PLATH00007

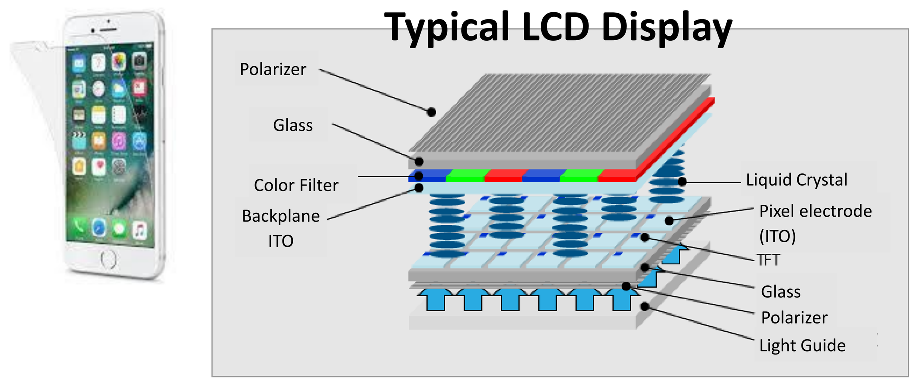
Deterioration mechanism of RF-sputtered ITO film on plastic substrates

Tsuneo FUKUDA, Masahiro TAGUCHI , Takayoshi SHINGU

Graduate School of Engineering, Osaka City University - OSAKA (Japan)

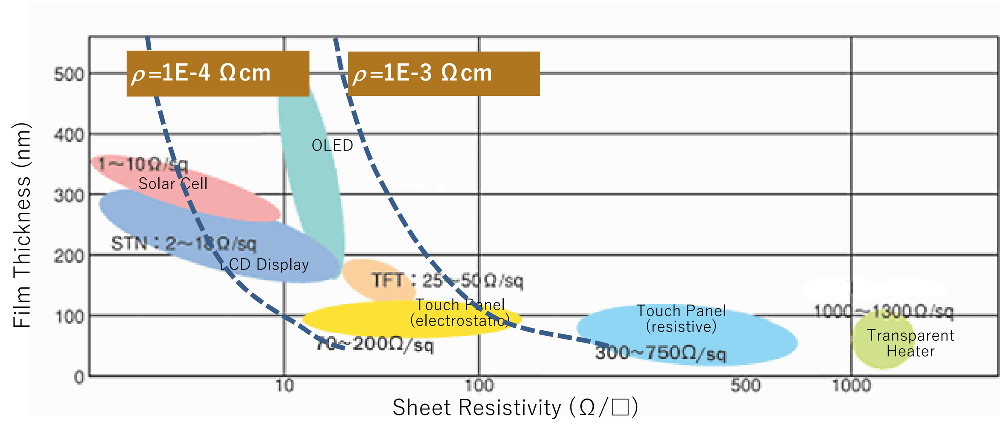
Introduction

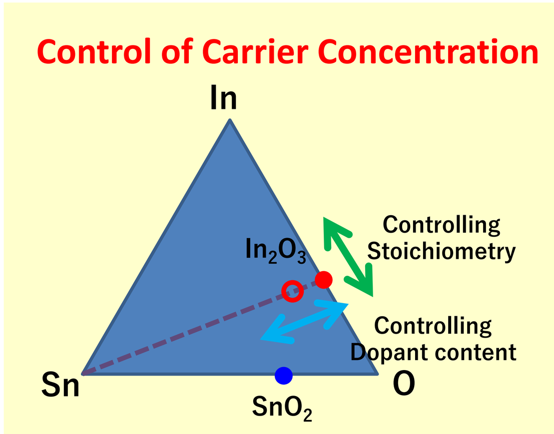
Forming thin films on flexible substrates such as polymer films is an important technical issue for manufacturing lightweight portable electronic devices. In particular, a transparent conductive film such as indium tin oxide (ITO) is indispensable technologies for liquid crystal displays as shown in Figures. Therefore, ITO film formation on flexible substrates that can be bent while maintaining low resistance and high optical transmittance is essential for the development of future portable display devices. However, research on the durability of such flexible transparent conductive films has only just begun, and there are many unclear problems regarding the mechanism of deterioration of electrical properties.



https://www.j-display.com/technology/lcdbasic.html

Item	Sheet Resistivity (Ω/□)	Bulk Resistivity ρ (Ωcm)	Transparency (%)	Material
Display (LCD/OLED)	2-20	<4E-4	>80	ITO
Display (Touch Panel)	100-1 k	<1E-2	>93	ITO
Solar Cell	1-10	<4E-4	>80 (with texture)	SnO_2:F AZO
Anti Reflecting Coating	N. R.	N. R.	Depending on application	ITO, SnO_2 TiO_2 etc.





Research Objective

- Forming a low resistance transparent conductive film on plastic substrates
- Evaluation of durability of transparent conductive film and clarify the deterioration mechanism

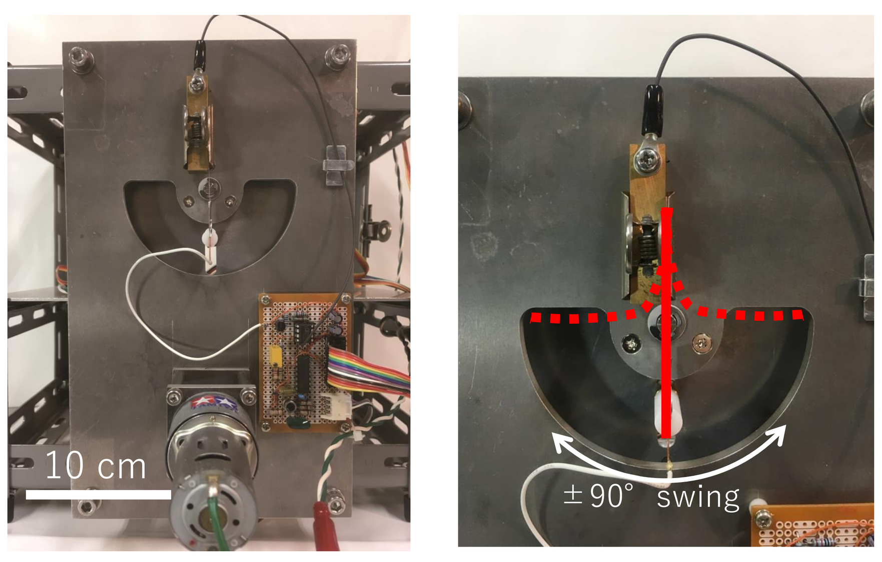
TCO Growth Condition

Substrate: Polyethylene naphthalate (PEN),
Teijin-DuPont Teonex QA65HA 125μm (Tg=155℃)
Growth Method: RF-magnetron sputtering
Growth Conditions:
Target: In_2O_3:SnO_2=90:10 (3'')
Power: 0.9W/cm^2
Sample-Target distance: 62 mm
Sputtering Gas: Ar+H_2 (O_2)
Film thickness: nom. 100 nm
Typical growth rate : 22 nm/min.
Sample temp. during film growth: Room Temperature (water cooled)

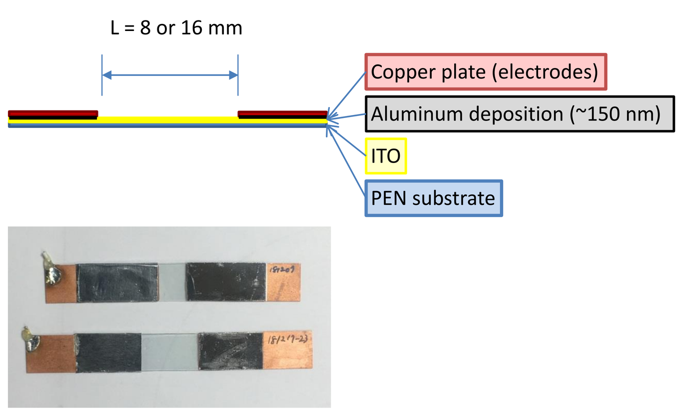
Evaluation

Film Thickness: Dektak 3030ST
Surface Morphology: AFM SII SPI-3800N
Carrier Mobility and Concentration: 4-terminal Van der Pauw (under ±1.0 T)
Optical transmittance: Home- made spectrophotometer
Crystallinity: XRD ($\theta - 2\theta$)
Durability: Home-made bending test equipment (In situ resistivity measurement possible)

Bending Tester



Test Sample

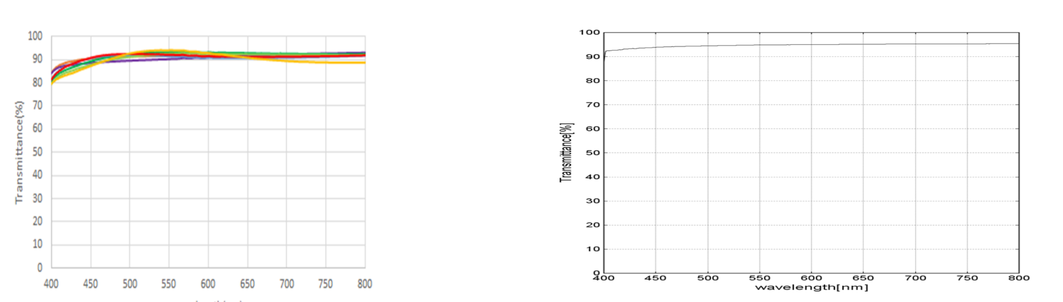


■ Two terminal *in situ* resistance measurement during bending test.

Results – Optical Transmittance

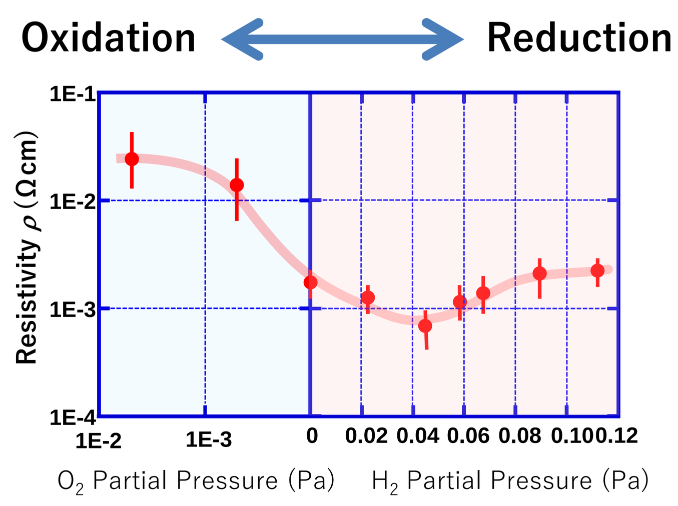
Transmittance (film absorption included)

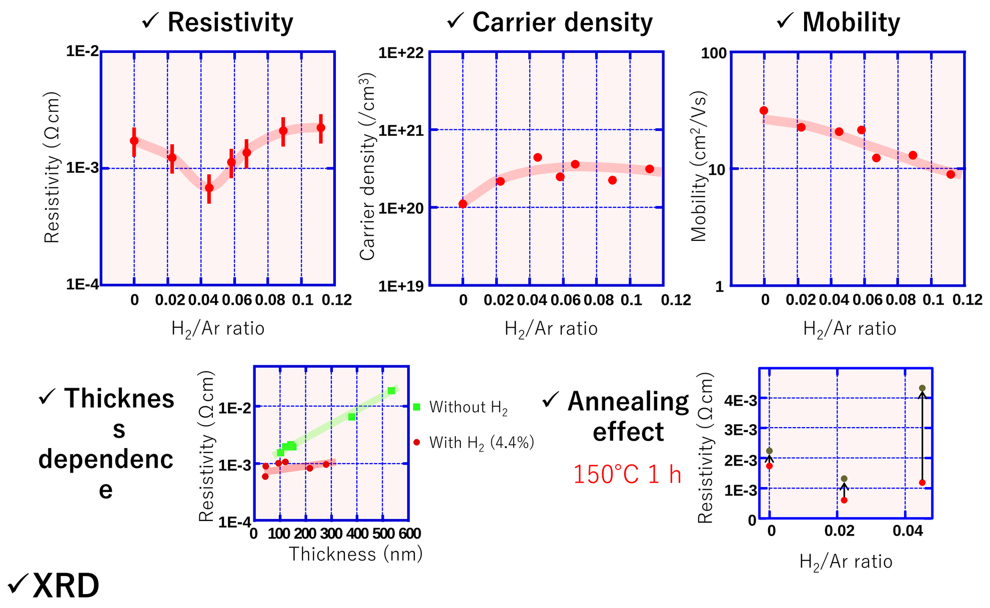
Transmittance (125 μm PEN film only)



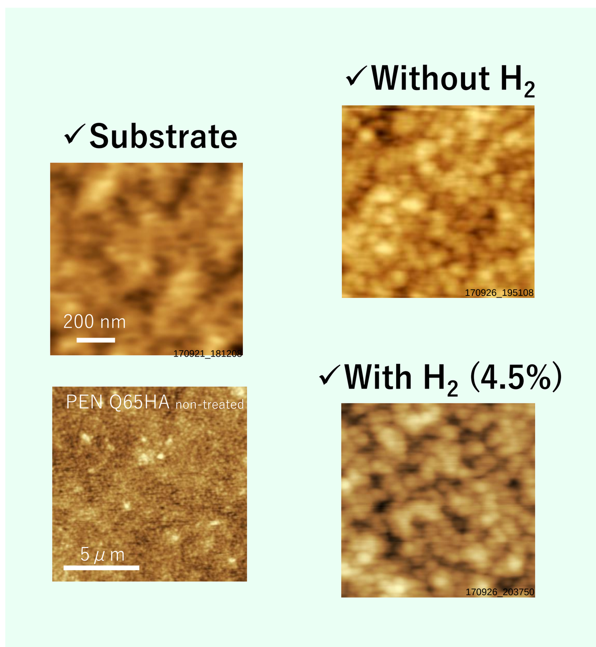
Results – Effect of H_2 and O_2 mixing

✓Resistivity

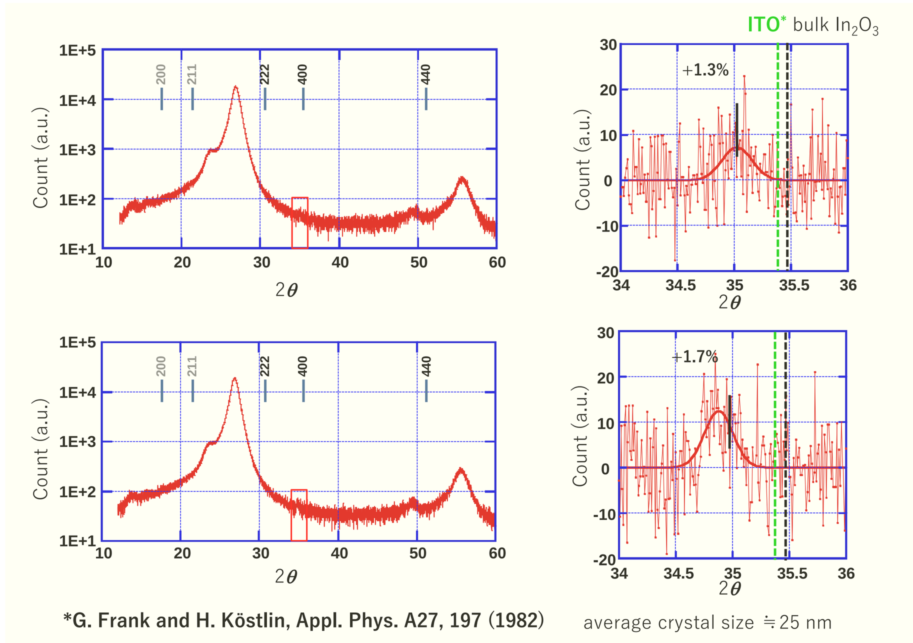




✓AFM image

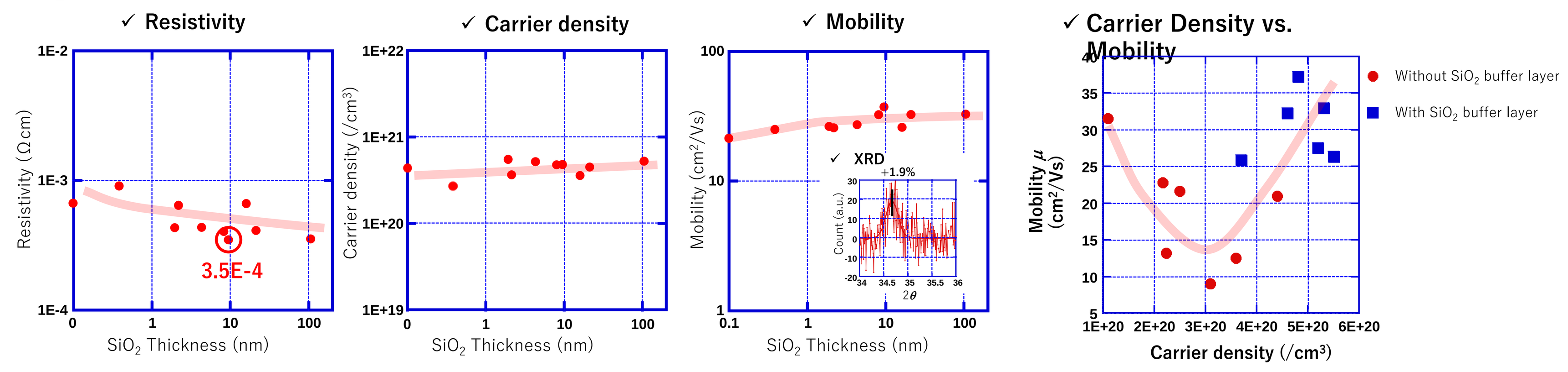


✓XRD



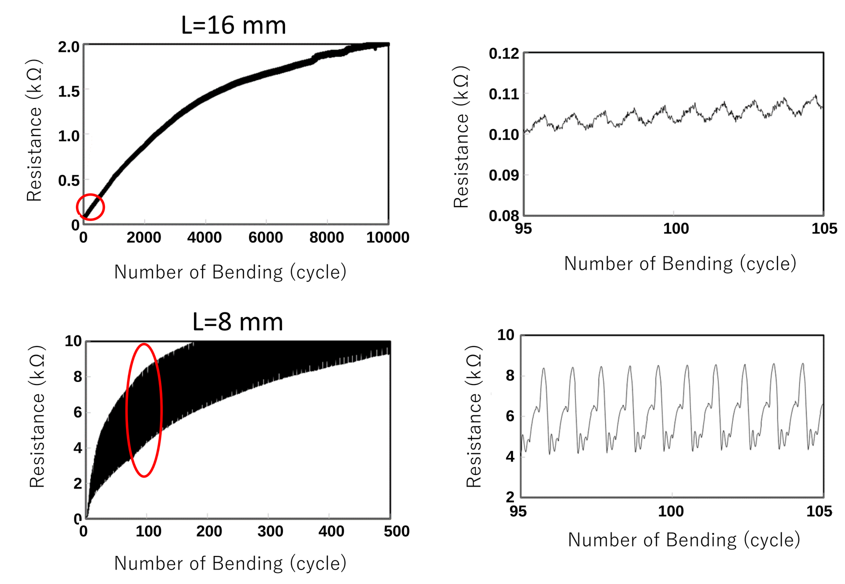
Results – Effect of SiO_2 buffer layer

H_2/Ar = 4.5%



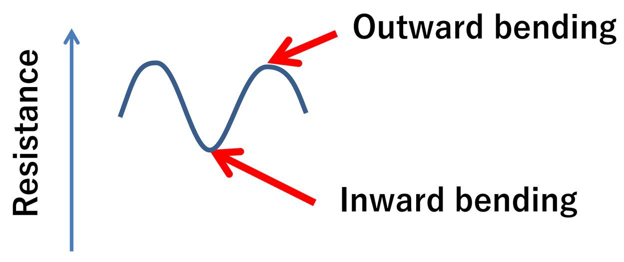
Bending Test

✓Resistance change by bending

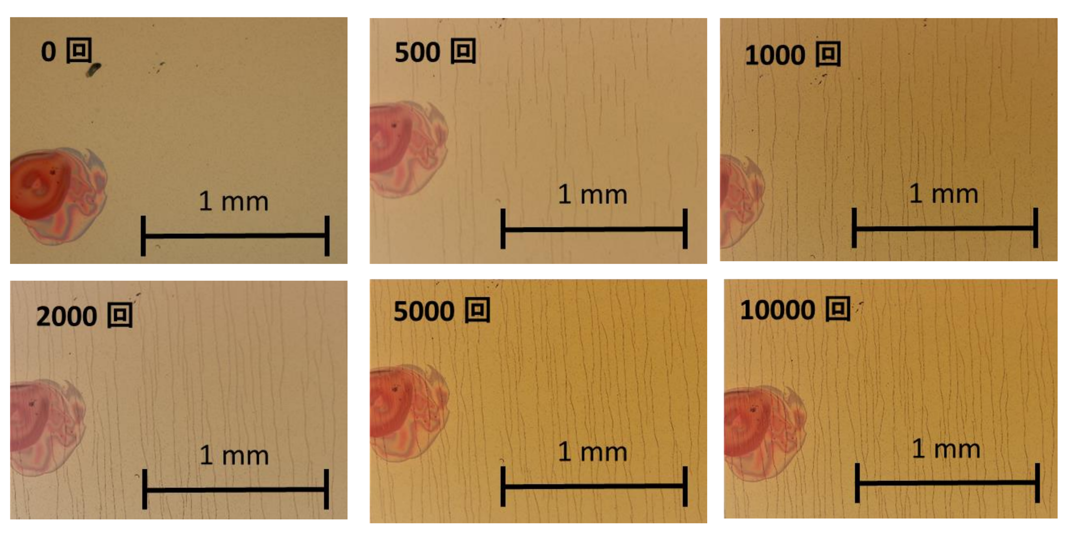


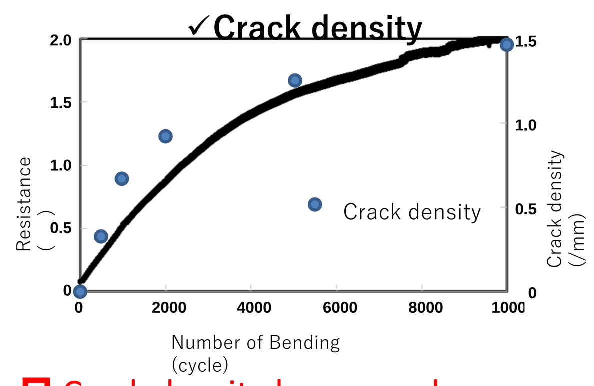
Resistance change has two part

- Slow rise in resistance due to the number of bends
- Increase and decrease of resistance by each bending cycle



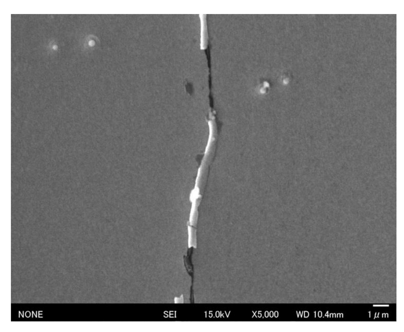
✓Crack formation – Optical microscopy observation



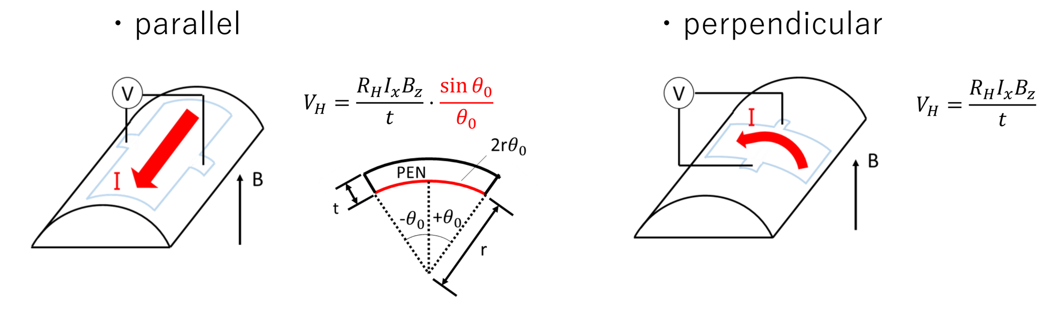


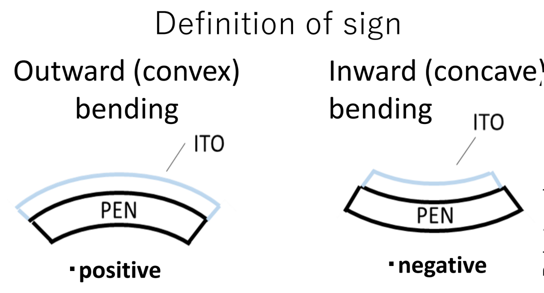
□ Crack density has a good correlation with the resistance!

✓SEM observation of individual crack

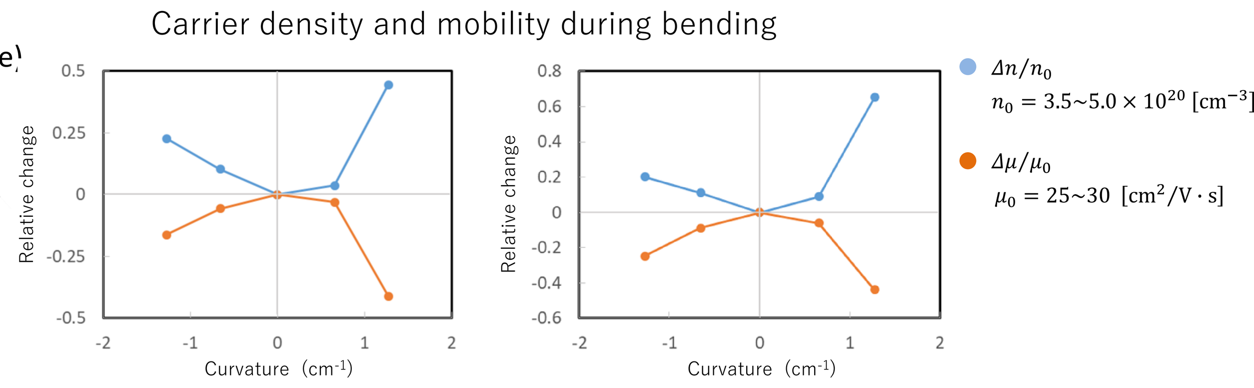


✓Resistance change – Hall measurement during bending





Carrier density and mobility during bending



□ Carrier density increased and mobility decreased in ether bending directions!

Take Home Messages

- Hydrogen addition and SiO_2 buffer layer insertion are effective for lowering resistivity of ITO films on the plastic substrate formed by RF-magnetron sputtering.
- There are two increase mechanisms in resistivity due to bending: deterioration in resistivity due to the number of bending cycles and a reversible change due to one bending.
- Optical microscopy revealed that the increase in resistance was caused by cracks in the film.
- reversible rise and fall of resistance in one cycle is due to the rise in carrier density and the decrease in mobility by bending.
- Durability due to bending has a critical value, and a strain of about 1% or more shortens the life of the ITO thin film.

Thank you for your kind attention