IOCN 2020

2nd International Online-Conference on Nanomaterials

15–30 NOVEMBER 2020 | ONLINE

ALD deposited ZnO:Al films on mica for flexible liquid crystal devices

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Section: Polymer Nanomaterials, Nanocoatings/Thin films and Nanostructured Surfaces

nanomaterials MDPI

Comparison of AZO/Glass with ITO/Glass

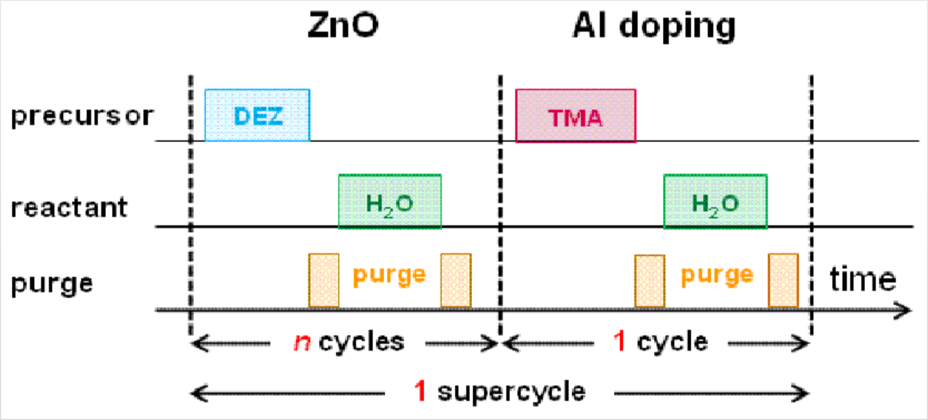
Three main requirements for foldable transparent electrodes:

- optical transparency,
- low sheet resistance,
- and high stability during bending without significant decrease in the electrical performance

Al-doped Zinc Oxide (AZO) is very attractive among transparent conductive oxides (TCOs), due to its high thermal stability, good resistance to damage by hydrogen plasma and low fabrication cost, compared to the ITO.

In addition to equivalent electrical and optical properties, AZO has further advantages over ITO like larger abundance, layers flexibility and lack of toxicity

	Al-doped ZnO (ZnO:Al)	Indium tin oxide (ITO)
Low resistivity (Ω cm)	10^{-5}	10^{-5}
Practical resistivity (Ω cm)	2-3x10^{-4}	1x10^{-4}
E_g (eV)	3.3	3.7
Index of refraction	2	2
Work function	4.6	4.8 - 5
Transparency in NIR spectral range	Yes	No
Cost	Inexpensive	Very expensive



Super cycle for Al doped ZnO ALD

- **AZO/mica ~ 173 nm, 200ºC**
- **AZO/ PET ~ 100 nm, 100ºC (15 nm buffer layer of Al_2O_3)**

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XRD analysis of AZO/mica and AZO/PET

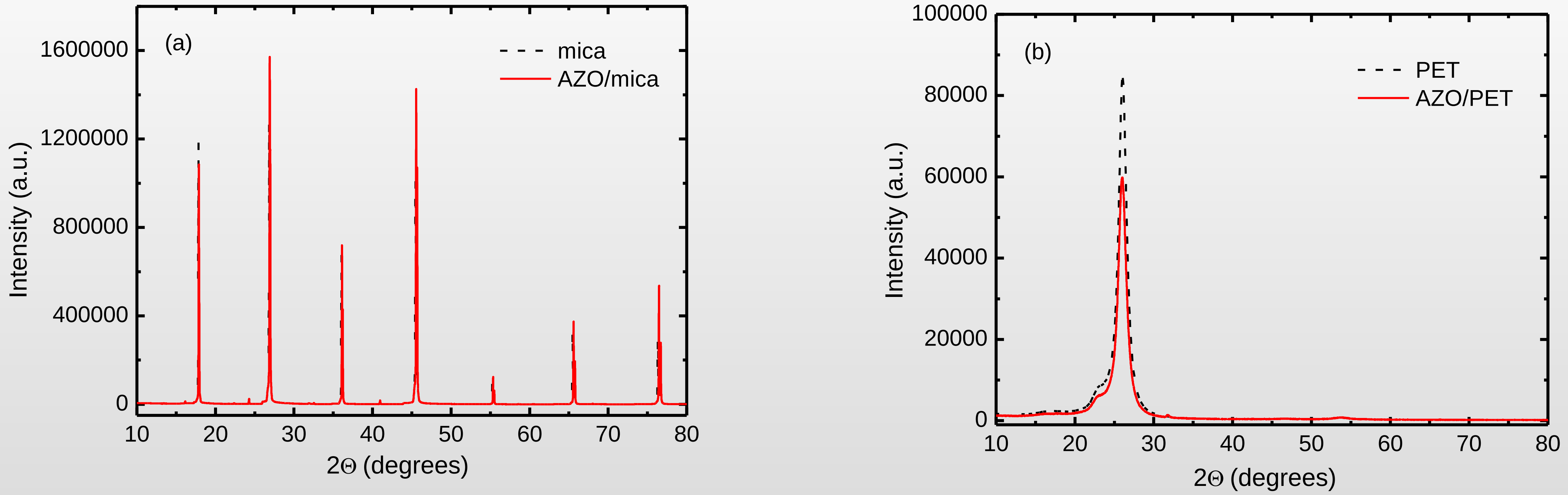
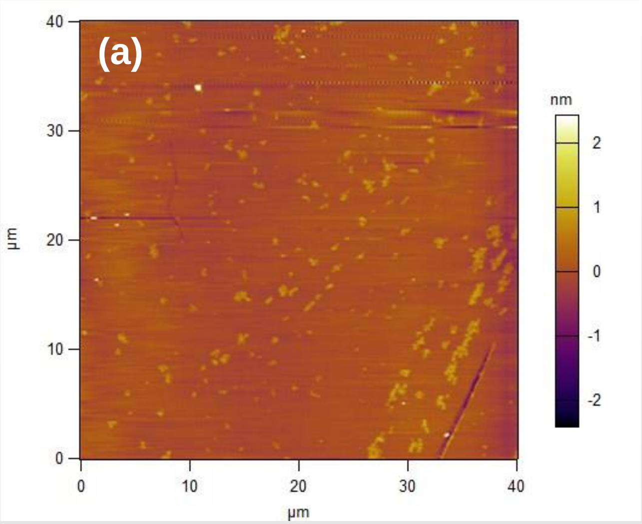


Figure: XRD of (a) AZO/mica and (b) AZO/PET structures

- AZO/mica: observation of only AZO (001) diffraction peaks suggests the epitaxial nature of TCO thin films without other secondary phases.
- AZO/PET: shows mostly reflections from the PET substrates and weak (100) peak, (002) and (101) are not detectable, (110) is very weak presumably pointing to the inferior crystallinity of the low-temperature deposited AZO.

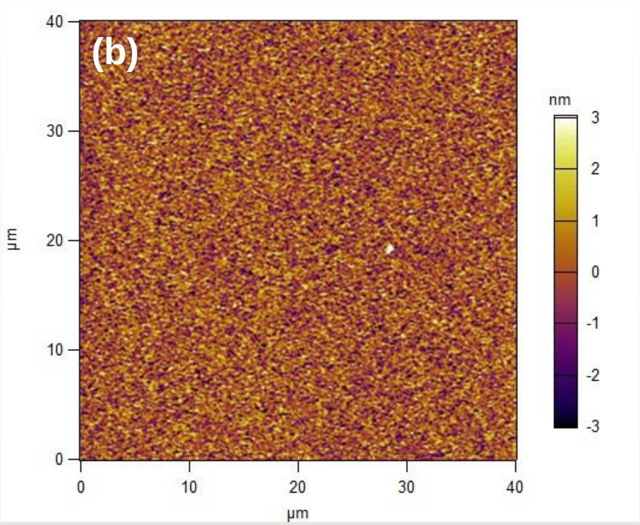
AFM analysis of AZO/mica and AZO/PET

Mica



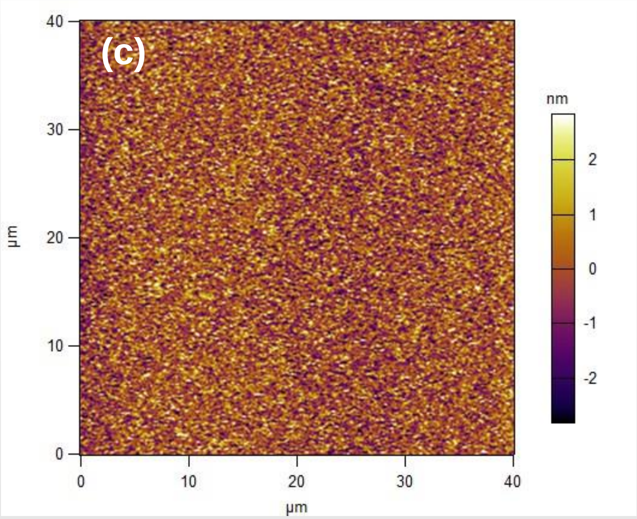
RMS: 249.042 pm

AZO/mica before bending



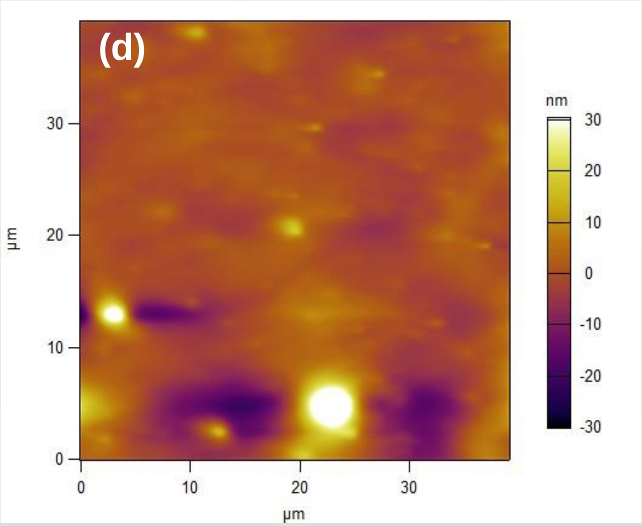
RMS: 1.061 nm

AZO/mica after bending



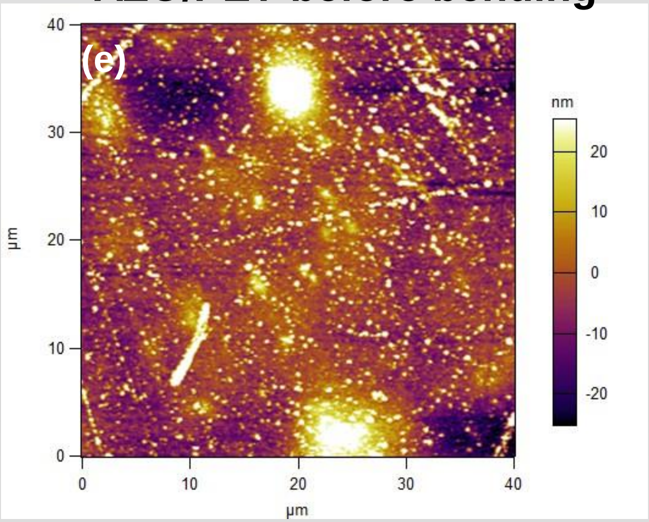
RMS: 1.043 nm

PET



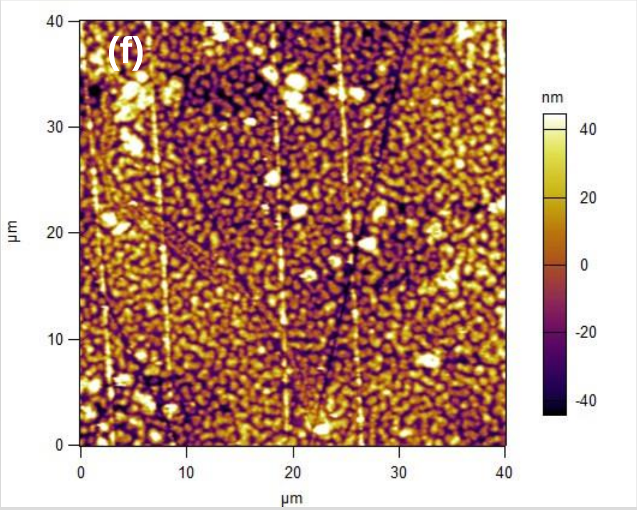
RMS: 6.263 nm

AZO/PET before bending



RMS: 12.45 nm

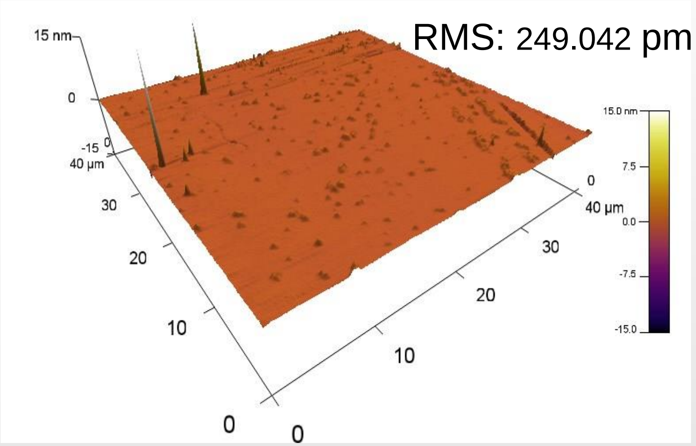
AZO/PET after bending



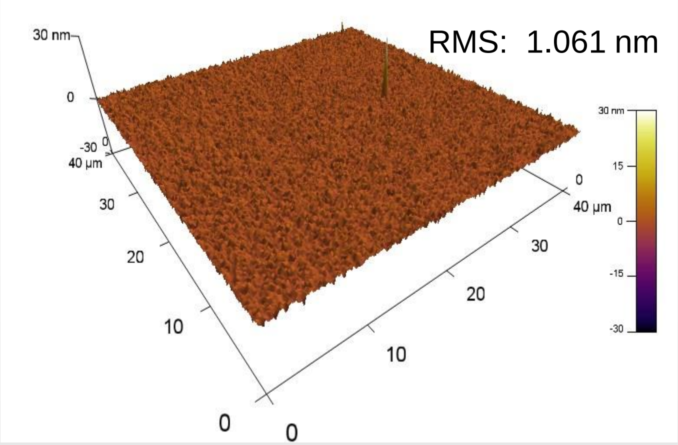
RMS: 22.03nm

AFM analysis of AZO/mica and AZO/PET

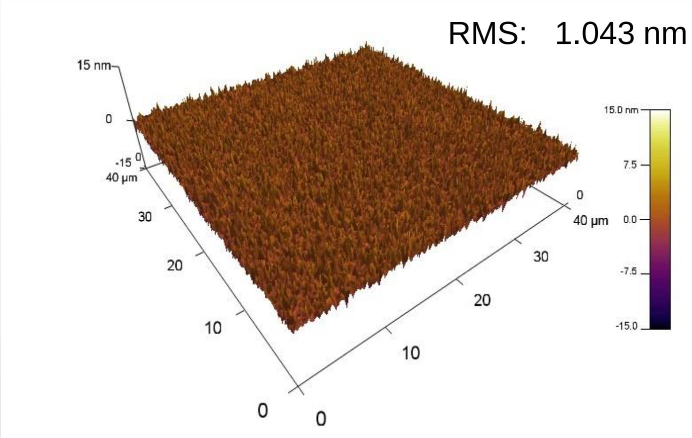
Mica



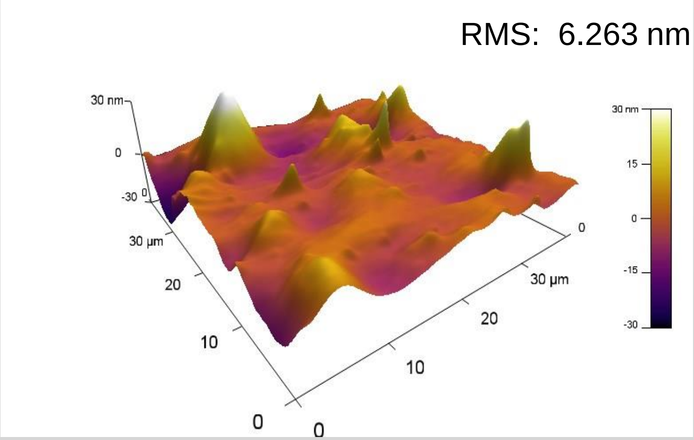
AZO/mica before bending



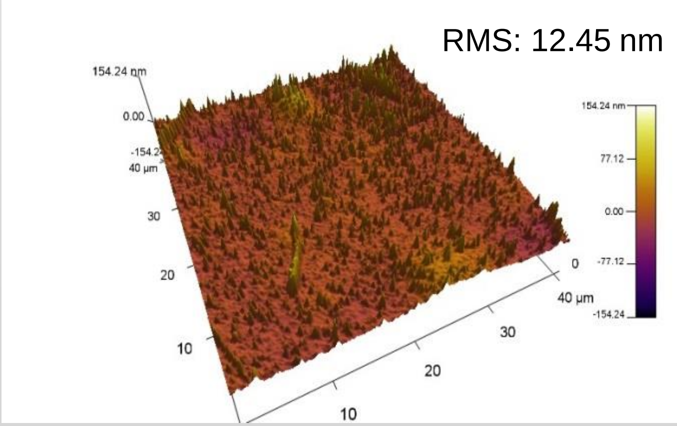
AZO/mica after bending



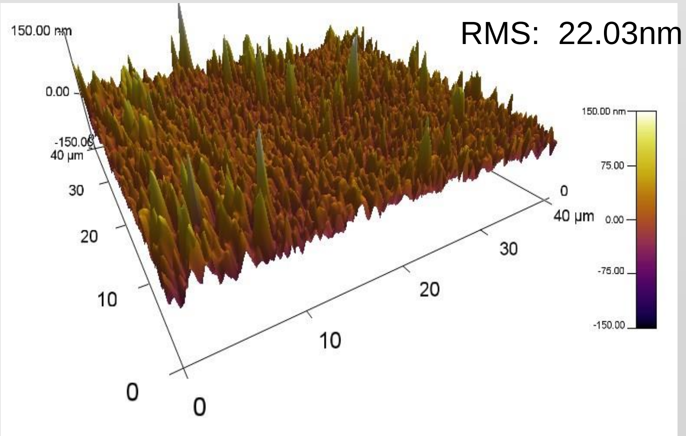
PET



AZO/PET before bending



AZO/PET after bending



- Freshly cleaved muscovite mica has very flat surface substrate- a prerequisite for growth of high quality AZO films
- RMS of AZO/mica does not change significantly after bending testing. However, RMS of AZO/PET increased almost twice presumably due to the surface deformation during bending.

Optical and electrical properties

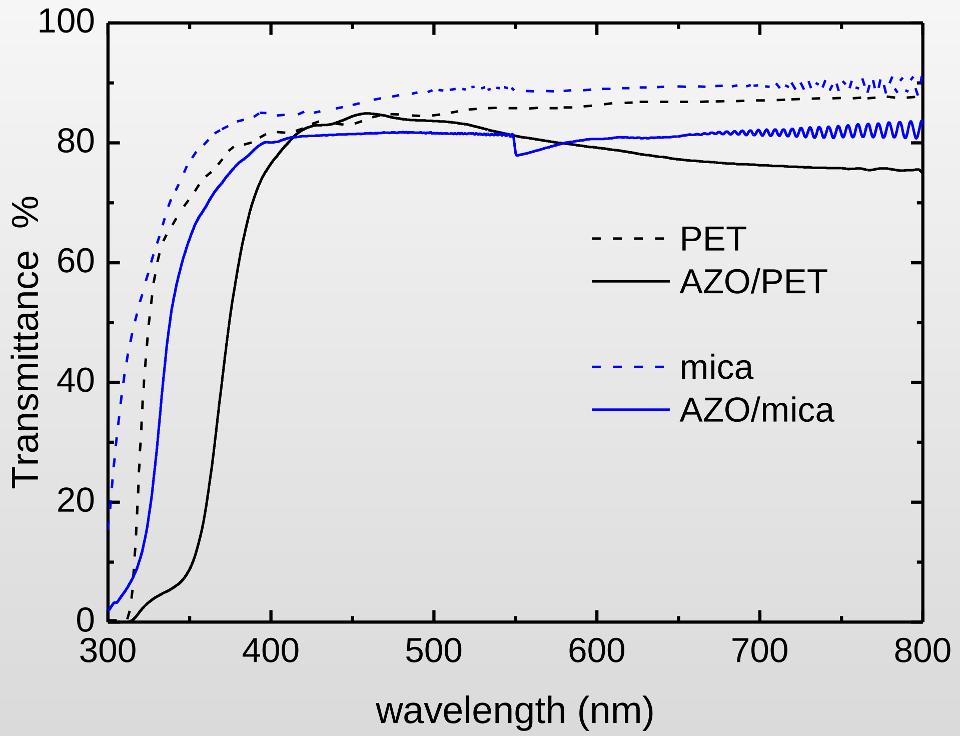


Figure: Transmittance spectra of AZO/mica and AZO/PET.

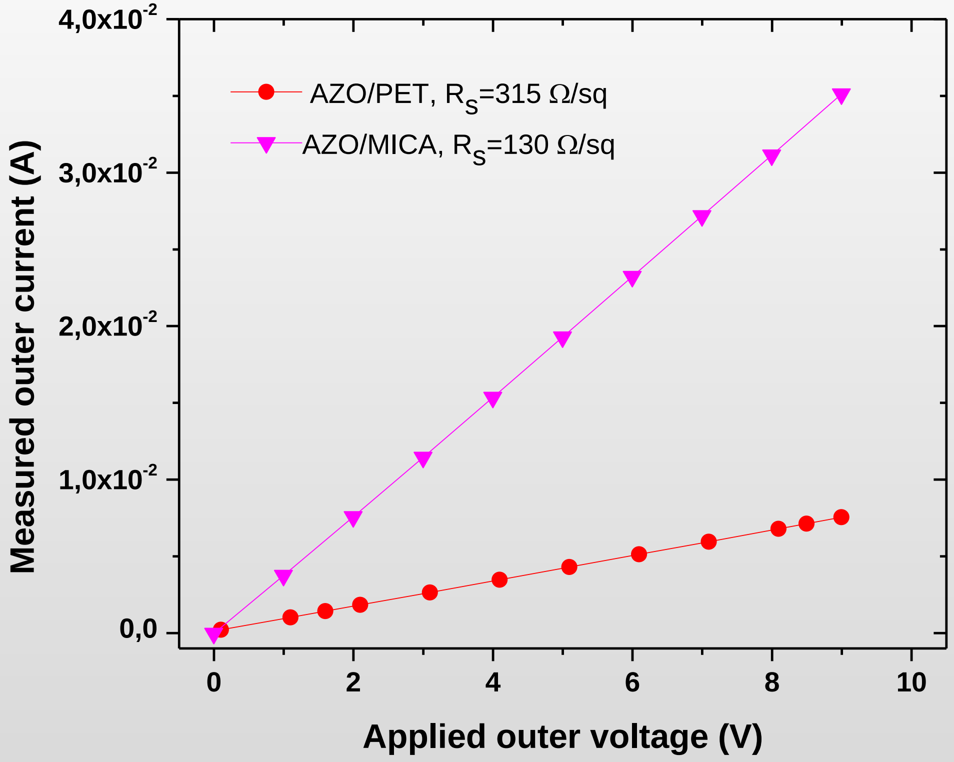
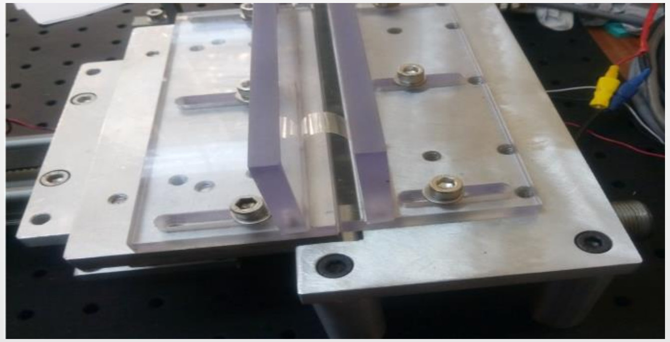
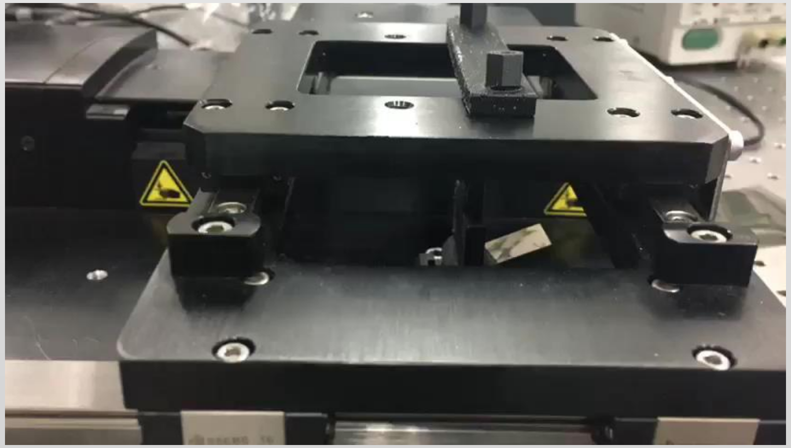


Figure: Ohmic behavior for AZO/mica and AZO/PET

- The absorption edges of AZO/mica and AZO/PET shifted to the longer wavelengths (red shift).
- Transparency of AZO/mica is higher than those of AZO/PET together with the benefit of improved conductivity.

Bending test ability of AZO/PET and AZO/MICA





Bending test set-up

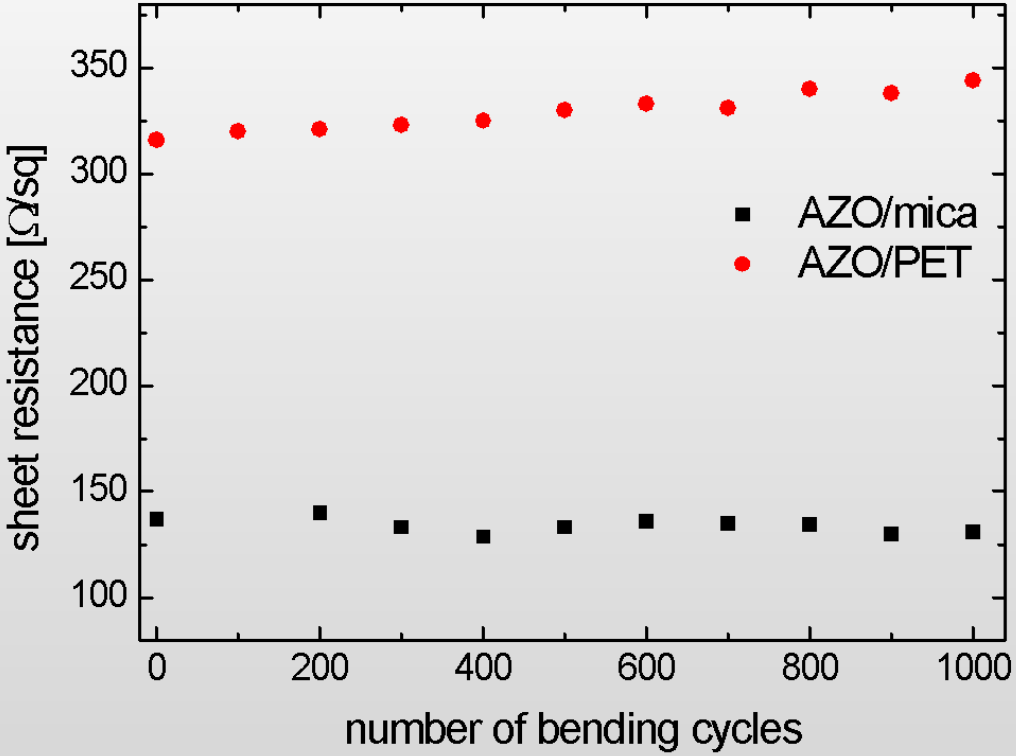
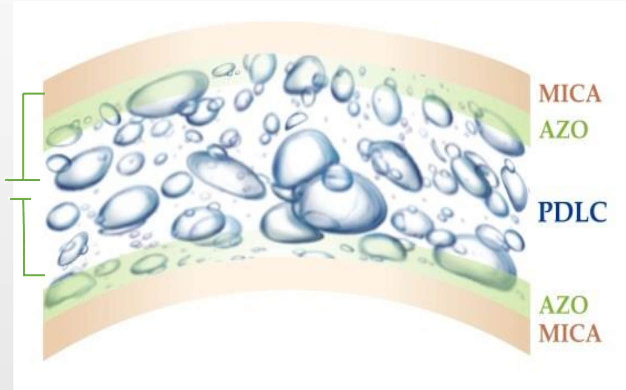
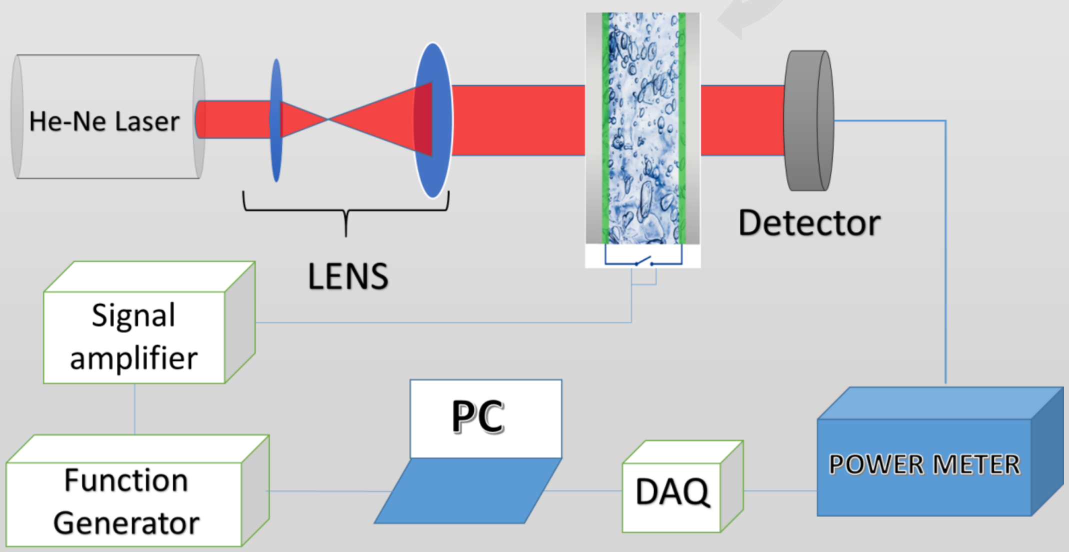


Figure: Sheet resistance dependence of the number of bending cycles for AZO/mica and AZO/PET

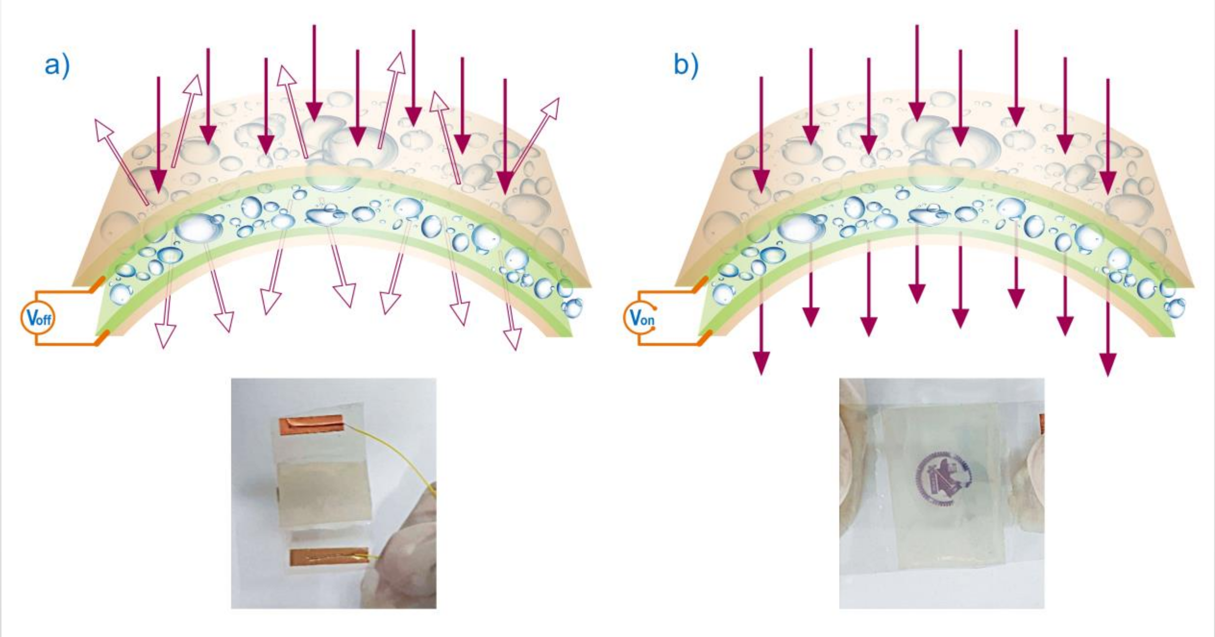
AZO as transparent conductive layer for flexible PDLC smart devices



Schematic structure of AZO/mica PDLC device



Experimental set-up to measure Voltage-Transmittance behavior and the response time



AZO/mica PDLC device at (a) “off” and (b) “on” states

Transmittance-voltage characteristics of AZO/mica and AZO/PET

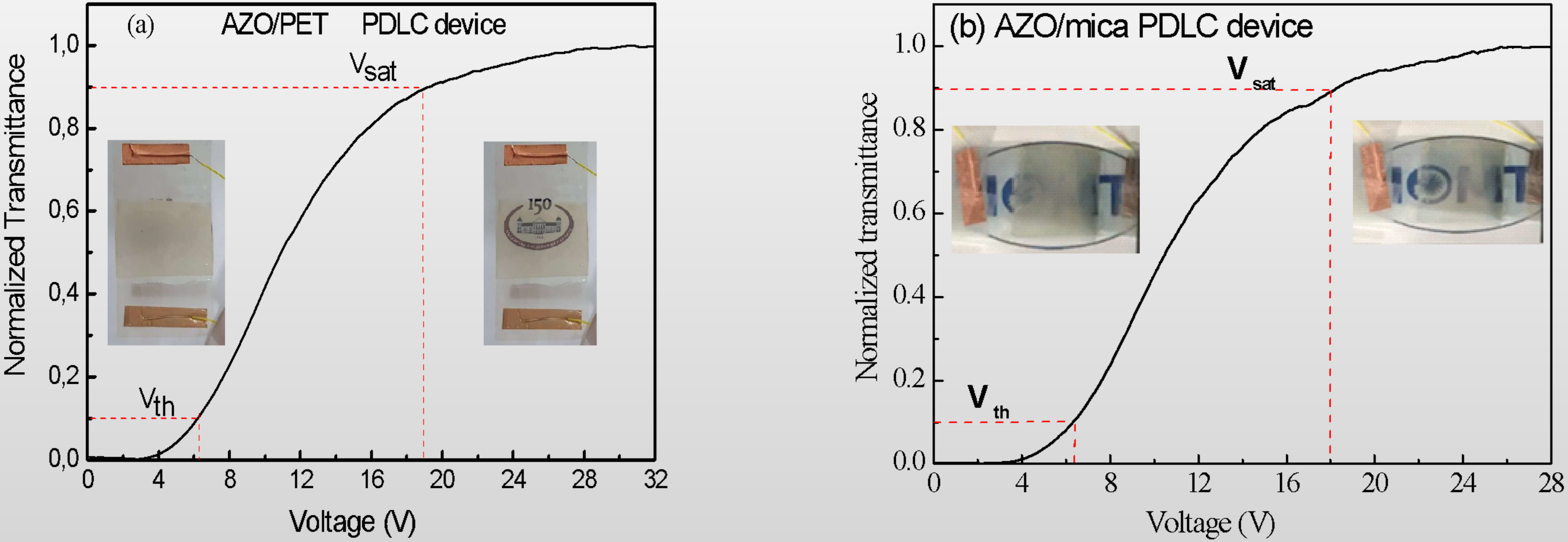


Figure: Voltage-transmittance curve and images at “off” and “on” states for AZO/mica and AZO/PET PDLC devices

Response time of AZO/mica and AZO/PET PDLC devices

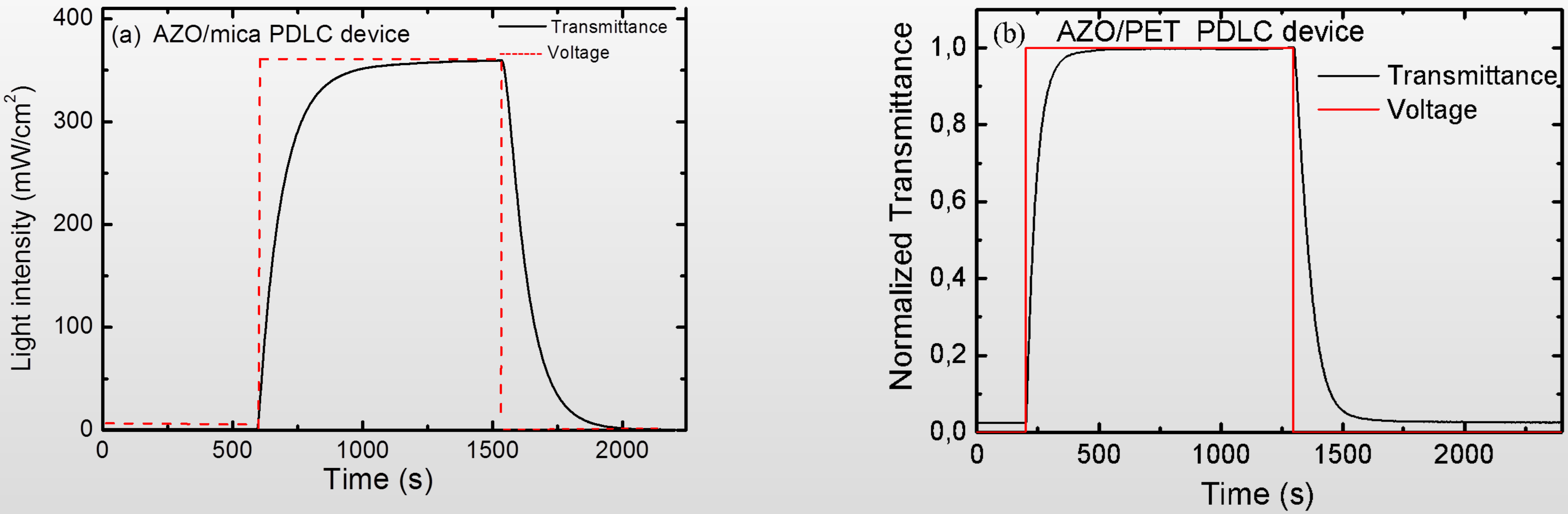


Figure: Response time of AZO/mica and AZO/PET PDLC devices

Conclusion

- High-quality AZO/mica with tunable optical and electrical properties are prepared by using ALD method.
- AZO/mica films have been succesfully implemented as transparent electrodes in PDLC devices

ФОНД НАУЧНИ ИЗСЛЕДВАНИЯ
МИНИСТЕРСТВО НА ОБРАЗОВАНИЕТО И НАУКАТА

Bulgarian Science Fund under the project DN-08/9

MOST 科技部
Ministry of Science and Technology

Ministry of Science and Technology (MOST), Taiwan contracts numbers: MOST 107-2221-E-009-120-MY3 and MOST 109-2927-I-009-507.

MINISTRY OF EDUCATION 教育部

Higher Education Sprout Project of the National Chiao Tung University (NCTU) and Ministry of Education (MOE), Taiwan.

Inframat

Research equipment of infrastructure INFRAMAT (Bulgarian National roadmap) supported by Bulgarian Ministry of Education and Science, D01-284/17.12.2019.

Thank you for your attention!