基于原子层沉积技术的ZnO:Al_2O_3材料制备及其在微通道板上的应用研究

闫保军，刘术林，衡月昆

高能所 探三组

11/04/2015

Content

I. Background

II. Performance of $ZnO:Al_2O_3$ (AZO) by atomic layer deposition (ALD)

Thickness uniformity, structure, element and resistivity

III. Performance of microchannel plate (MCP) via ALD method

Thickness, element uniformity and chemical analysis

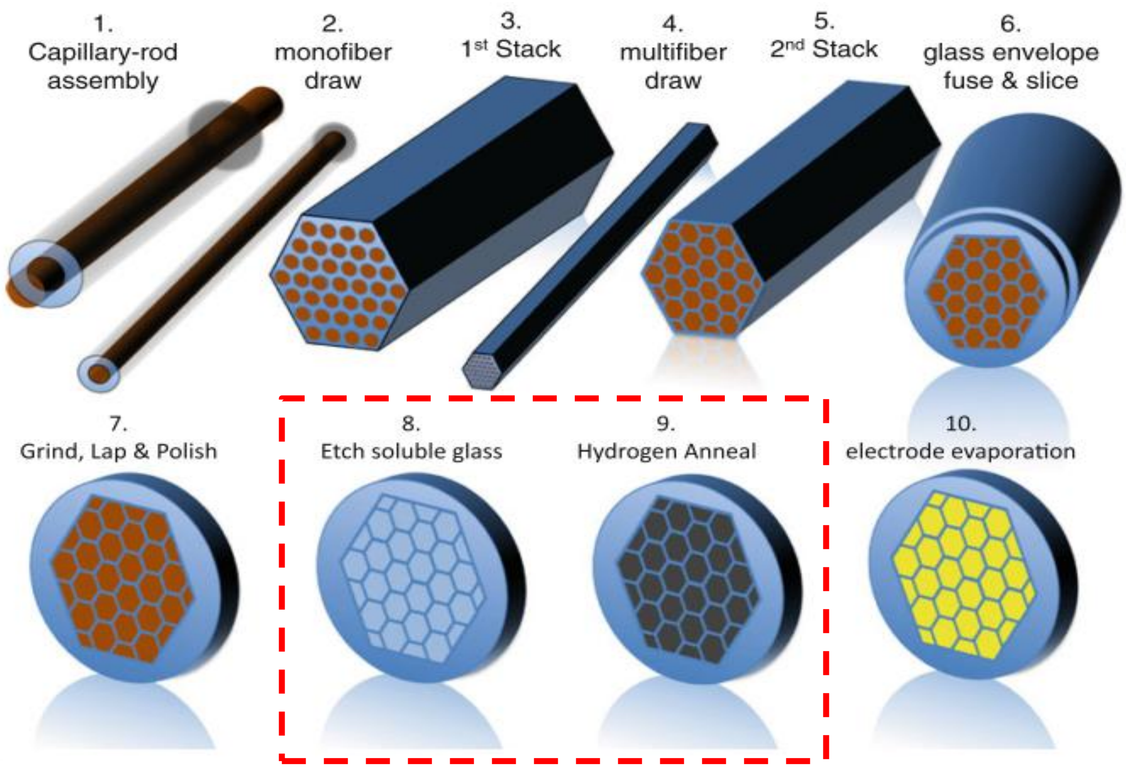
Gain and resistance

IV. Use of fund

V. Implementing status

1. Background

Microchannel plate (MCP) usually as a kind of electron multiplied device can be used in many scientific applications, such as MCP-PMT, night vision devices, electron microscopy. Traditional MCP is made of lead silicate glass, and production process is complex.



Traditional MCP drawbacks:

1.High noise.
chemical etching increase R_a on inner surface of pore， noise factor increase and S/N reduce when multiplied the opto-electrons.

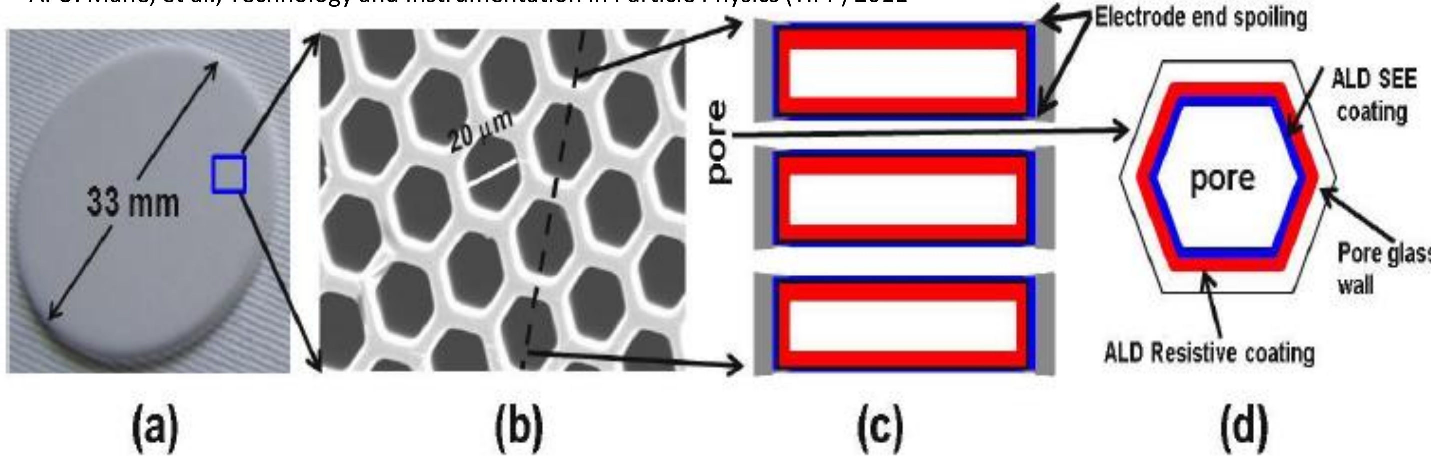
2. Vacuum baking and electron scrubbing result in MCP surface element variation and reduce the extracted charge and gain of MCP.

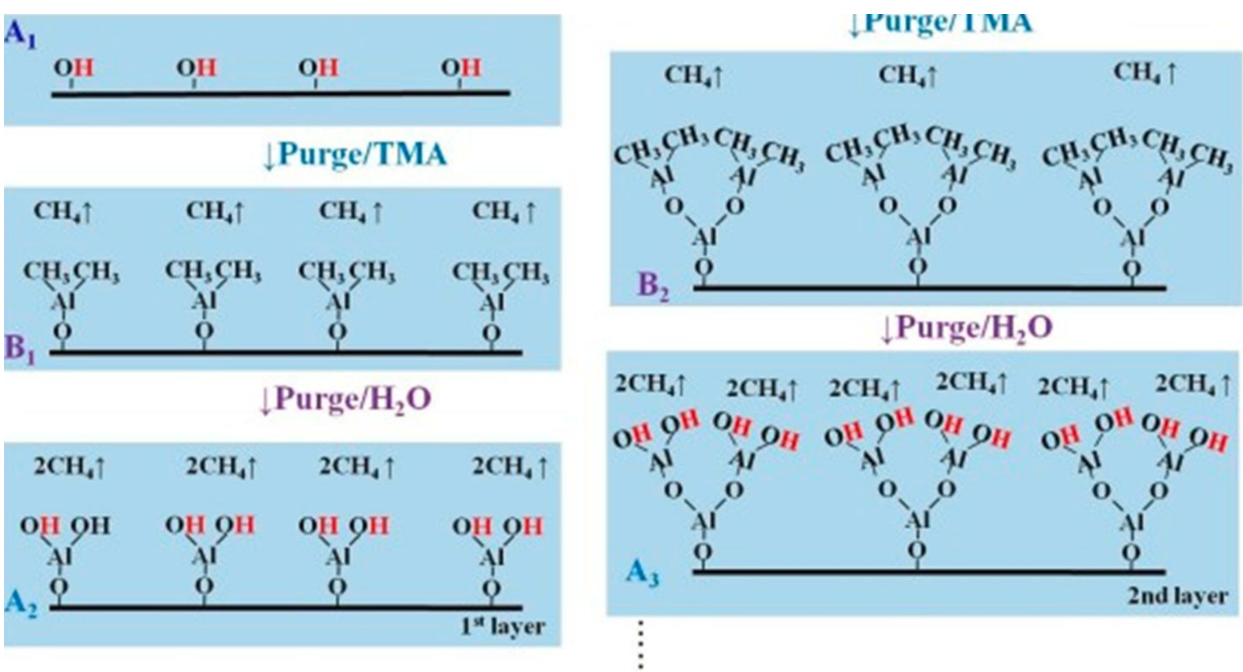
3. Electrical resistance and the secondary electron emission properties cannot be adjusted independently.

Z. Cao. et al., Microchannel plate electro-osmotic pump. Microfluid Nanofluid 13 (2012) 279-288.

Argonne Lab.

A. U. Mane, et al., Technology and Instrumentation in Particle Physics (TIPP) 2011





$$\text{A: Substrate-}(OH)^{*}+Al(CH_3)_3 \rightarrow \text{Substrate-O-}Al(CH_3)_2{}^{*}+CH_4\uparrow$$

$$\text{B: Substrate-O-}Al(CH_3)_2{}^{*}+2H_2O \rightarrow \text{Substrate-O-}Al(OH)_2{}^{*}+2CH_4\uparrow$$

ALD principle

The typical process of Al2O3 deposited by ALD has been described by two successive ‘half reactions’ presented in Equations A and B

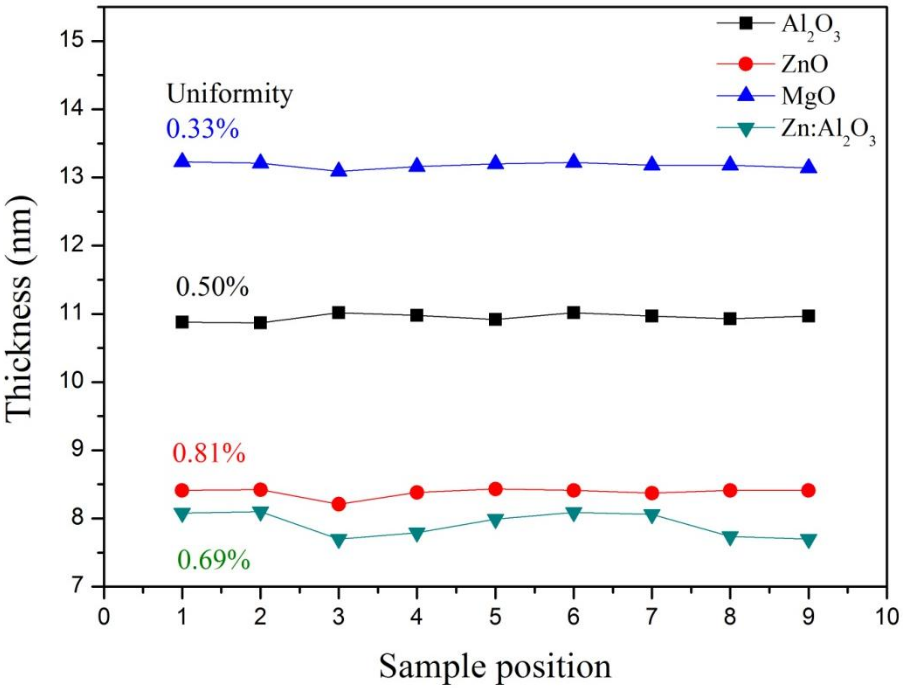
Features：

1. Precise controlling thin film thickness
2. Good conformity

2. Performance of Zinc oxide doped with aluminium (AZO) by ALD

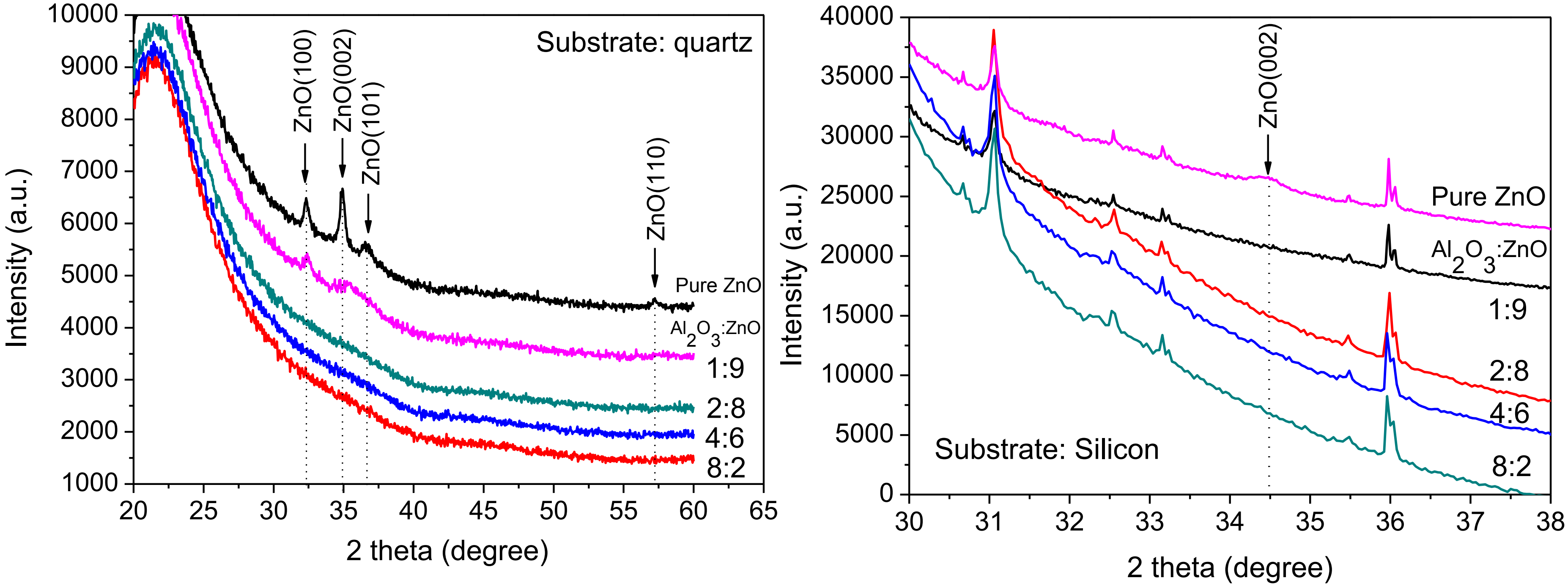
Thickness uniformity on planar substrate

ALD system



The thickness of MgO, Al_2O_3, ZnO, and AZO deposited on 4" silicon substrate by ALD are 13.18 nm, 10.95 nm, 8.38 nm, and 7.92 nm, thickness uniformity are 0.33% , 0.5%, 0.81% and 0.69%, respectively.

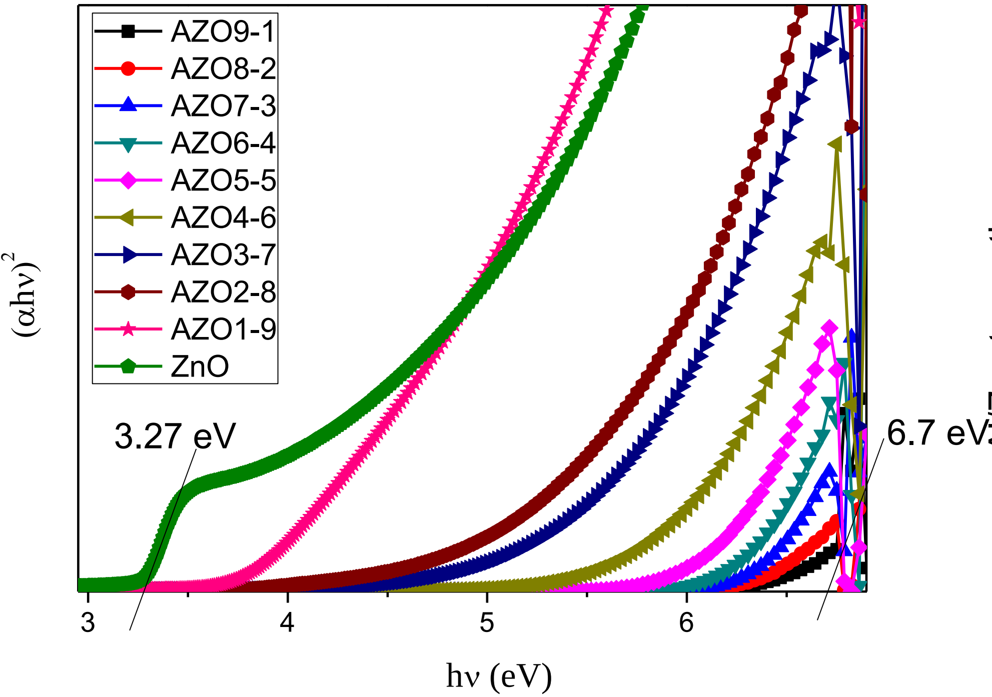
Structure of AZO (with different Al doping)



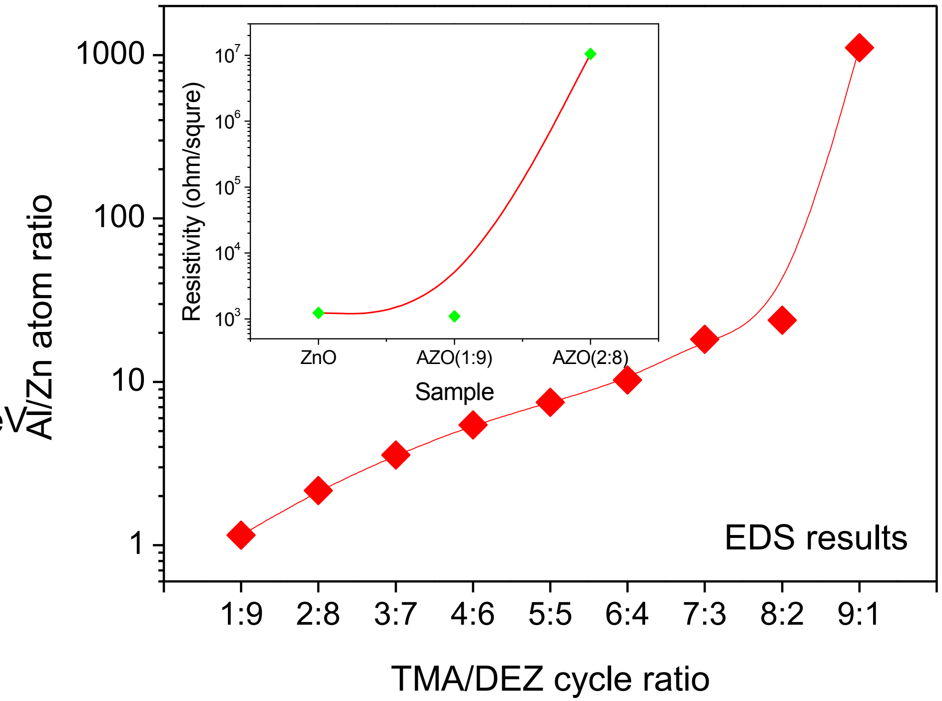
XRD results

These data suggest that layer growth appears to be substrate sensitive and film thickness and composition have an influence on the crystallization of films.

Element, resistivity and bandgap of AZO thin films

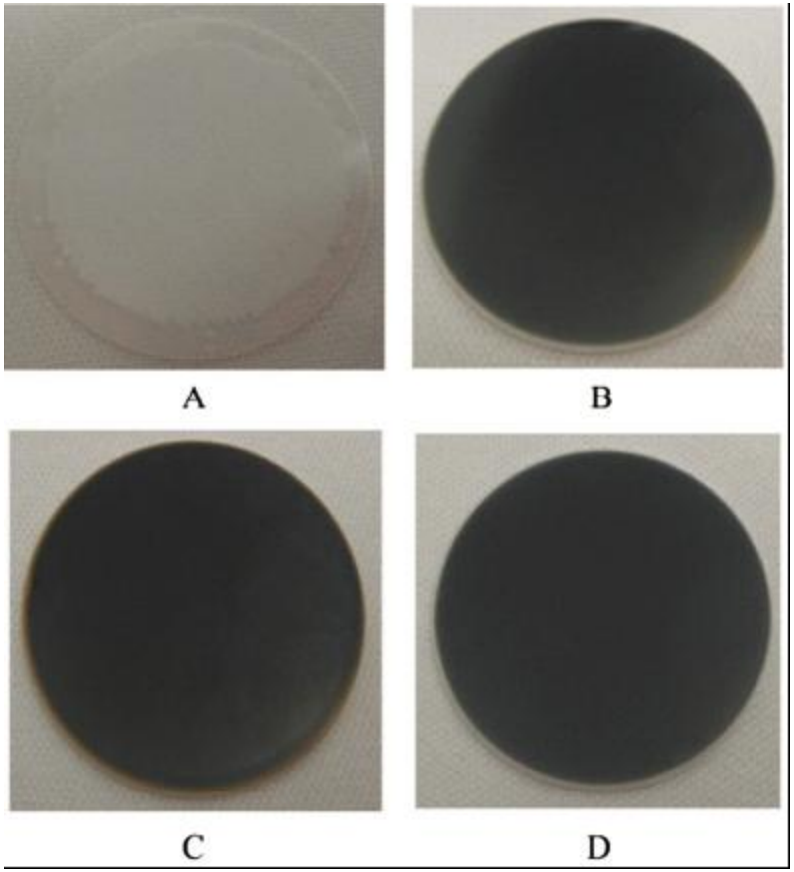


Bandgap

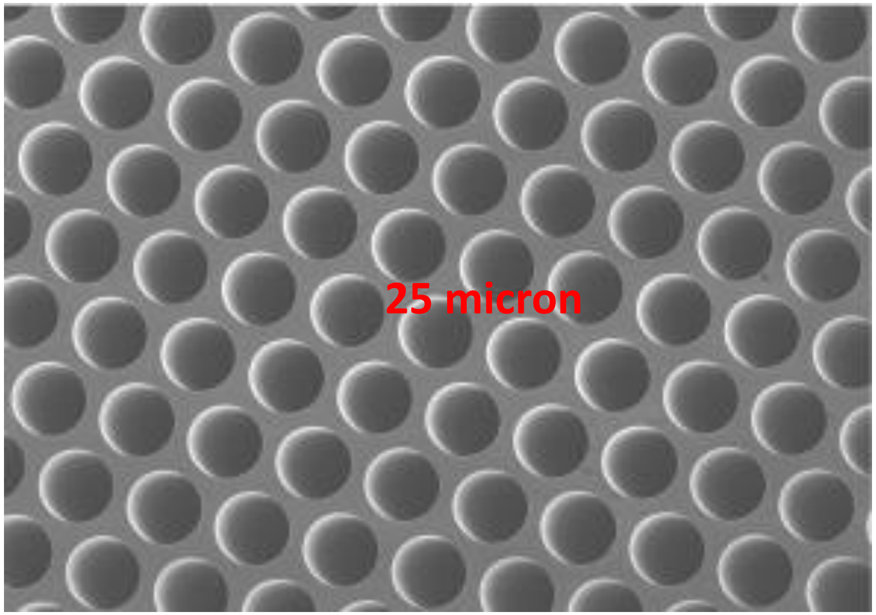


Element and resistivity

3. Performance of MCP via ALD method

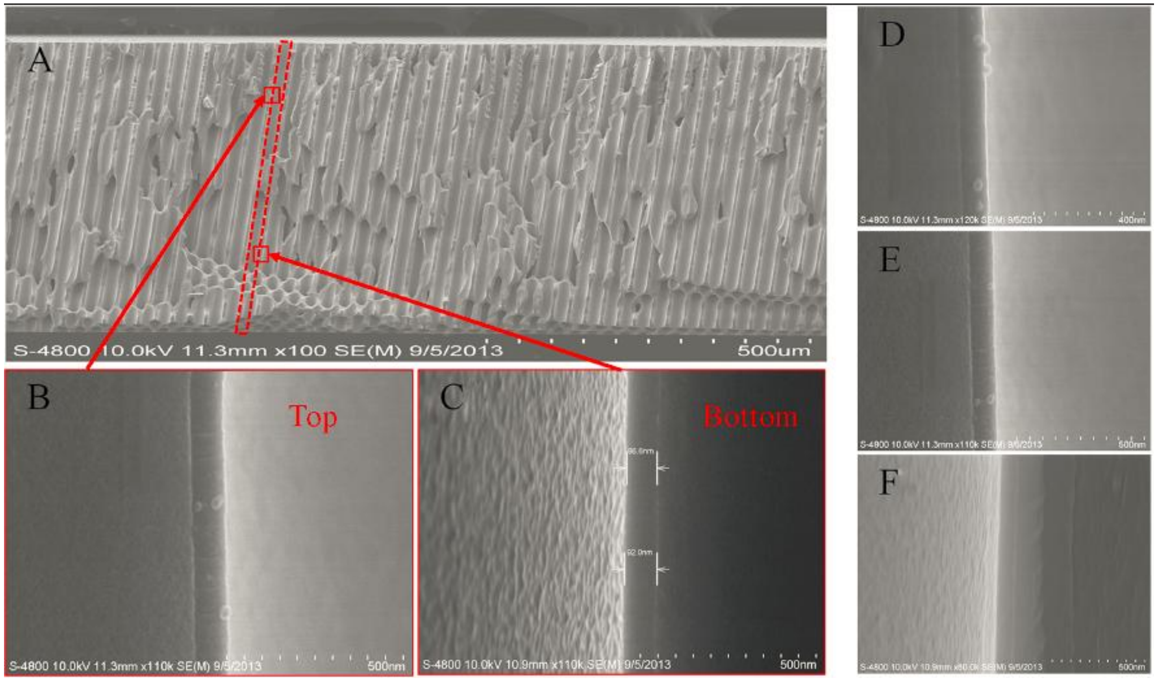


photographs of ALD-MCP samples
at different process steps



the top-view SEM picture of nano-oxide
thin films deposited on MCP

Thickness uniformity

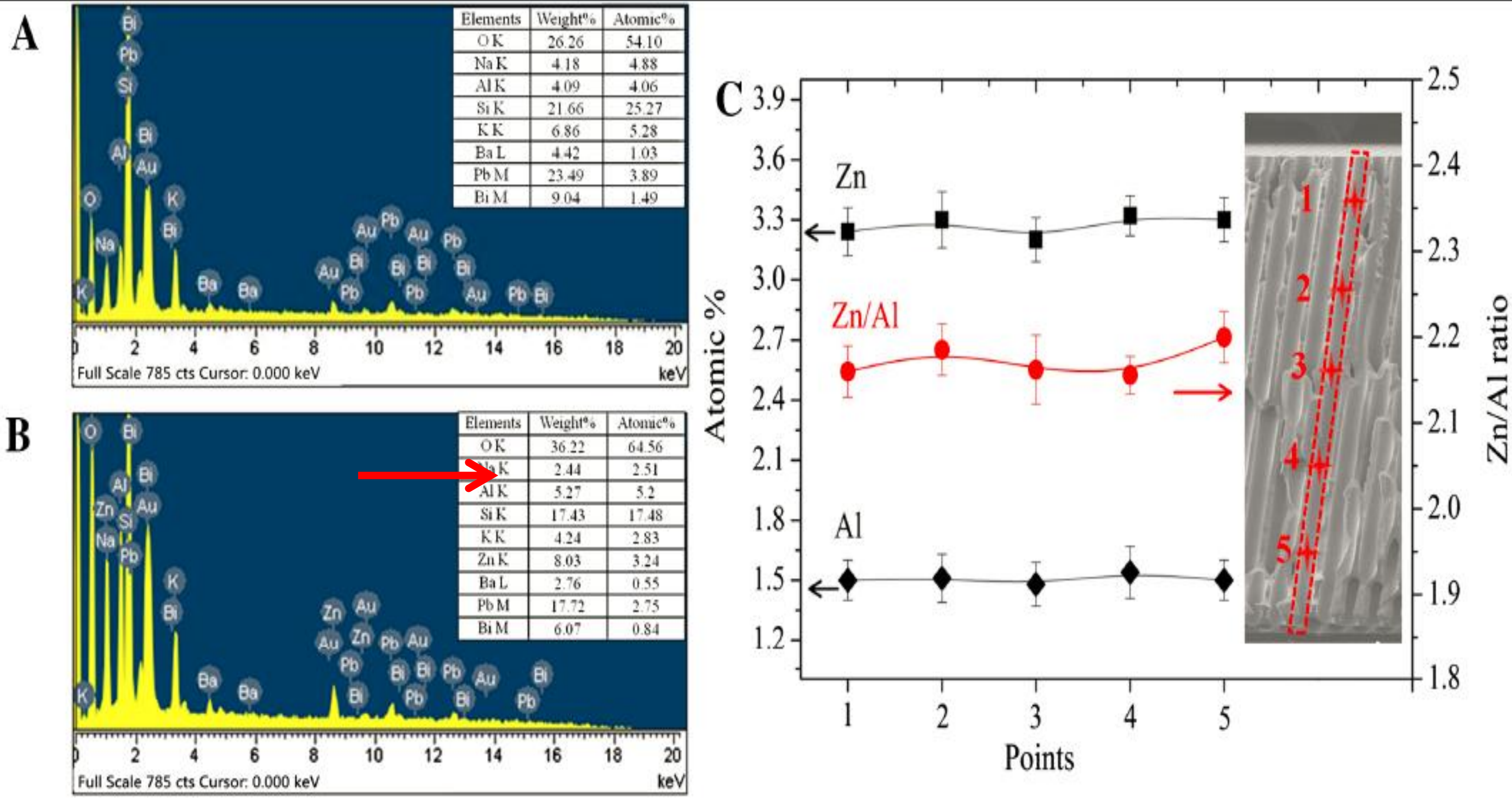


the cross-sectional SEM pictures of ALD-MCP samples

Description	Thicknesses of coatings located in different locations of a pore (nm)								Average value (nm)	Uniformity (%)
	Top part				Bottom part					
Condition 1	91.3	92.2	92.4	91.5	86.6	92.1	92.9	93	91.5	2.26
Condition 2	102.2	106.4	106.5	105.2	105.9	107.1	105.7	107.4	105.8	1.53
Condition 3	122.1	124.2	125.6	121.5	122.9	121.0	121.1	121.6	122.5	1.34
Condition 4	247.1	251.4	252.5	247.7	246.9	252.2	245.9	250.7	249.3	1.07

Uniformity = (Standard variation / Average variation) × 100%. Standard variation calculation formula: $S = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})^2}$; average variation calculation formula: $\frac{X_1+X_2+\cdots X_N}{N}$.

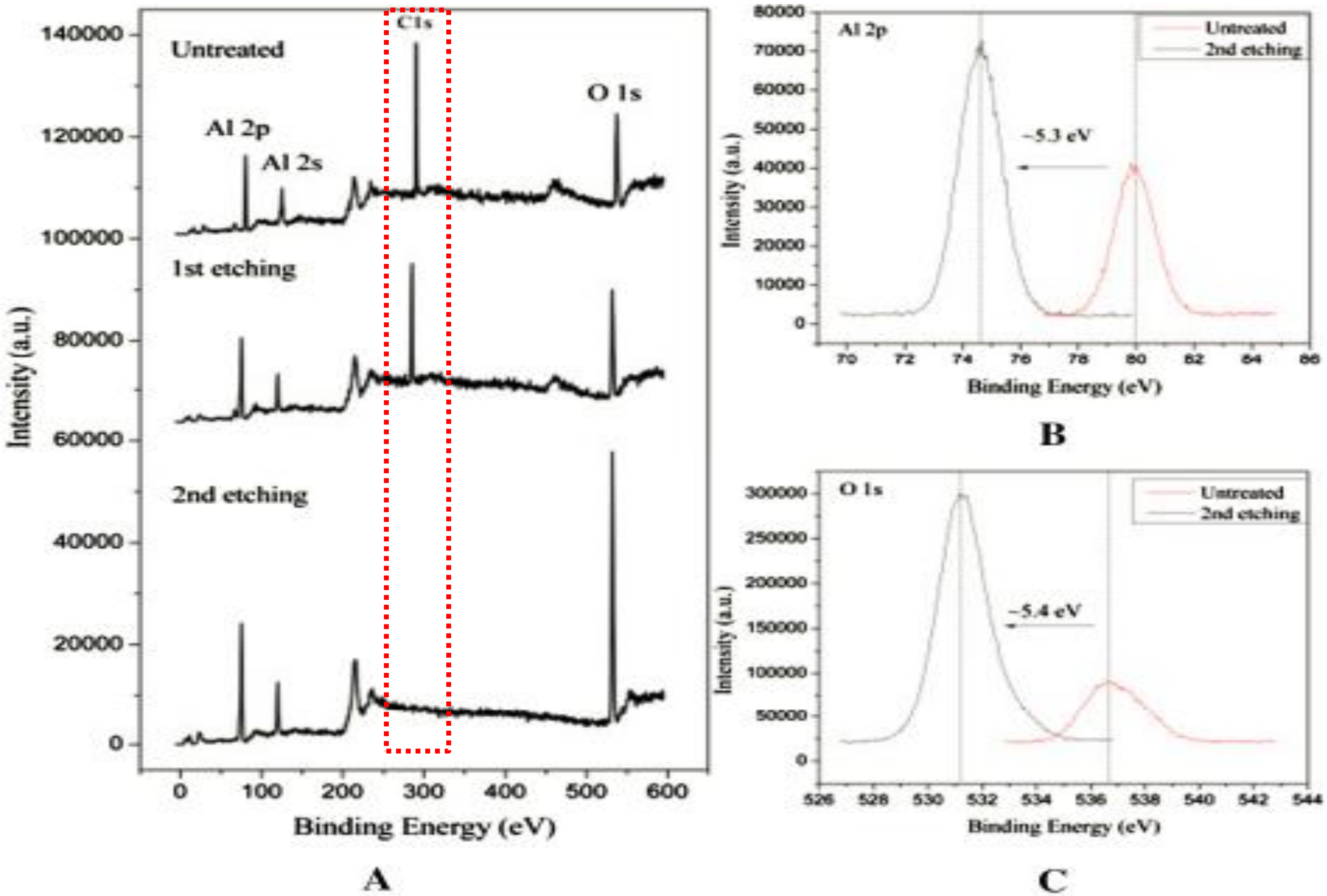
element uniformity



The spectra and elemental composition of cross-sectional bare MCP and ALD-MCP samples

The uniform composition of Al and Zn elements of ALD-MCP sample is characterized by EDS at five locations along the pore inner. The results of Al and Zn contents at different locations signify that the elements are nearly uniformly distributed in the pore inner surface.

chemical analysisat 4B9B beamline of BSRF

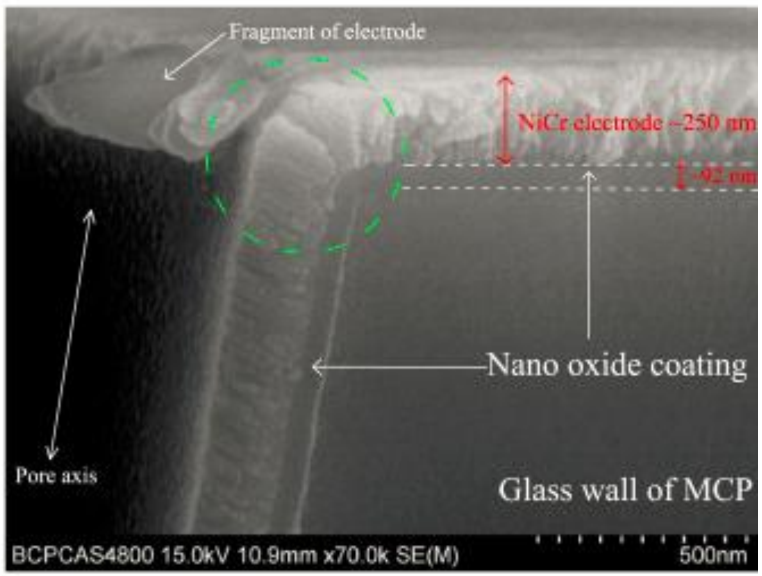


The thickness of thin films containing carbon atoms is approximately 5 nm.

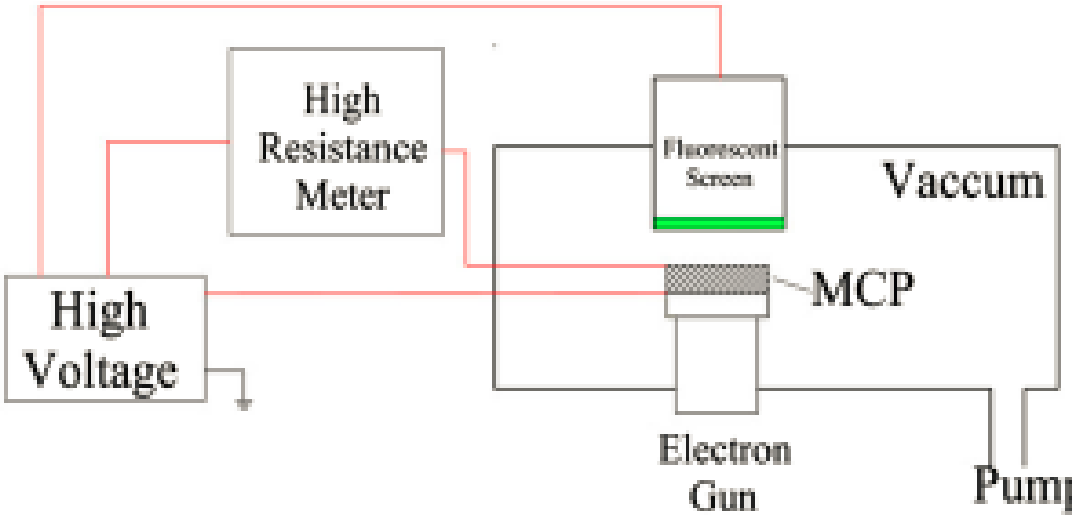
Due to the adsorbed atmospheric carbon and result from remnants of the organic precursor .

The containment of carbon have negative effects on the SEE and also the electrical performance.

Gain and resistance



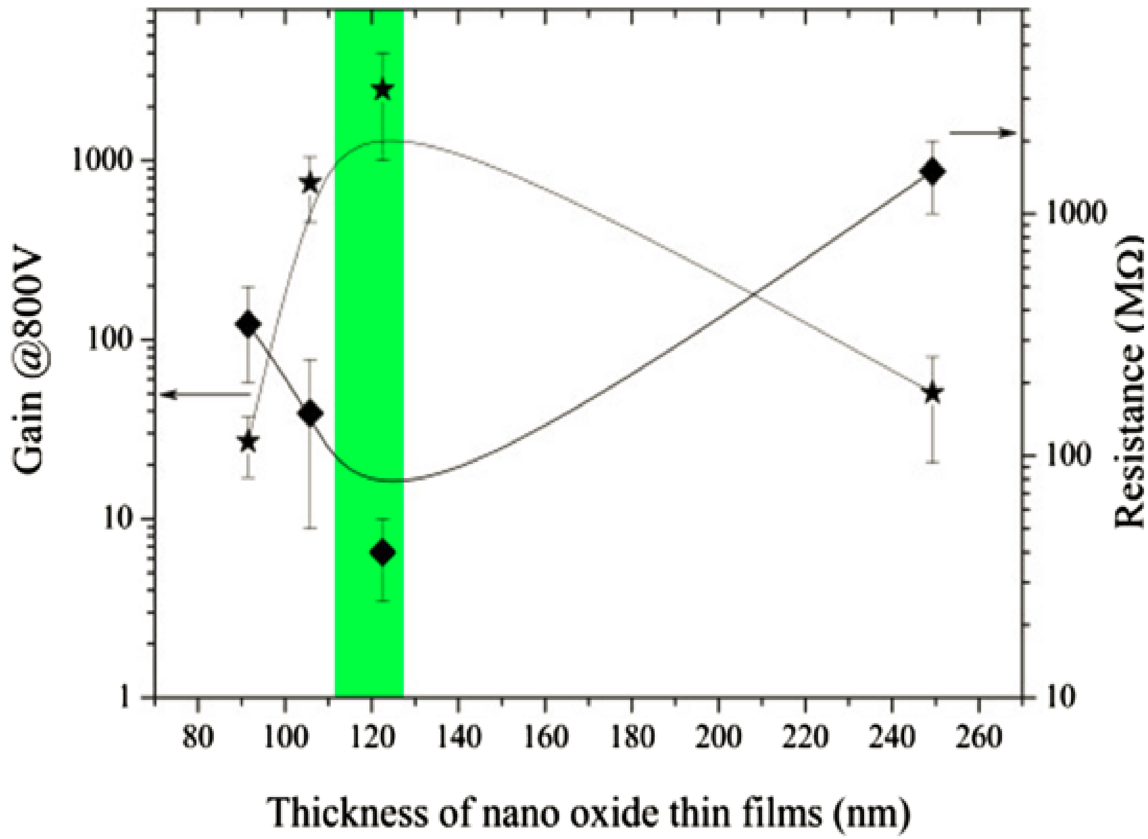
cross-sectional ALD-MCP



MCP electrical measurement system

Electrical measurements:

- Resistance
- Gain
- Screen view



Gain and resistance of ALD-MCP as a function of nano-oxide thin film thickness

- The gain reaches to maximum at 122 nanometers.
- The screen can be lightening showed in green color area.
- Current jitter phenomenon. The mechanism of this phenomenon is not fully understood.

Baojun Yan, Shulin Liu, Yuekun Heng. Nanoscale Research Letters 2015, 10:162.

4. Use of fund

支 出 科 目	金 额（万元）	使用情况
1.科研业务费	4	3
2.实验材料费	4	2.1
3.仪器设备费	0	0
4.会议、差旅费	1	0.9
5.文献信息费	1	0.68
合 计	10	6.68

5. Implementing status

预期目标	完成情况
1. 掌握ALD-MCP制备工艺	1. 掌握了AZO材料性能和ALD工艺参数之间的关系，并初步掌握利用ALD技术制备新型MCP的方法。
2. 获得高增益的MCP（单片MCP增益大于10^3@800V）	2. 目前制备的单片MCP的增益大于$2x10^3$@800V，对应的纳米薄膜的厚度约122 nm。 不足：需提高增益稳定性。
3. 发表1~2篇学术论文（EI或SCI）	3. 已发表1篇SCI论文和1篇EI论文。 ●Baojun Yan, Shulin Liu, Yuekun Heng. Nanoscale Research Letters 2015, 10:162. (IF=2.48) ●Baojun Yan, Shulin Liu, Luping Yang. Advanced Materials Research 2015, 1096: 93.

感谢国家重点实验室支持！