2012

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Presented at the 9th International Conference on High Capacity Optical Networks and Enabling Technologies (HONET), 12th-14th December, 2012, Kadir Has University, Istanbul, Turkey.
This Presentation is posted at Research Online.
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Thin Film Coatings for Solar and Thermal Radiation Control Prepared by Physical Vapour Deposition

**Yamna El Mouedden, Ramzy Alghamedi, M. Nur E Alam,
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- **Introduction to energy-saving glazings**
 - Metal-dielectric thin film coatings
 - Materials science of metal-dielectric thin-film systems
 - Solar control glazings: aims and challenges
- **Physical Vapour Deposition (PVD) of metal-dielectric systems**
 - Material properties and layer intercompatibility
 - Deposition methods and characterisation procedures
 - Manufacturability of designs optimized theoretically
- **Experimental development and characterization results**
 - Multilayer thin film structures – manufacture and properties
 - Main results achieved
- **Conclusions**

- **Energy saving glazings and optical coatings:**

- Multilayer films on glass and radiation control
- Cooling- and heating-related electricity savings
- Solar control and low emissivity combination suits most climates

- **Enabling technologies and materials:**

- Solar IR control through reflecting it back out
- Thermal insulation improvements (Low-E glass)
- Material combinations: $\text{TiO}_2/\text{Ag}/\text{TiO}_2$, $\text{WO}_3/\text{Ag}/\text{WO}_3$ etc.
- New research is required to achieve better coating durability, higher visible transmission and spectral selectivity

Aims: to demonstrate advanced coatings on glass substrates which

- Block (selectively) most of the UV, solar IR (0.75-2.3 μm) and thermal (2.5-40 μm) radiations.
- Achieve high transmission (>80%) in the visible range.

Materials science of metal-dielectric systems:

- Selection of appropriate materials - $n(\lambda)$, $k(\lambda)$
- Ensuring optimum growth mode in ultrathin layers
- Preventing chemical reactivity
- Design of nanocomposite materials (or cross-contamination prevention)

Ultrathin metal layers can have different morphologies

Optimisation of metal-dielectric multilayers

- Optilayer 8.85 software used
- **Dielectrics**
 - Oxides, nitrides sulfides and fluorides of refractive index from 1.38-2.4
 - Materials had high transparency across the entire visible range

- **Metal layers (Ag)**

- **Structures:**

Glass/ $D_{(adh.)}$ / $D_1 \dots D_n$ /Ag/ $D_k \dots D_l$ /Ag/ $D_x \dots D_{y(cover)}$

Single-Ag and triple-Ag designs were also trialled

Simulated spectral transmittance curves for different metal-dielectric multilayer thin film structures.

E-Beam and thermal evaporation

RF magnetron sputtering

- Glass substrates were not heated (at 20°C).
- Base vacuum pressures achieved in both deposition chambers were near 10^{-6} Torr.
- Layer growth rates were typically between 0.5-2.5 Å/s
- Ag layers were either sputtered or evaporated thermally
- Non-metallic layers were all E-Beam evaporated
- The argon (Ar) partial pressure used in RF sputtering chamber was between 1-2 mTorr.
- No O₂ input used – selected oxides with minimum O₂ loss

Experimental results – sputtered and evaporated metal-dielectric coatings on glass

Simulated and measured spectral transmittance curves for the optimized multilayer thin films

Experimental results – sputtered and evaporated metal-dielectric coatings on glass

Ultraclear/Clear glass substrates (left) and sputtered coatings on glass (right)

Evaporated coating on glass (200x200 mm)

Evaporated large-area, stable metal-dielectric coatings for advanced glazing systems

<http://windows.lbl.gov/software/window/window.html>

Evaporated coating on glass (200x200 mm)

Glazing performance calculations performed using LBNL's **WINDOW 6.3** software resulted in the following data set:

Center of Glass Results Temperature Data Optical Data Angular Data Color Properties						
Ufactor W/m ² K	SC	SHGC	Rel. Ht. Gain W/m ²	Tvis	Keff W/m-K	Gap 1 Keff W/m-K
1.639	0.528	0.460	345	0.729	0.0300	0.0300

Main double-pane glazing parameters are

- Solar Heat Gain Coefficient (SHGC) = 0.46
- Visible Transmission VT = 72.9 %
- Relative Heat gain = 345 W/m²
- Thermal insulation U-factor = 1.639 W/(m²*K)

In an insulated glass unit, when used as an intermediate coating, a very attractive combination of multiple energy-saving performance parameters results

- Thin film coatings suitable for solar+thermal radiation control were studied experimentally
- E-Beam, Thermal Evaporation and RF sputtering processes optimised for spectrally-selective metal-dielectric systems
- PVD parameters optimised for high quality thin films production, including the control over ultrathin layer properties
- Transparent and stable heat-mirrors designed and fabricated

Thank you

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