Electrochromic Behavior in Flexible WO_3 and Prussian Blue Thin Films for Use in Ski Goggle Lenses

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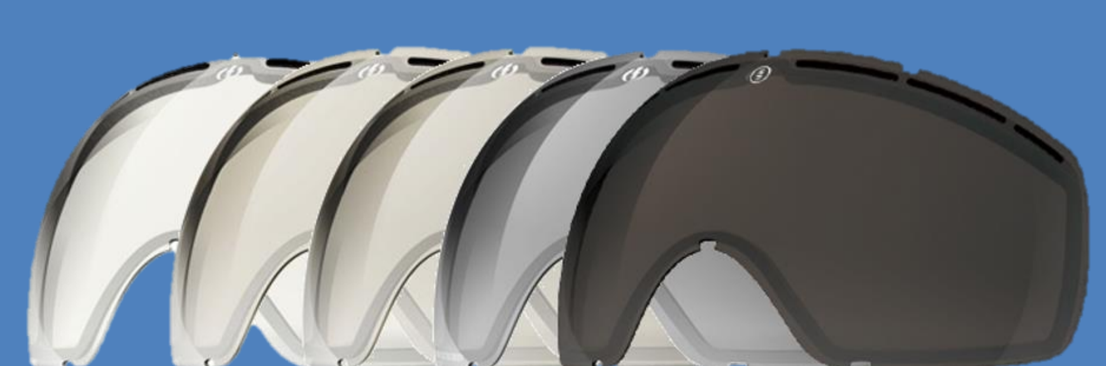
Problem

Snow reflects 80-95% of the sun's light. This means that even on cloudy days, skiers need proper eye protection. The degree of tint on ski goggle lenses is closely tailored to specific sets of weather conditions. A variety of lens tints and colors is shown to the right. Currently, skiers must swap out their goggle lenses when the weather changes in order to maintain their comfort and safety.

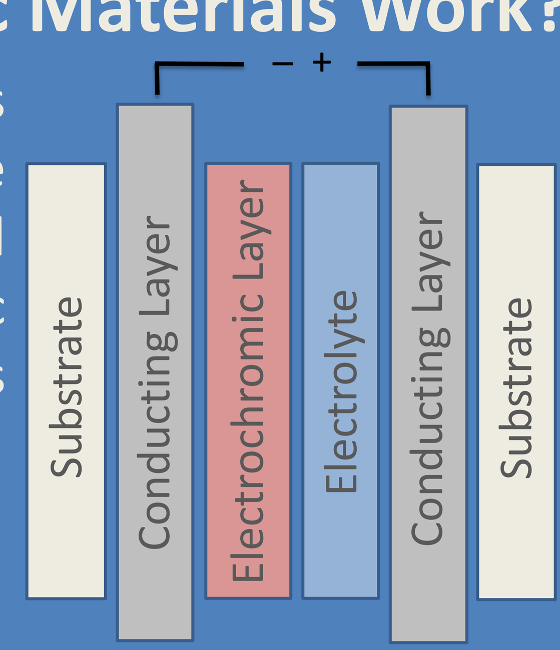
Proposed Solution and Project Goal

Electrochromic materials respond to an applied voltage by changing their tint. Using this effect, one goggle lens could take on an entire range of tints. Traditionally, electrochromic devices are created using rigid substrates inappropriate for ski goggle lenses. The purpose of this project is to develop a flexible electrochromic cell which could be scaled up for use in goggle lenses.



How Do Electrochromic Materials Work?

An applied voltage causes lithium ions from the electrolyte to intercalate with the crystal structure of the electrochromic layer. This reaction for WO_3 is as follows:

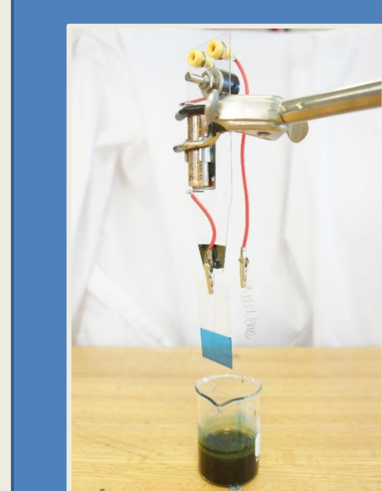


$$WO_3 + Li + e^- \longleftrightarrow LiWO_3$$

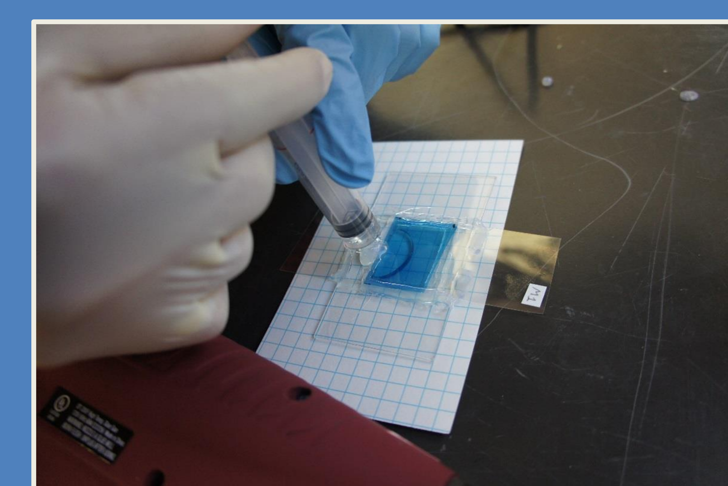
This causes a reduction of W^{6+} to W^{5+}. Each electron released by the reaction can absorb more light.

Methodology

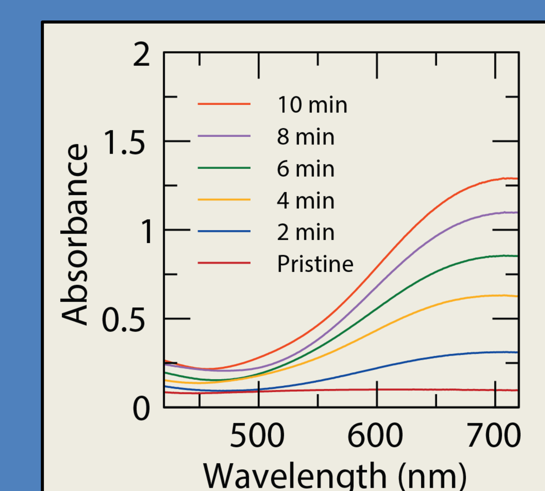
1. Gel electrolytes were prepared by mixing and heating PMMA, propylene carbonate, and $LiClO_4$ in two concentrations: 1 and 2 weight percent
2. Electrochromic cells were assembled using electrodeposited Prussian blue (PB) and sputtered WO_3 thin films on ITO coated PET substrates
3. Films were switched between clear and dark states using 2 AA batteries and variations in opacity were measured using UV-VIS spectroscopy at 700nm



Deposition rig

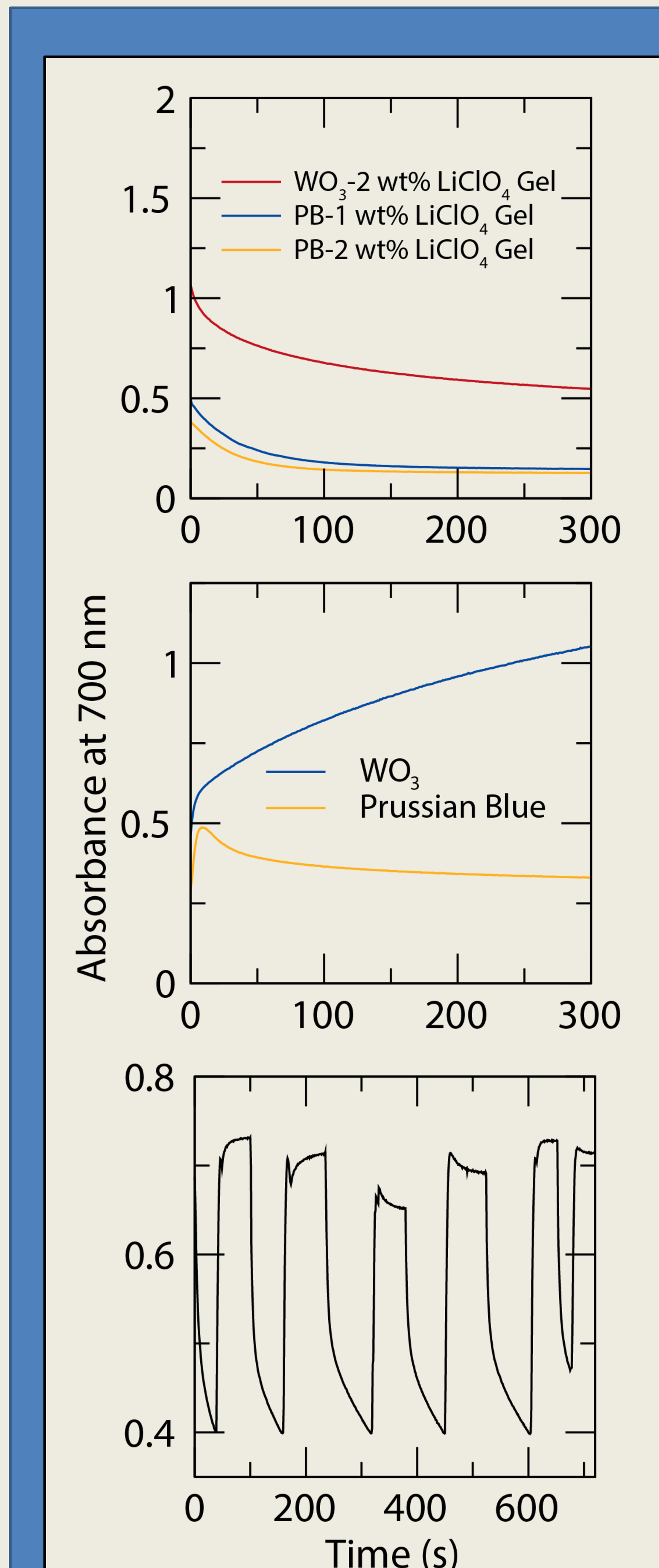


Insertion of gel into cell before final sealing



PB absorbance tailorable with deposition time

Results



The transition between the dark and light states fits the Avrami kinetic model:

$$Y = 1 - \exp(-Kt^n)$$

With the Avrami exponent, n, equal to 0.75, and K varying with the material:

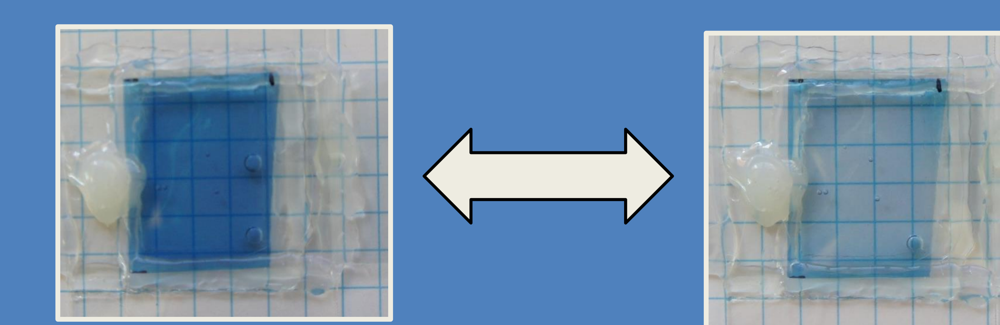
Material	K value
WO_3-2 wt% $LiClO_4$	0.044607
PB-1 wt% $LiClO_4$	0.065355
PB-2 wt% $LiClO_4$	0.069412

WO_3 and Prussian blue showed different behavior in their transition profiles from the dark to light states. This may be caused by polarization in the Prussian blue device.

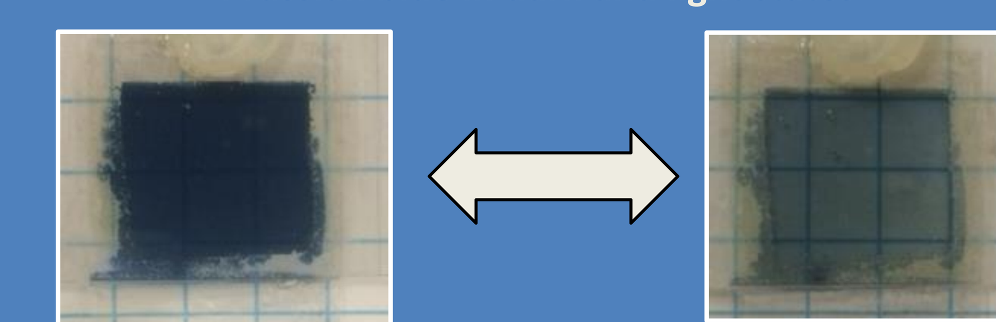
The transition cycle was reproducible in both materials with no observable degradation. Cells functioned properly days after their initial creation.

Conclusion

Because of its grey tint, higher overall absorbance, and larger tint range, WO_3 is a more appropriate material choice for a ski goggle lens. Additionally, WO_3 shows symmetric behavior between the forward and backward transitions while the two directions are vastly different for the Prussian blue cells.



Prussian blue in dark and light states



Tungsten oxide in dark and light states

Future Work

The next step in this project will be to apply this method of construction to an electrochromic ski goggle lens. Challenges will include uniform deposition of WO_3 over a large surface area, construction of control module to be mounted on the goggle frame, and investigation of different methods of deposition for the electrolytic gel. Additionally, we will investigate possible polarization phenomena in the Prussian blue devices.

Acknowledgements and References

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[1] J. Garcia-Jareno, D. Benito, J. Navarro-Laboulais and F. Vicente, 'Electrochemical Behavior of Electrodeposited Prussian Blue Films on ITO Electrode: An Attractive Laboratory Experience', J. Chem. Educ., vol. 75, no. 7, p. 881, 1998.

[2] Tzi-Yi Wu, Wen-Bin, Chung-Wen Kuo, Chiu-Fong Chou, Jian-Wei Liao, Ho-Rei Chen, Ching-Guey Tseng, 'Study of Poly(Methyl Methacrylate)-Based Gel Electrolyte for Electrochromic Device', Int. J. Electrochem. Sci., 8 (2013) 10720 – 10732.