Institut für Oberflächenmodifizierung
Abteilung Ionenstrahltechnik

University of Nebraska-Lincoln
Electrical Engineering Department

All-Solid-State Electrochromic Multilayer System For Surface Heat Radiation Control

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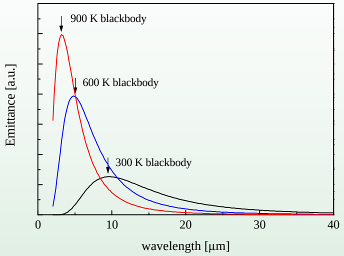
Radiation Characteristics The blackbody spectrum



$$M(l)=\frac{2phc^2}{(l\times10^{-6})^5}\times\frac{1}{\exp(\frac{h\times c}{l\times10^{-6}kT})-1}$$

T...temperature
l...wavelength

Emissivity ε and Device Performance Paramters

$$e=\frac{\int_{l_1}^{l_2}[1-R(l)]M(l,T)dl}{\int_{l_1}^{l_2}M(l,T)dl}$$

R...reflectance
M...blackbody spectral emittance

Emissivity modulation

$$e_{modul.}=e_{high}-e_{low}$$

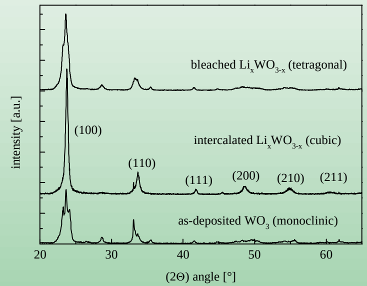
e_{high}*...emissivity in high emittance state*
e_{low}*...emissivity in low emittance state*

Emissivity ratio

$$e_{ratio}=e_{high}\div e_{low}$$

General comments

- All films were grown by either r.f. or d.c. magnetron sputtering
- Electrochemical Li^+ intercalation performed in a 1M solution of $LiClO_4$ in propylene carbonate
- Irreversible phase transformation in polycrystalline WO_3 upon Li^+ intercalation and deintercalation

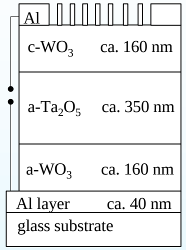


4. Optical constants of intercalated and deintercalated single film device constituents were measured and analyzed using spectroscopic ellipsometry from 0.03 to 1 eV

5. Experimentally measured optical constants of device constituents layers have been used for simulations of device performance

For details see:
E. Franke et al., APL **77**, 930 (2000)
E. Franke et al., JAP **88**, 5777 (2000)
E. Franke et al., JAP **88**, 5166 (2000)
E. Franke et al., TSF **388**, 283 (2001)

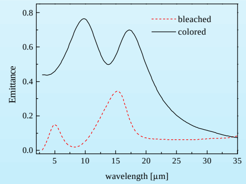
Reflectance modulating single-grid electrochromic device



Note:
Devices were optimized and tested for application in the 300 K blackbody spectral region.

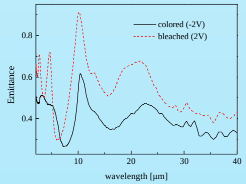
Legend:
a…amorphous
c…polycrystalline

Simulated device performance



300 K blackbody
$e_{colored}=0.88$
$e_{bleached}=0.45$
$e_{ratio}=1.94$
$e_{modul.}=0.43$

Experimentally measured device performance

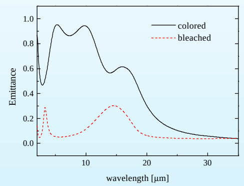


300 K blackbody
$e_{colored}=0.4$
$e_{bleached}=0.58$
$e_{ratio}=1.45$
$e_{modul.}=0.18$

Single-grid device performance simulations

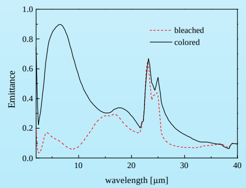
Purpose of cover layers:
- protect the polycrystalline WO_3-layer
- prevent Li^+ chemical reactions
- prevent moisture incorporation
- act as a optical impedance match to improve switching performance

Simulated device performance with a 600 nm thick ZnSe cover



300 K blackbody
$e_{colored}=0.61$
$e_{bleached}=0.13$
$e_{ratio}=4.56$
$e_{modul.}=0.48$

Simulated device performance with a 900 nm thick MgF_2 cover

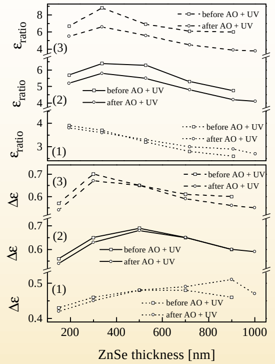


300 K blackbody
$e_{colored}=0.46$
$e_{bleached}=0.17$
$e_{ratio}=2.66$
$e_{modul.}=0.29$

600 K blackbody
$e_{colored}=0.65$
$e_{bleached}=0.13$
$e_{ratio}=4.88$
$e_{modul.}=0.52$

900 K blackbody
$e_{colored}=0.62$
$e_{bleached}=0.12$
$e_{ratio}=5.2$
$e_{modul.}=0.50$

Emittance modulation and ratio as function of ZnSe thickness and temperature



-Stability of ZnSe single layers in atomic oxygen (AO) and during UV radiation was tested (simulation of low earth orbit conditions).
-Change in ZnSe optical constants during AO and UV treatment was used to simulate degradation effects for device performance
-ZnSe thickness was optimized for several environment temperatures [(1) 300K, (2) 600K, (3) 900K) to achive best emissivity modulation and ratio

Conclusions

- Operational all-solid-state electrochromic devices for thermal emittance modulation
- Single-grid device with opposite switching behavior than predicted by simulation, because of non-ideal Li^+ distribution (Li^+ trapped in interfaces, a certain Li^+ amount remains in the layer, which is supposed to be free according to the voltage polarity)
- Best experimental device performance for single-grid device
- Cover layer improves device switching behavior and reliability
- Atomic oxygen exposure and UV radiation cause degradation of the ZnSe layer, and therefore a change in emissivity modulation and ratio of the device

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