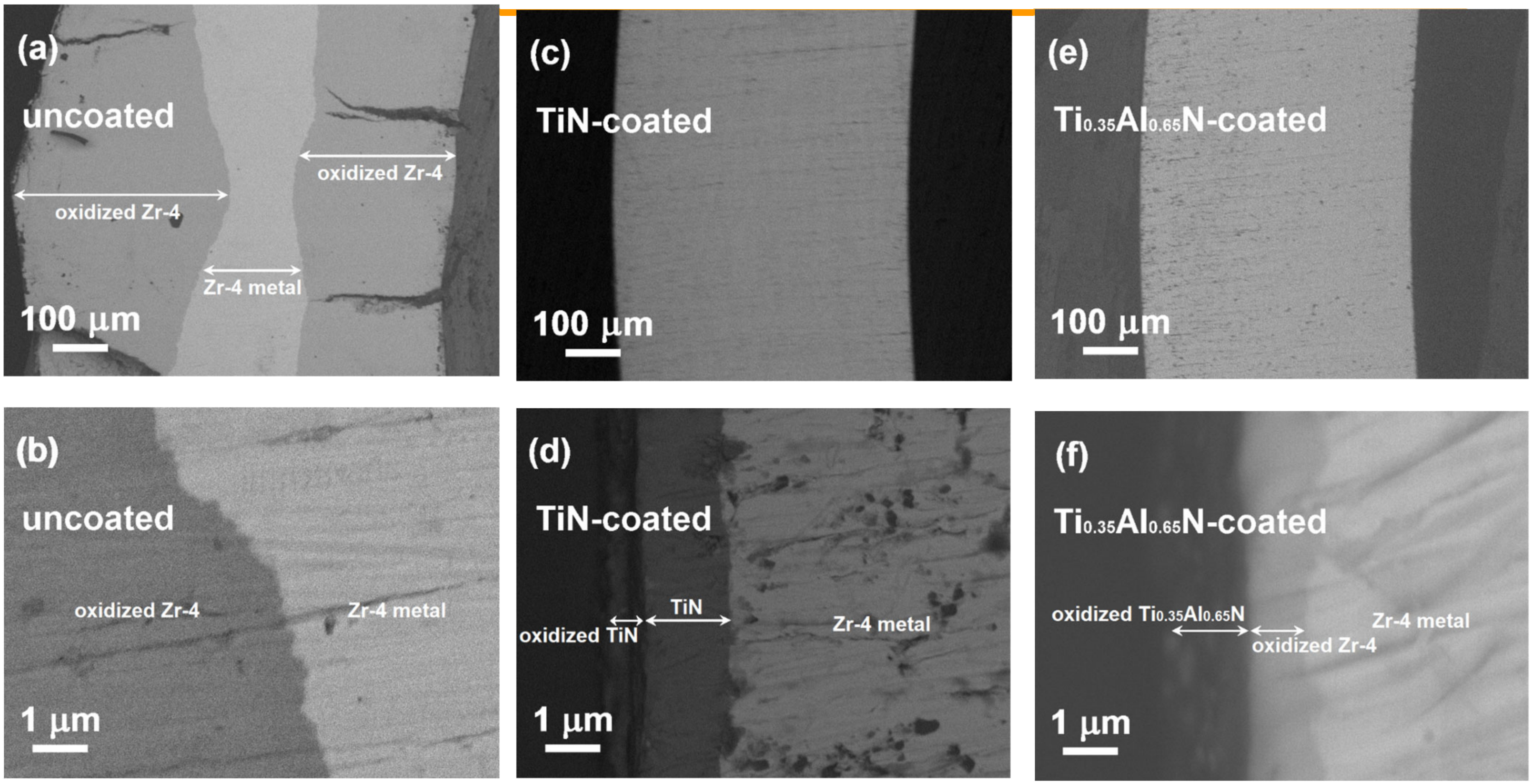
SEM: Cross-sectional interfaces of the tested samples



Nitride coatings effectively prevented the corrosion and diffusion during the supercritical water test.

Journal of Nuclear Materials, 451, 346-351,.2014.