A New Conductive Material for Energy Efficient Window Applications

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Abstract

- Silver-based and TiN based thin film glass coatings with thicknesses of tens of nanometers are widely used in today's energy-efficient building windows. In this study, new materials Ag-Ti alloy was studied for energy-efficient window coating at world class nano-thin facilities. Thin film Ag, Ti, Silicon nitride was generated and characterized. The new materials AgTi (83.5:16.5) and AgTi(77.5:22.5) were generated and characterized.
- The thin film stack of SiN/Ag-Ti/SiN on glass was generated, the new proto-type energy saving window coating was demonstrated. Low SHGC in one product can be 0.27 that is excellent performance in energy saving

Table of content

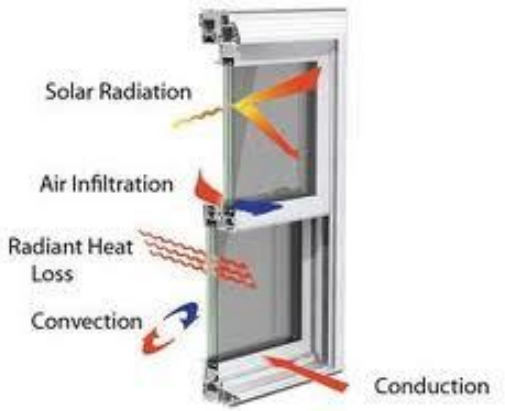
Introduction

Introduction to the energy efficient window coating research

- Silver-based and TiN based thin film glass coatings with thicknesses of tens of nanometers are widely used in today's energy-efficient building windows.
- However, there is no Ag-Ti alloy thin film coating on optical coating applications reported.
- In this presentation
  - Explored Ag-Ti alloys optical properties
  - Design their optical application products
  - Generate an energy efficient window proto-type product and characterize it

Why energy efficient coating window is needed

- Windows are often considered the least energy efficient component in a building.
- Radiation losses occur through the window glass and represent about 60% of total heat loss in a standard window*
- Radiative heat flow can be reduced by choosing low-emissivity (low-E) materials:
  - Emissivity is the value given to materials based on the ratio of heat emitted compared to a blackbody, on a scale from zero to one. A blackbody would have an emissivity of 1 and a perfect reflector would have a value of 0.



Materials surface**	Thermal emissivity
Aluminum foil	0.03
Asphalt	0.88
Brick	0.9
Concrete, rough	0.91
Glass, smooth (uncoated)	0.91
Limestone	0.92
Marble, Polished or white	0.89 to 0.92
Marble, Smooth	0.56
Paper, roofing or white	0.88 to 0.86
Plaster, rough	0.89
Silver, polished	0.02

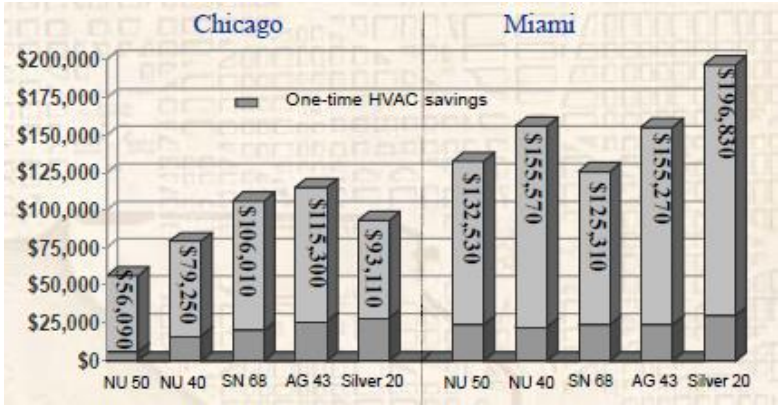
- "low-E basics.ppt , Guardian Industries-NT window" http://www.ntwindow.com/uploads/Forms/Additional%20information/Low-E%20Basics.ppt
- ** Low emissivity - Wikipedia, the free encyclopedia

Example of energy efficient window products in the markets

glazing	type	%Tvis	SHGC	U-value
clear glass	Mono	89%	81.8%	1.1
no coating	I.G. U	80%	71.3%	0.48
SN 68	I.G. U	68%	37.4%	0.29
Nu 50	I.G. U	50%	39.2%	0.34
AC 43	I.G. U	43%	29.6%	0.31
NU 40	I.G. U	40%	31.3%	0.33
silver 20	I.G. U	18%	20.0%	0.41

(6mm clear/ 12mm air / 6mm clear, coating #2 surface)

10 year energy saving is $100~200k



Assumption: 6 stories building /120,000 sq ft floor area, 20, 000 sq. ft window area at Chicago & Miami

EX118 "THE EVOLUTION OF GLASS AND HIGH-PERFORMANCE COATINGS" JOHN WILSON, GUARDIAN INDUSTRIES
AIA 2012 national convention and design exposition
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.aia.org%2Faiaucmp%2Fgroups%2Faia%2Fdocuments%2Fpdf%2Faiab094232.pdf&ei=pv55VM-3G-mDiwLPtoAQ&usg=AFQjCNHf5fS74aWoKuICzL9cxOwk0vxngw

Why the new materials AgTi was selected

- There are two type of materials for transparent low-emissivity coating
  - Semi-conductive coating, i.e. ITO, FTO
    - the extinction co-efficient k is very small such as 0.01 at 550nm, so that typical thickness is micro-meter with acceptable absorptions
  - Metallic coating, i.e. Ag , Au, Al, Ti
    - the extinction co-efficient k is very high such as 3.5 at 550nm, so that typical thickness is below 20nm for acceptable absorptions
- Ag and Ti (TiN) are common metal materials for energy saving window coating, but there is no AgTi alloy in energy saving coating, and there no such literatures on those materials for optical coatings
- We might be the first to explore this new materials AgTi optical properties and their applications

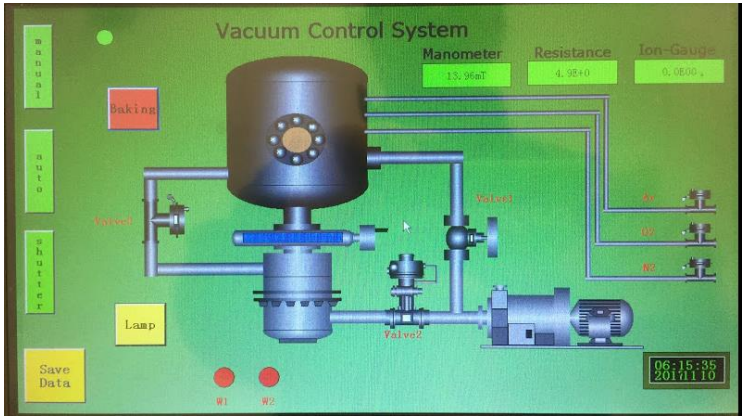
Experimental setup

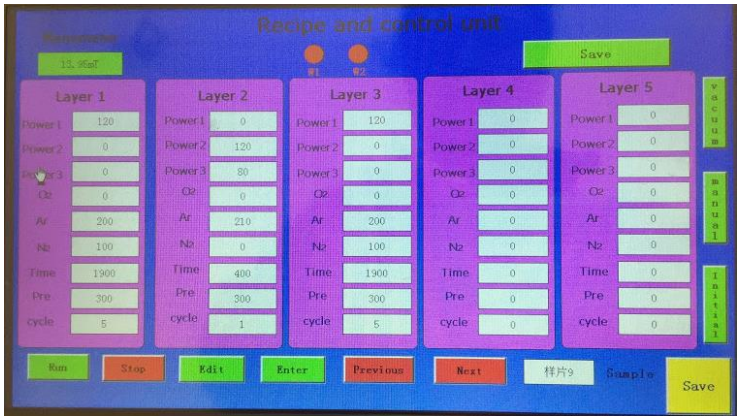
Nano-thin Film Research, World Class Facilities

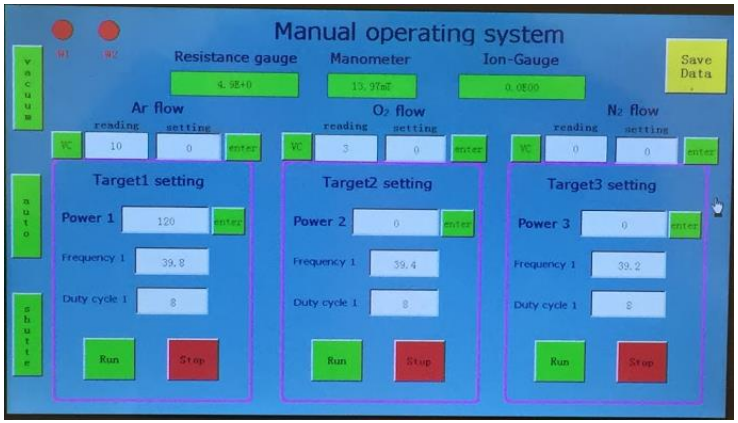
- World class physical sputter deposition facility,
  - ultra high vacuum to 1.6×10^{-7} Torr
  - Automatic run process for new materials and new thin film coating stack research

Friendly operation interface

- The nano thin film can be deposited by computer controlled system
- All the experimental conditions could be programed in a recipe , and automatic run.
- Experimental parameters can be monitoring and recorded.

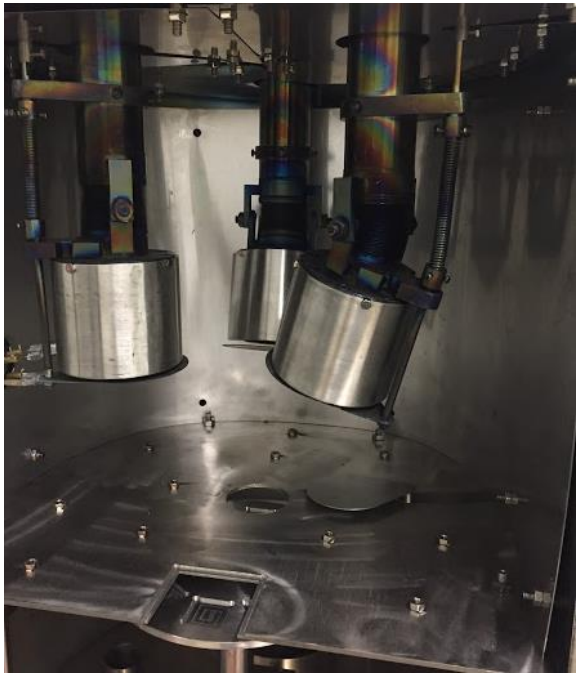


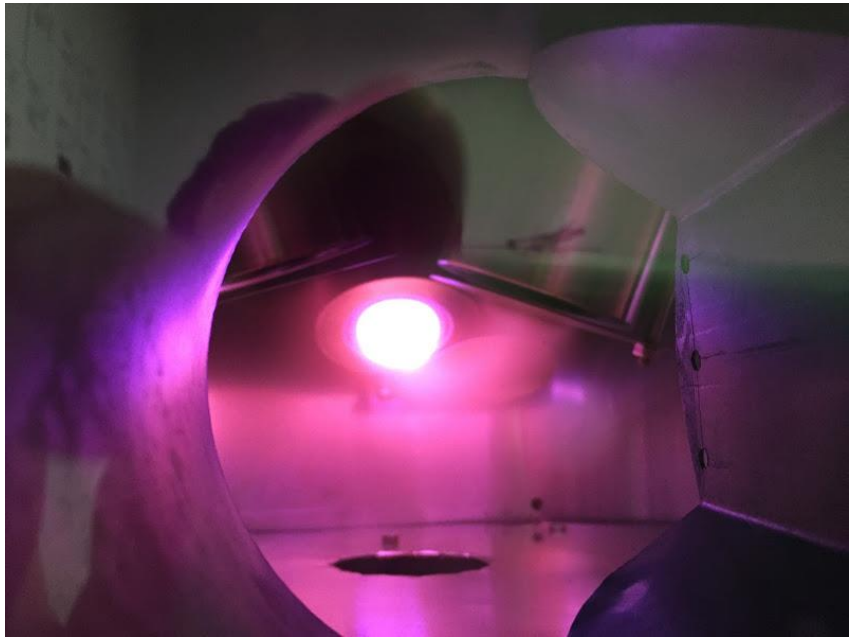


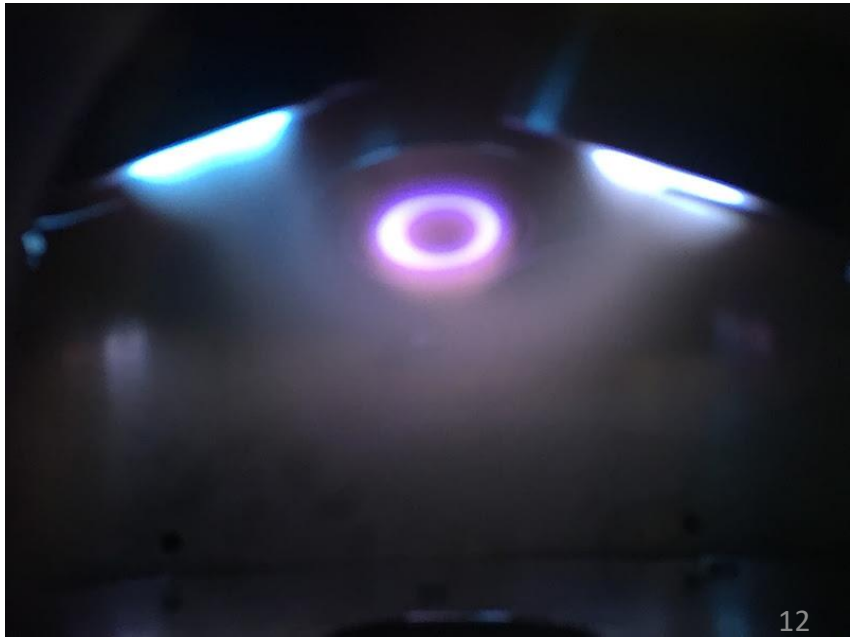


Thin film deposition & new materials, products developments

- New materials can be easily generated from 3 different guns for different materials
  - Co-sputter to generate new materials
  - Multiple stack for new products

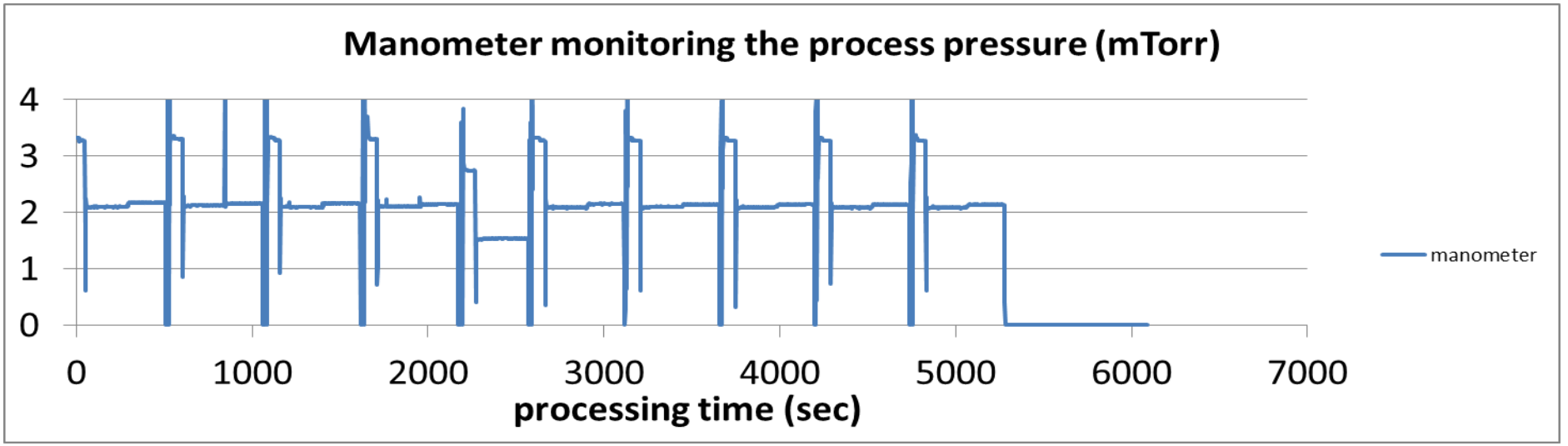


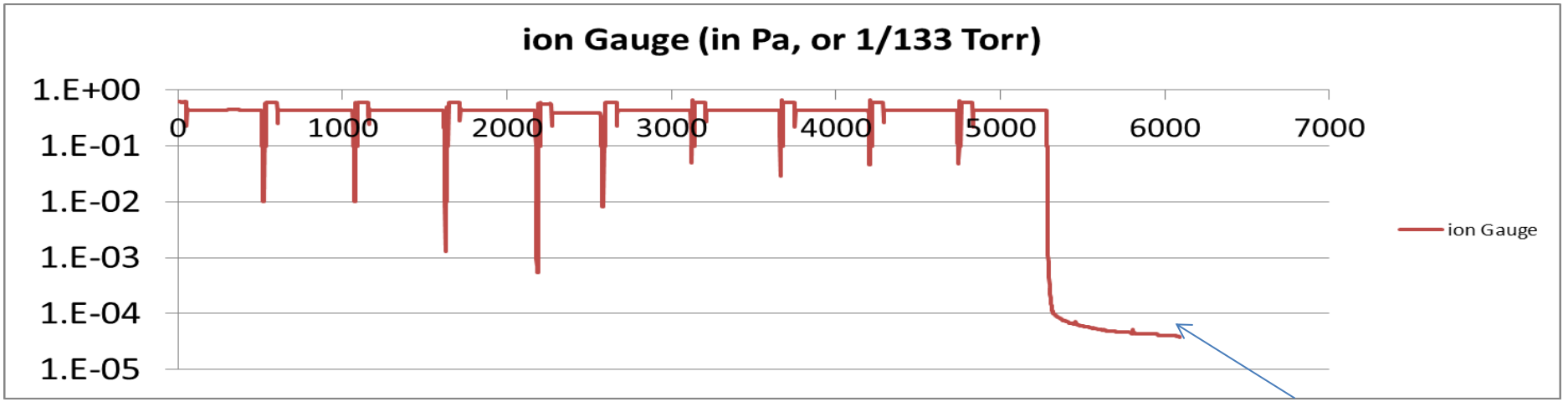




Experimental Vacuum pressure conditions

- Excellent background vacuum 1.6×10^{-7} Torr (2.1×10^{-5} Pa)

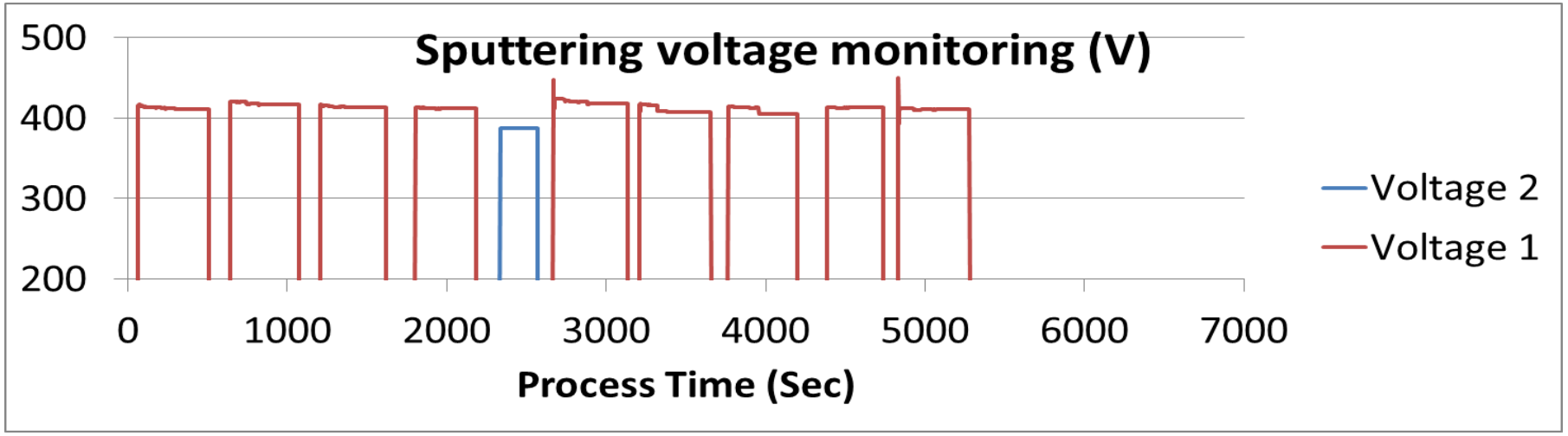


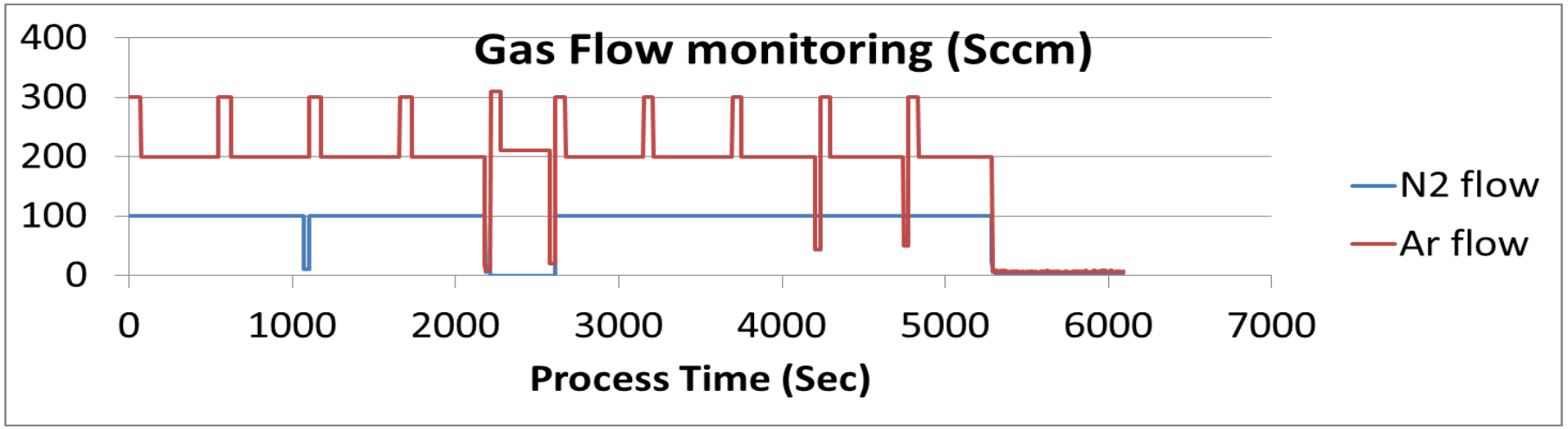


3.8x10-5 Pa =2.2x10-7 Torr

Experimental conditions monitoring

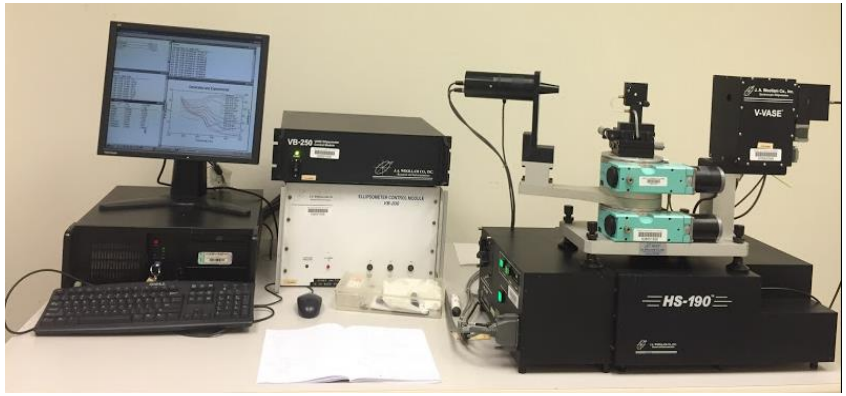
- Stable process, with 2hr running multiple steps / cycles





World class metrology tools

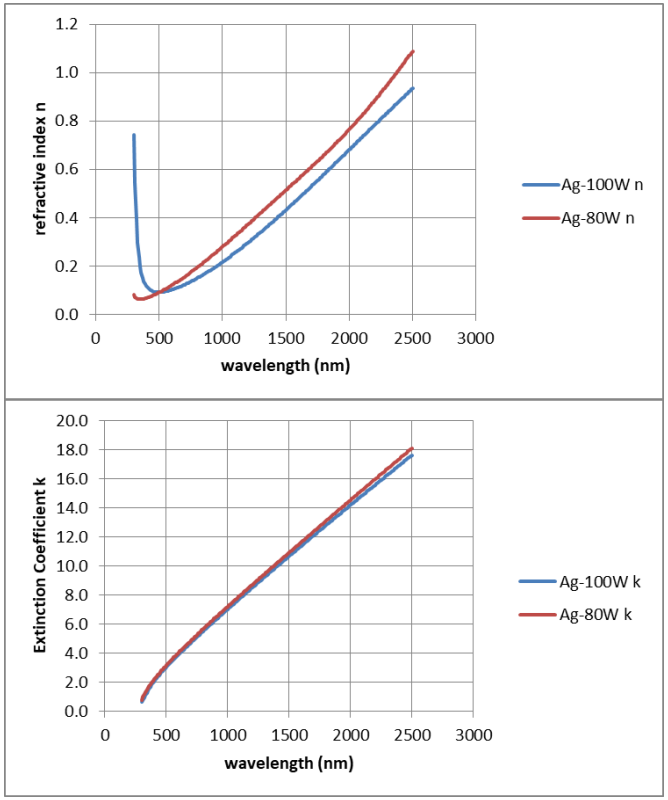
- **UV-Vis-IR spectrometer**: Top brand Shimadzu solidSpec 3700, offering high sensitivity and high accuracy, with measurements ranging from 250nm to 2500 nm.
- **Spectroscopic Ellipsometer** from the most famous Woollam company, Varying wavelengths and angles of incidence allow flexible measurement capabilities,
- **Four point probe** measuring the sheet resistance.



Standard Thin Film qualifications

Silver thin film characterization

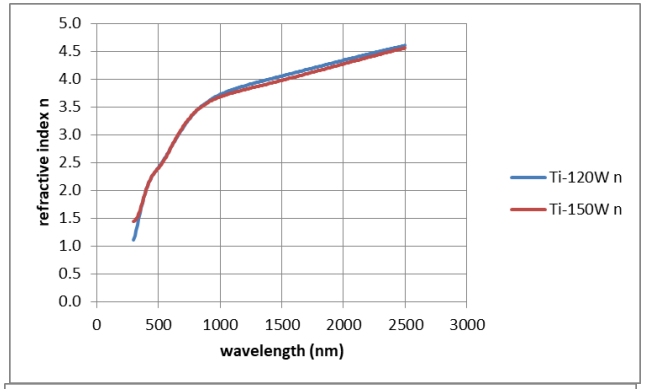
- Single layer Silver thin film around 200 A were deposited by 100W and 80W power
- Their film refractive index n,k were calculated from the measurements by Ellipsometer and UV-VIS-IR spectrometer
- Slightly lower refractive n at visible/IR region can be obtained from higher power deposition.

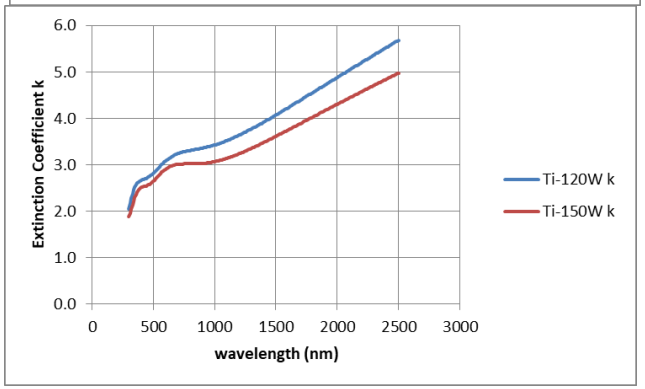


gun3	power3	dep rate (A/s)	Total thickness (A)	n[400nm]	k[400nm]	n[550nm]	k[550nm]	n[1000nm]	k[1000nm]
Ag	100w	4.2	210.05	0.12	2.06	0.10	3.49	0.22	7.02
Ag	80w	3.2	194.6	0.07	2.20	0.11	3.61	0.28	7.21

Titanium thin film characterization

- Single layer Titanium thin film around 200 A were deposited by 120W and 150W power
- Their film refractive index n,k were calculated from the measurements by Ellipsometer and UV-VIS-IR spectrometer
- Slightly higher refractive k values can be obtained from higher power deposition.

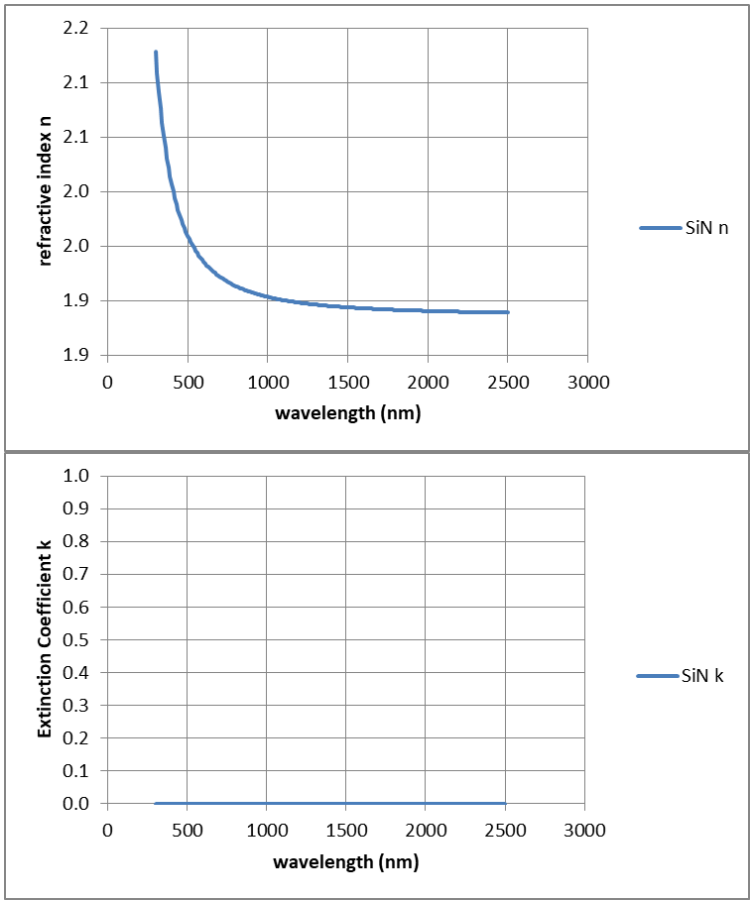




gun2	power2	dep rate (A/s)	Total thickness (A)	n[400nm]	k[400nm]	n[550nm]	k[550nm]	n[1000nm]	k[1000nm]
Ti	120W	0.66	144.60	2.02	2.66	2.58	2.95	3.72	3.42
Ti	150W	0.96	211.9	2.02	2.51	2.57	2.78	3.68	3.07

Transparent Dielectric film was generated and characterized

- Dielectric silicon nitride was deposited by reacting sputter with SiAl(92:8) target,
- 200sccmAr was mixed with 100sccm N2 gas controlled by Mass-Flow-controller,
- Transparent Silicon nitride was achieved

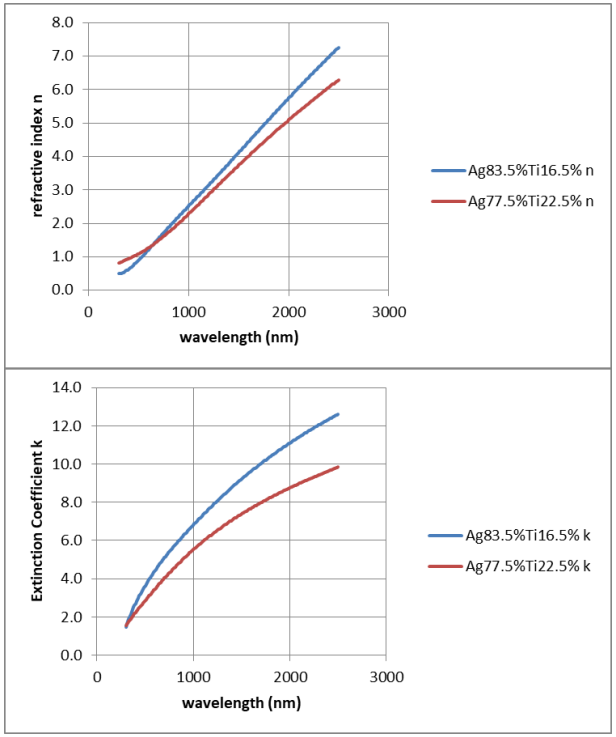


gun1	power1	Ar flow (sccm)	N2 flow (sccm)	dep rate (A/s)	Total thickness (A)	n[400nm]	k[400nm]	n[550nm]	k[550nm]	n[1000nm]	k[1000nm]
SiAl(92:8)	120W	20	10	0.5	485.80	2.01	0.00	1.95	0.00	1.90	0.00

New materials research

New materials AgTi research and characterization

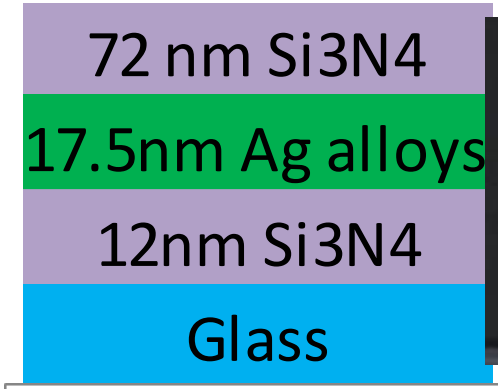
- Alloy Silver/Titanium thin film around 200 A were deposited by co-sputter Ag and Ti, and conditions shown as below:
- Their film refractive index n,k were calculated by measurements from Ellipsometer and UV-VIS-IR spectrometer
- The higher k values were found at the higher Ag content conditions, because the k value for Ag is higher
- The lower n values at the visible region were found at the higher Ag content condition, because n of Ag at visible region is lower.

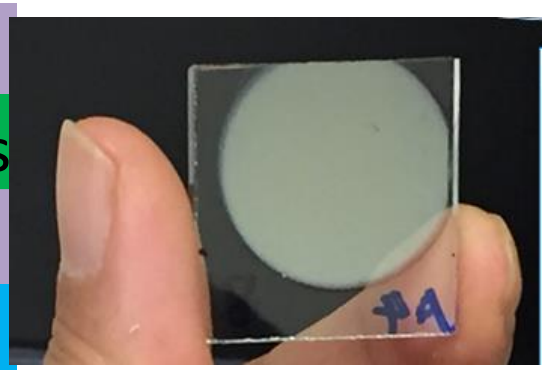


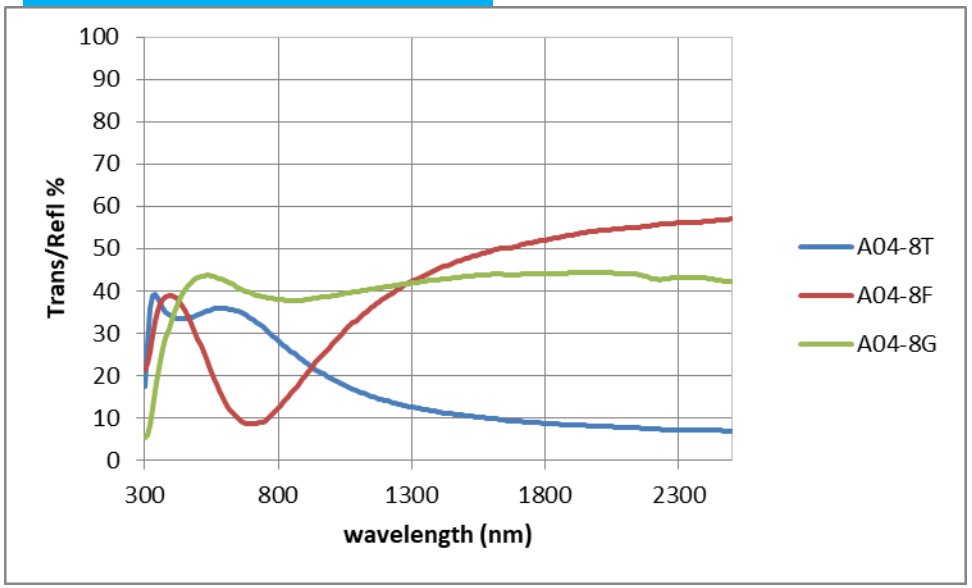
gun2	power2	gun3	power3	dep rate (A/s)	Total thickness (A)	n[400nm]	k[400nm]	n[550nm]	k[550nm]	n[1000nm]	k[1000nm]
Ti	120W	Ag	80w	4.0	197.72	0.63	2.72	1.05	4.04	2.51	6.82
Ti	150W	Ag	80w	4.6	229.03	0.94	2.23	1.17	3.16	2.28	5.52

New materials AgTi in a stack for energy saving window coating

- The co-sputter AgTi new materials was used in the glass coating.
- The optical transmittant (T), film side reflectance (F), and glass side reflectance (G) were shown.
- Visible transmittance Tvis is 35.4% which is enough in many applications.
- The Low emissivity of 0.25 for this window coating was obtained

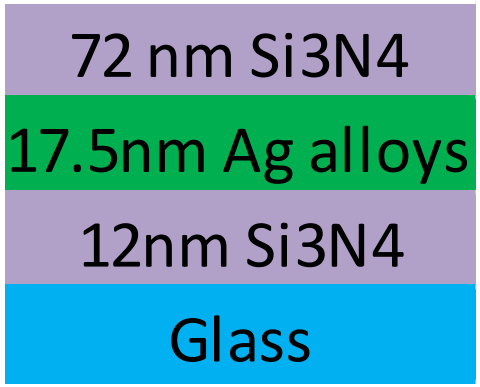


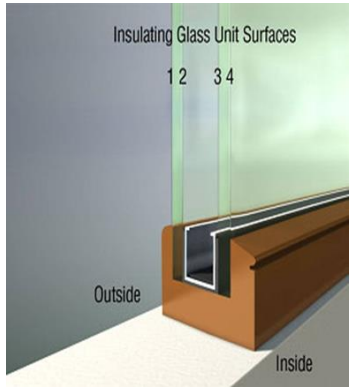


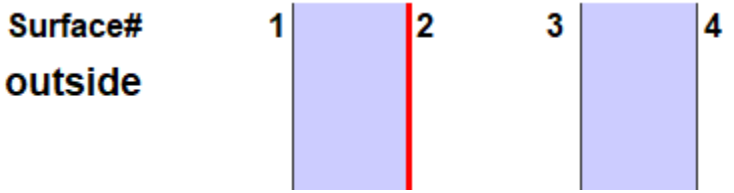


New materials AgTi in a stack for energy saving window coating

- Glass coating can be installed in a double pane Insulated Glass Unit (IGU).
- The glass coating color is Outside blue and inside tint
- The low SHGC 27.7% in IGU is lower than most energy saving products in the market today for reducing solar heating in the room





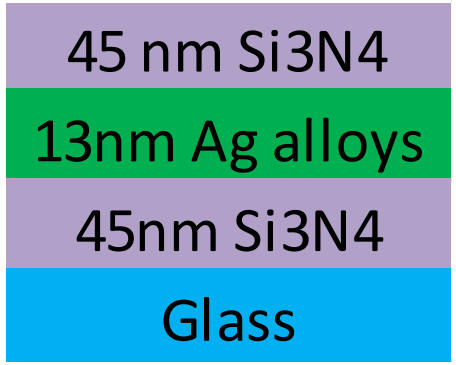


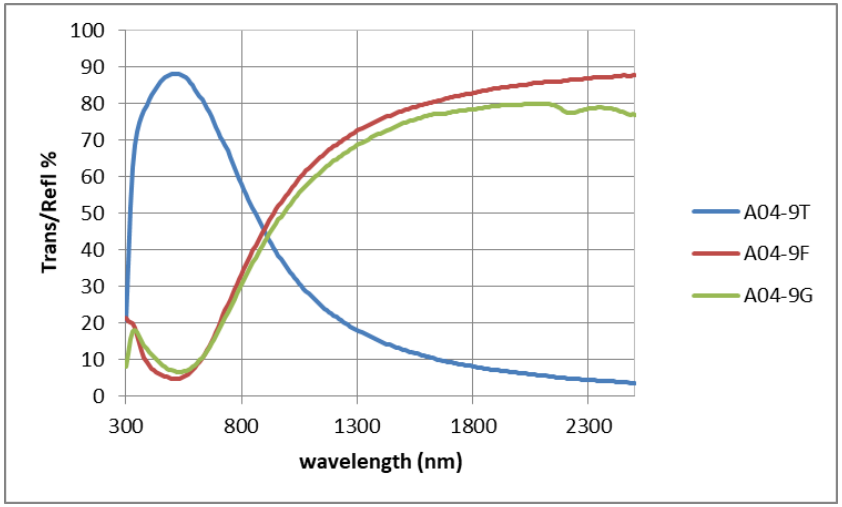
16 mm gap with Ar

Tvis	Rvis	Tsol	Rsol	Asol	SHGC	SC	LSG	Uval
32.9%	44.1%	24.1%	40.8%	35.1%	0.275	0.316	1.2	0.329

High visible transmittance low emissivity energy efficient window product

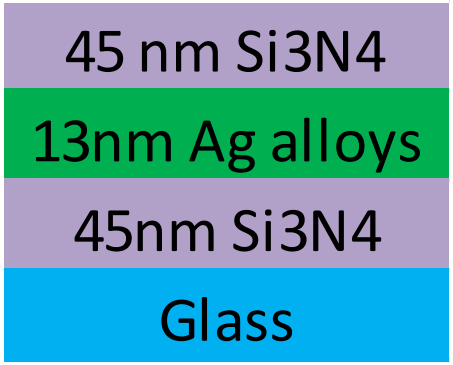
- High transmittance energy efficient window coating generated
  - T_{vis}: 86% for mono glass (in comparison: T_{vis} for glass is 91%)
  - Emissivity 5% , matches the high performance low-E products

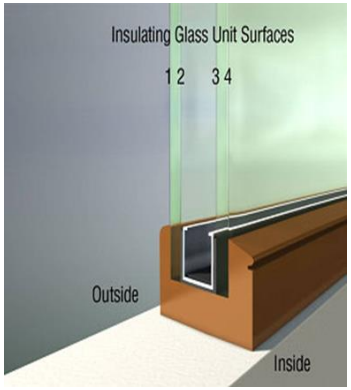


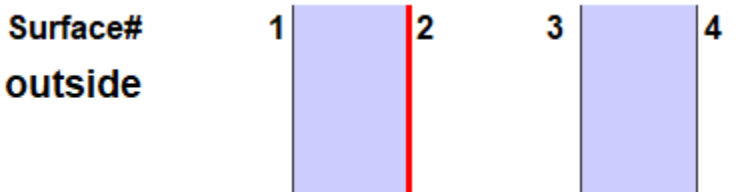


High performance energy saving window prototype products

- Such window coating could be put in double pane window
- The optical and thermal performance are excellent as below







16 mm gap with Ar

Tvis	Rvis	Tsol	Rsol	Asol	SHGC	SC	LSG	Uval
79.0%	13.7%	51.4%	37.2%	11.4%	0.525	0.604	1.51	0.259

Summary

- Glass coating could benefit energy saving for residential or commercial buildings.
- New research for the new materials AgTi was studied AgTi(77.5%/22.5%) and AgTi(83.5%/16.5%).
- The new materials optical properties are characterized, and those n,k data might be the first published data for those materials.
- A new proto-type product for energy saving window was generated with excellent solar gain coefficient down to 27%. Also the high transmittance produce was demonstrated with Tvis 79%, and LSG 1.51, which are the high end energy saving product performance.