Nanometer Thick Diffused Metal Oxide Light Sensing Film Structures

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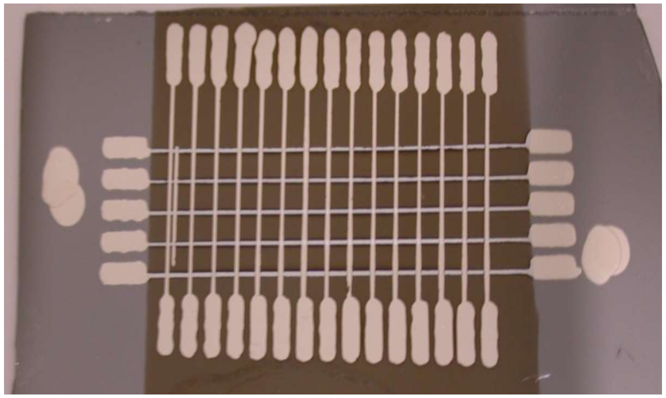
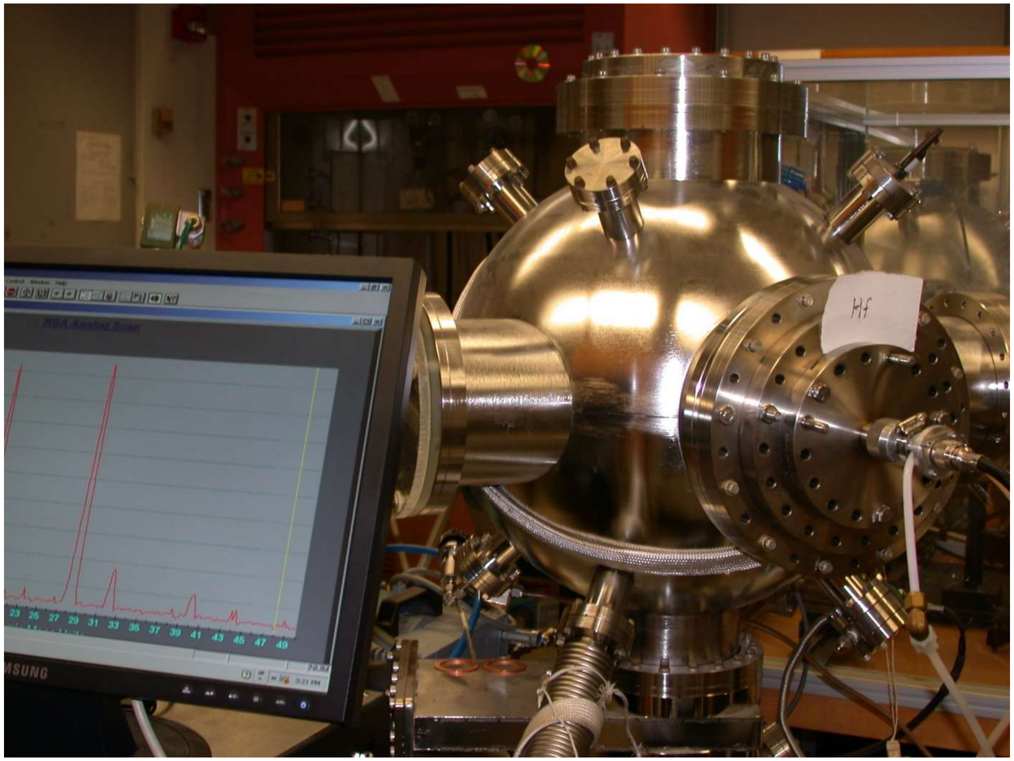


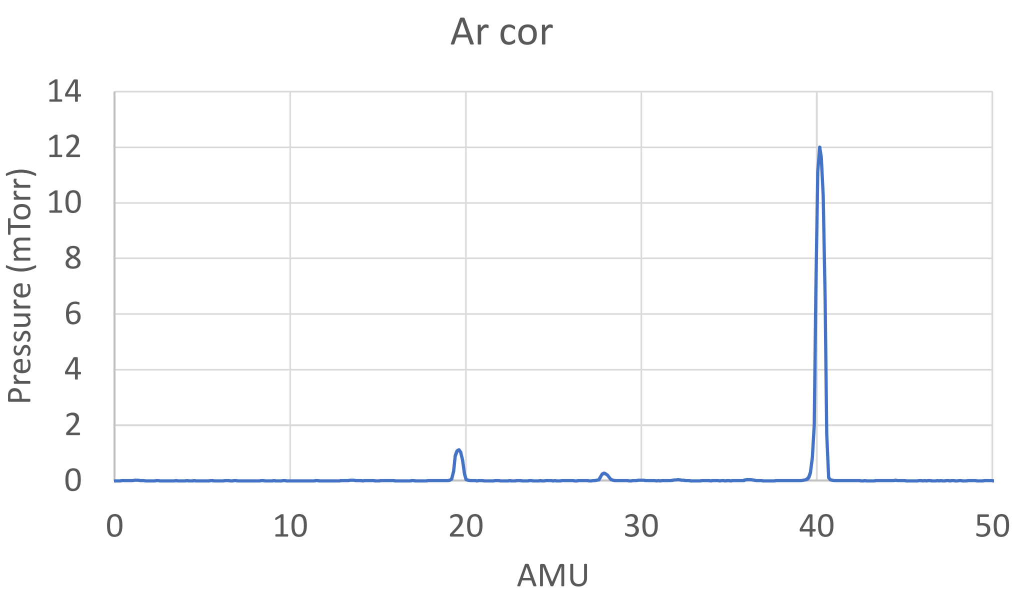
F. J. Cadieu, Device with Light Responsive Layers, U.S. Patent No. 9,040,982

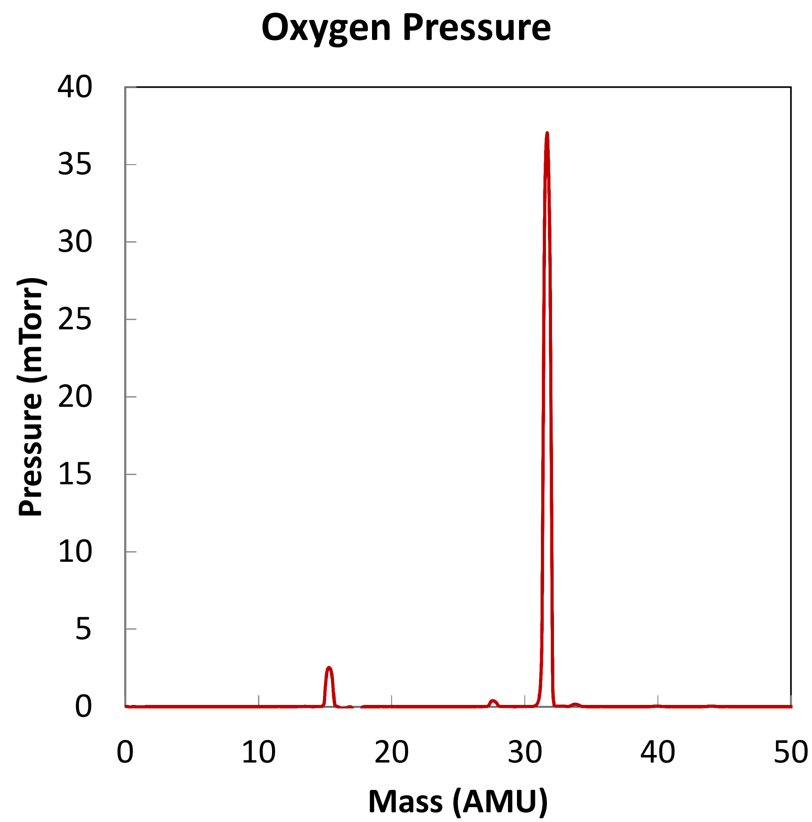
Fred J. Cadieu and Lev Murokh, World Journal CMP, 2017, 7, 36-45

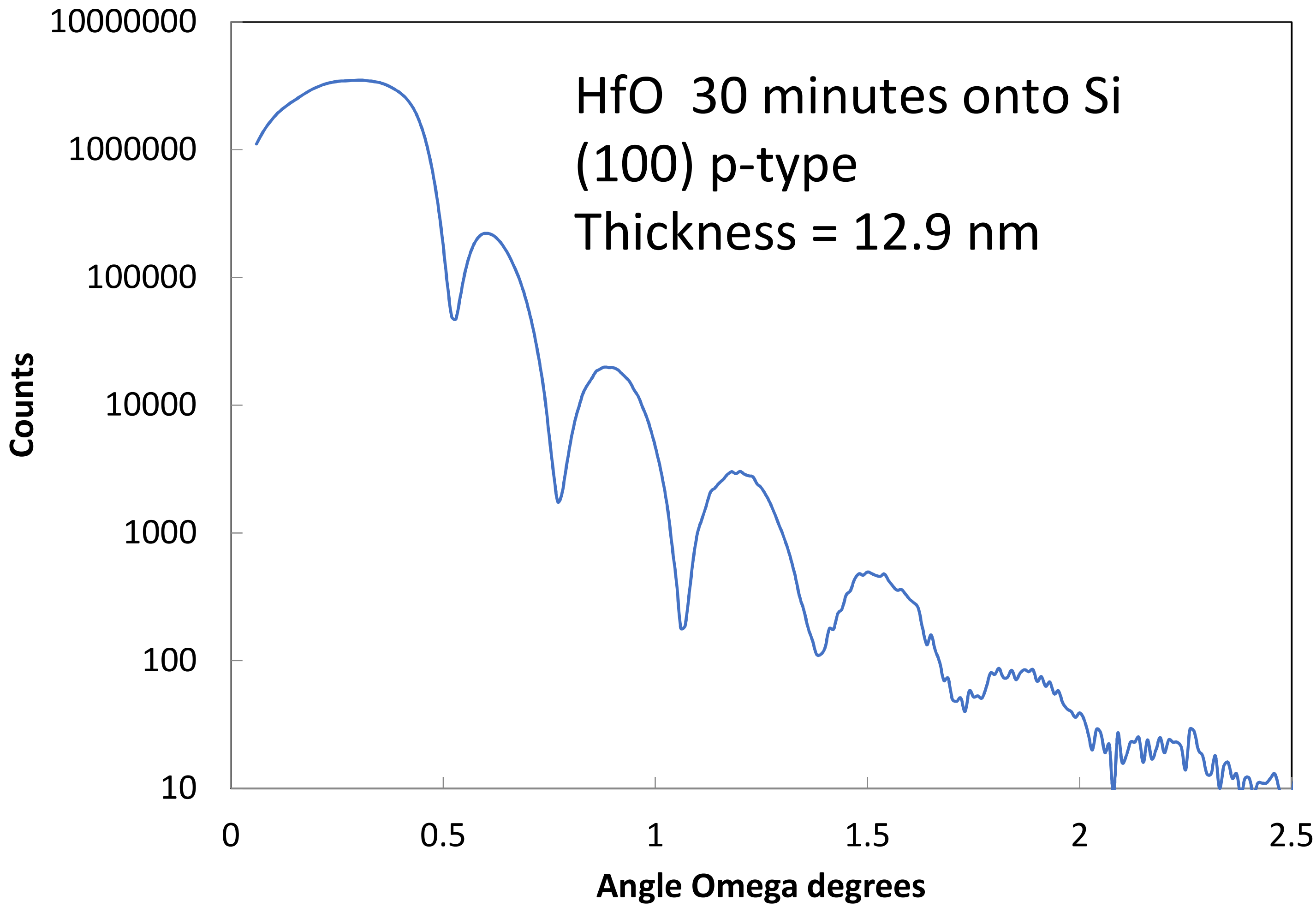
Useful Film Laminates Made With Hafnium, Titanium, and Aluminum



Films sputtered sequentially in 37 mTorr O_2 and then in 12 mTorr Ar, then in 37 mTorr O_2





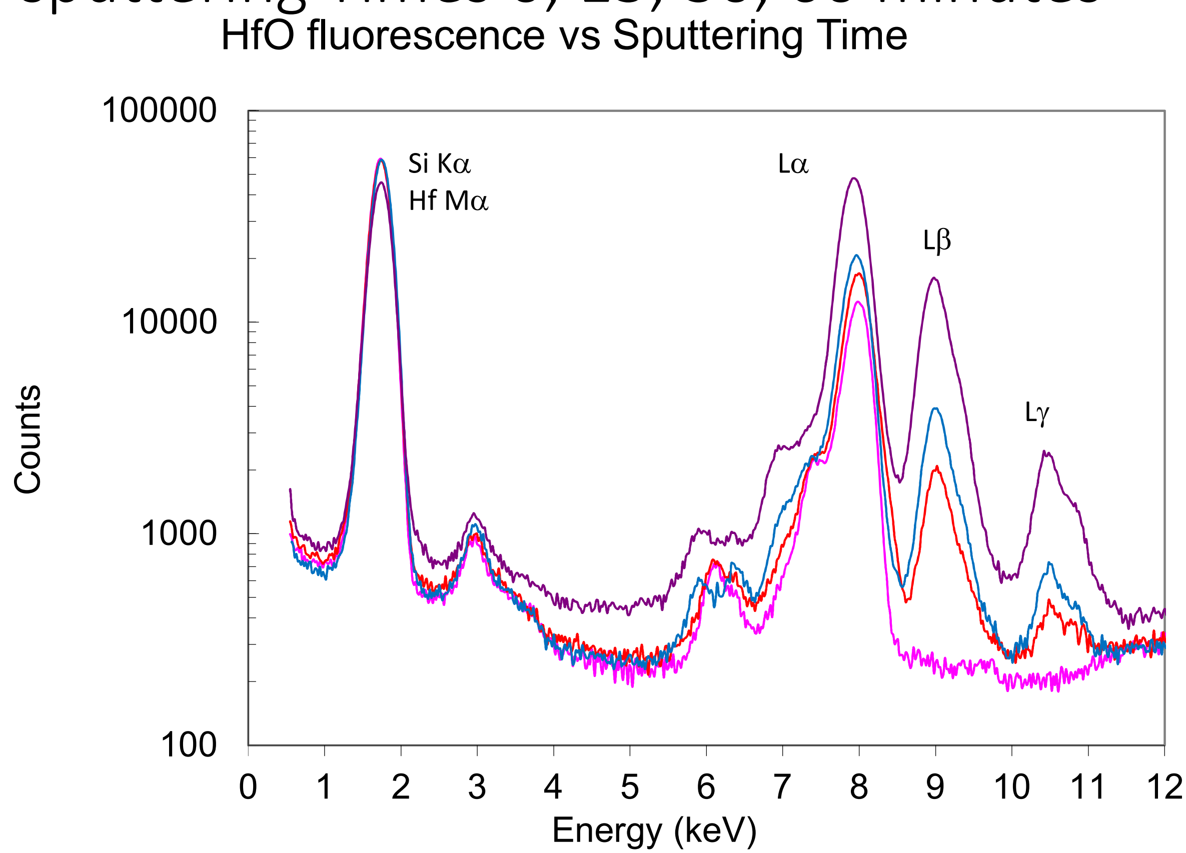

HfO 30 minutes onto Si
(100) p-type
Thickness = 12.9 nm
Counts
Angle Omega degrees
10000000
1000000
100000
10000
1000
100
10
0
0.5
1
1.5
2
2.5

Ta, Hf metal sputtered at 3.0 KVDC,
12 mTorr Ar onto 350 C Si (100)
TaO, HfO sputtered at 3.0 KVDC,
36 mTorr O_2 onto 350 C Si (100)

	Deposition Rate (nm/minute)
Ta	10.9
Hf	17.3
Ta + O_2	0.76 for t < 23 nm
Ta + O_2	1.0 for t > 23 nm
Hf + O_2	0.43 for t < 13 nm
Hf + O_2	1.4 for t > 13 nm

Hf/Ta metals as expected from published relative sputtering rates.

HfO on Si sputtering Times 0, 15, 30, 60 minutes



Hf(O) Lβ Fluorescence Counts and Reflectivity Thickness Precisely Scalable

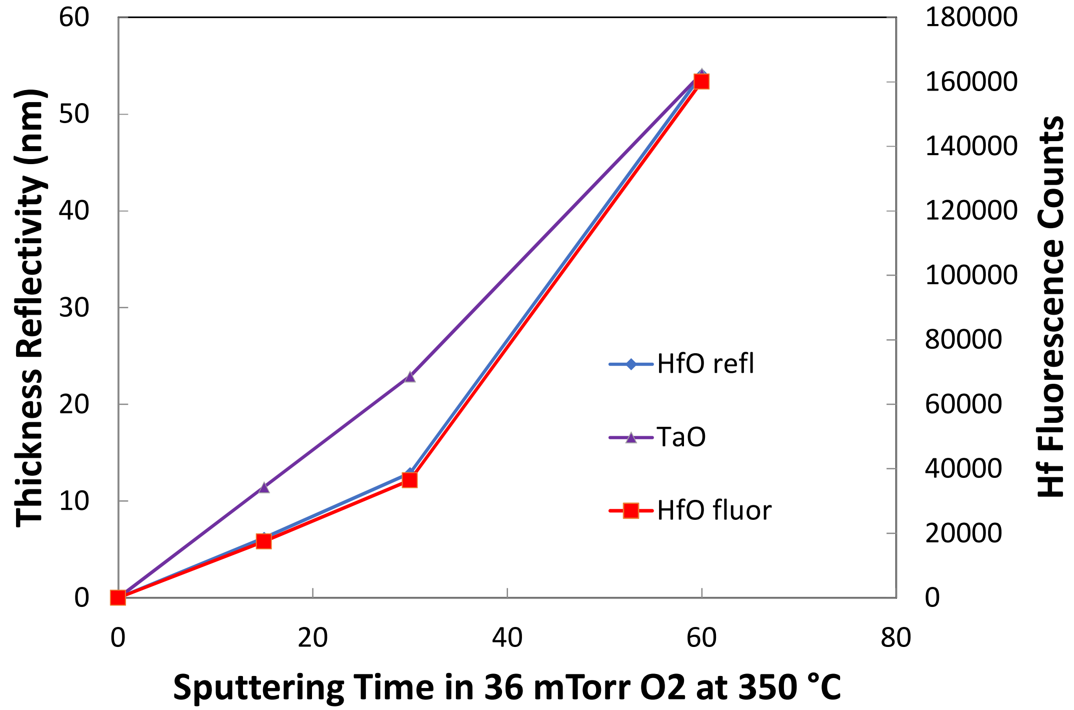
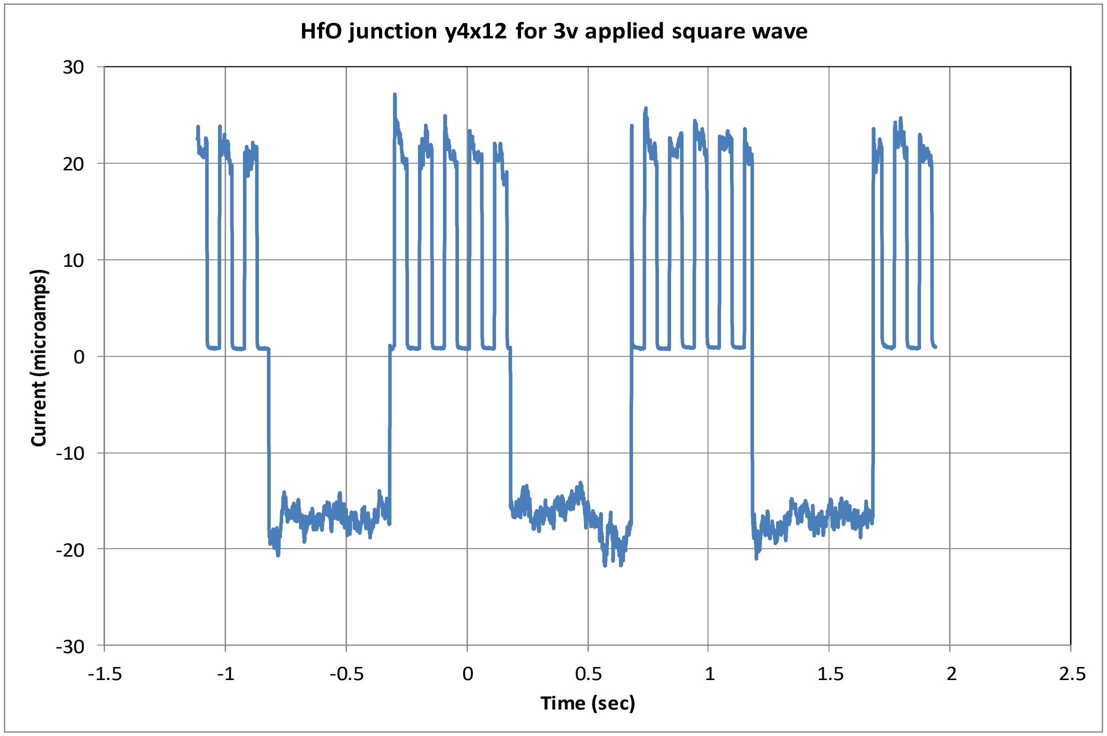


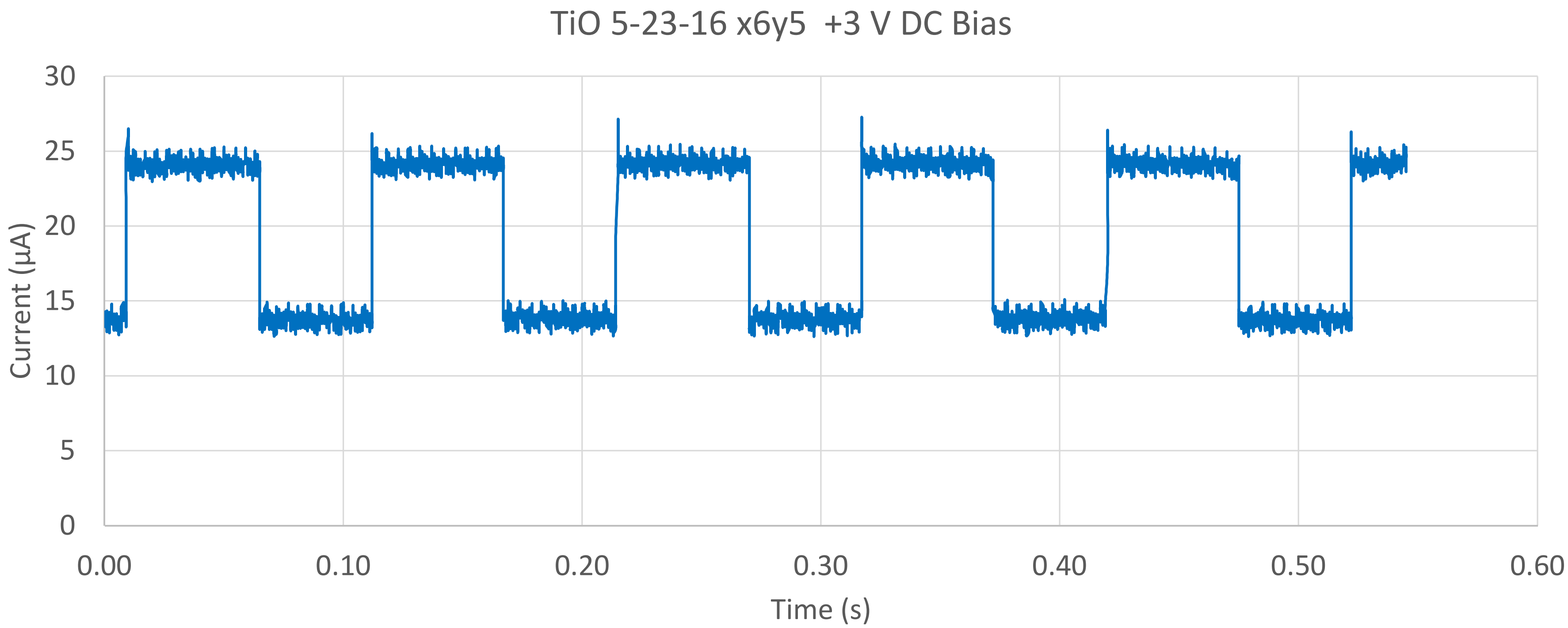
Fig. 1. The current passing through the thickness of a film layer structure is shown for a 3 volt square wave bias in the presence of a white LED strobe light operating continuously.

- 

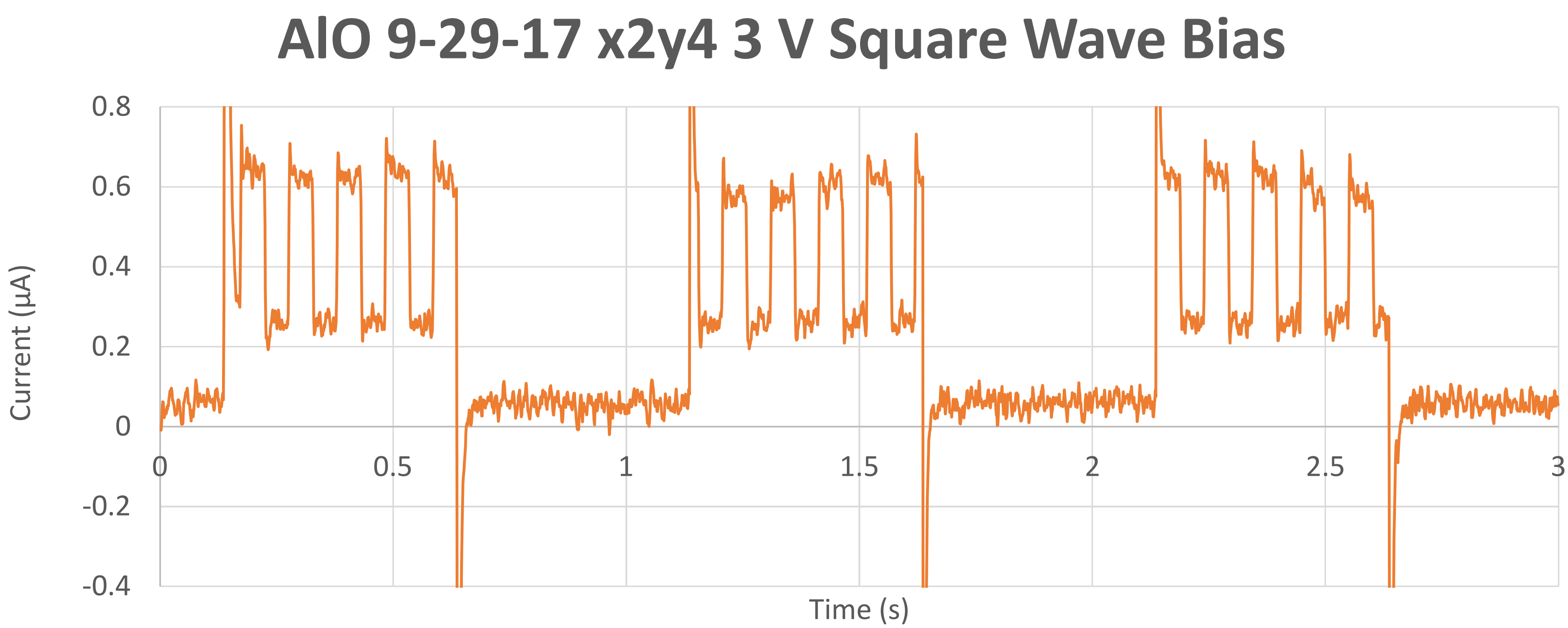
Ratio Current in Light to Current in Dark = 22

When Reverse Biased No Light Response

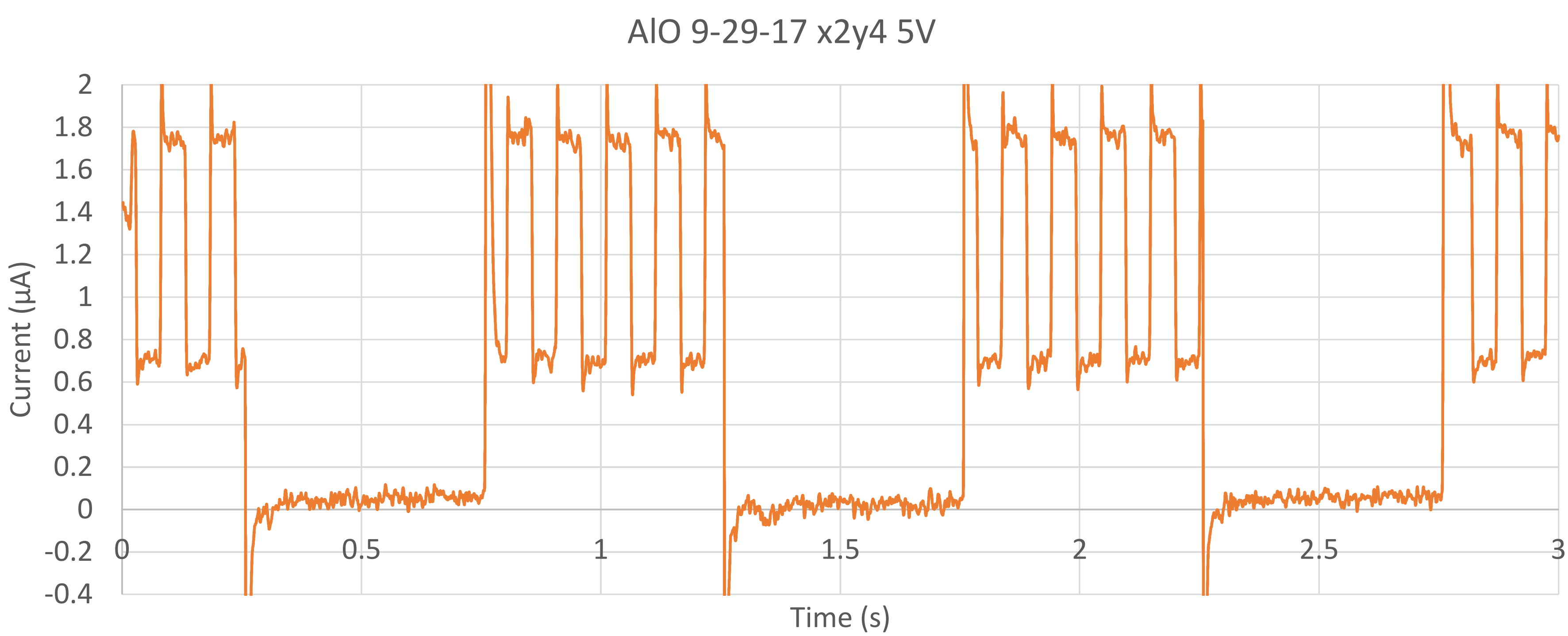
White LED Strobe Light Illumination



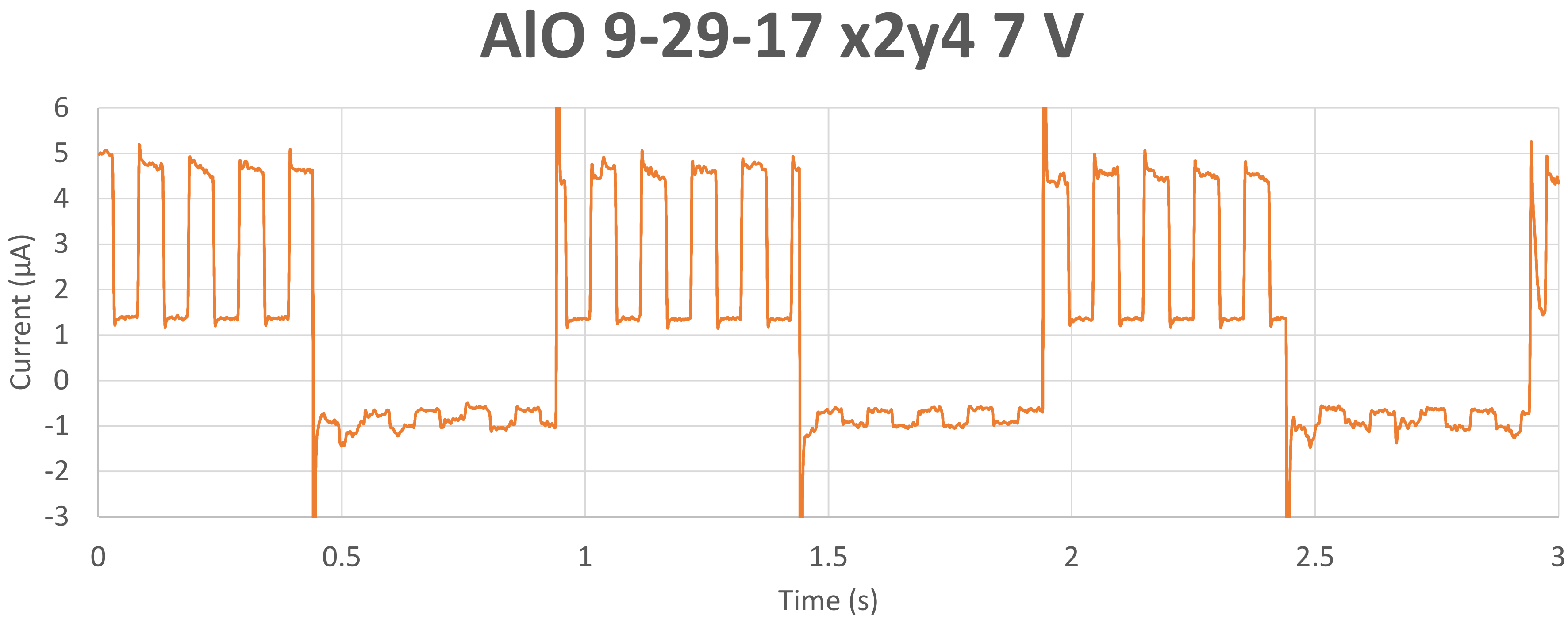
Junction Biased With 1 Hz Square Wave
With Continuous 10 Hz White LED Strobe Light Illumination



Bias Square Wave Amplitude Increased to 5 V

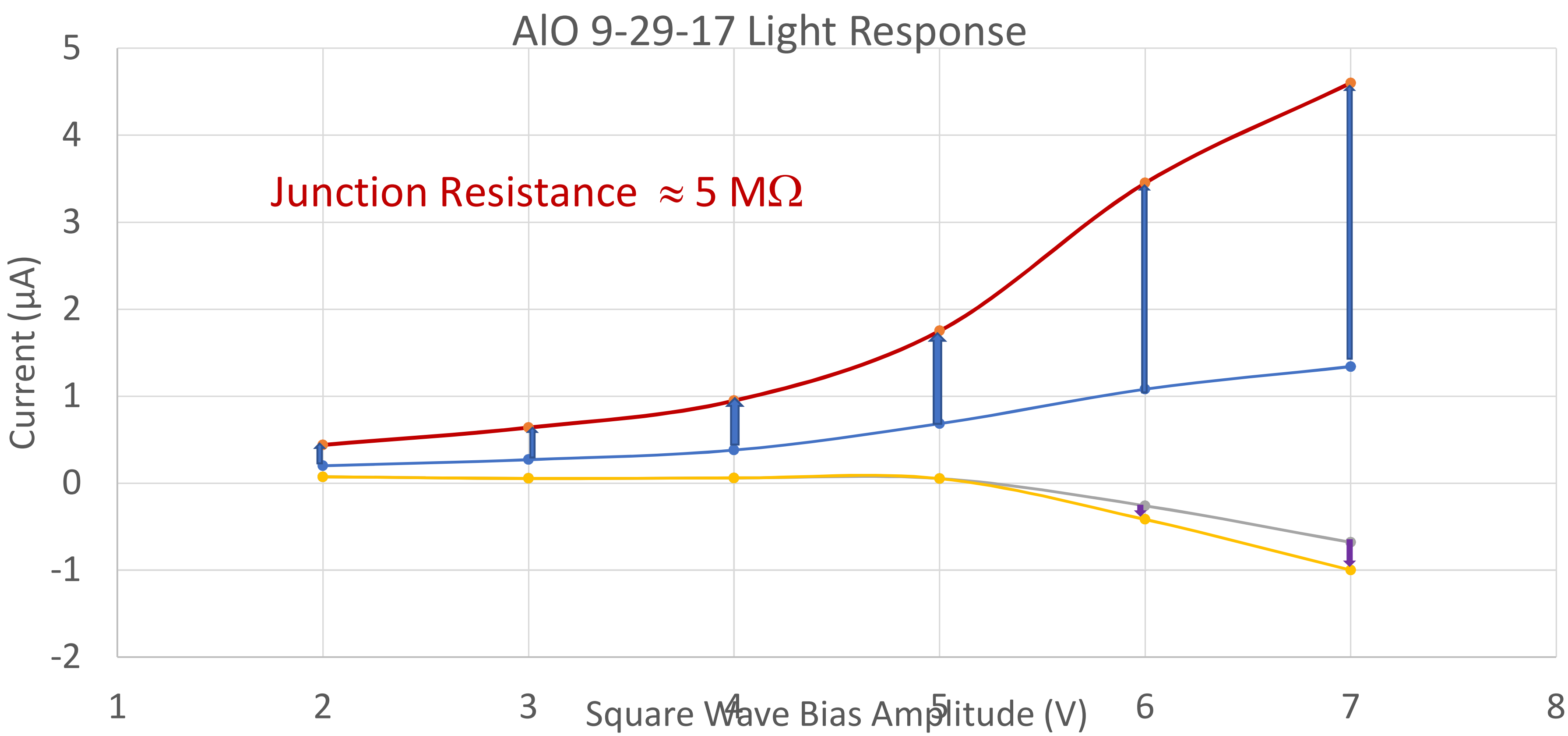


Bias Square Wave Amplitude Increased to 7 V

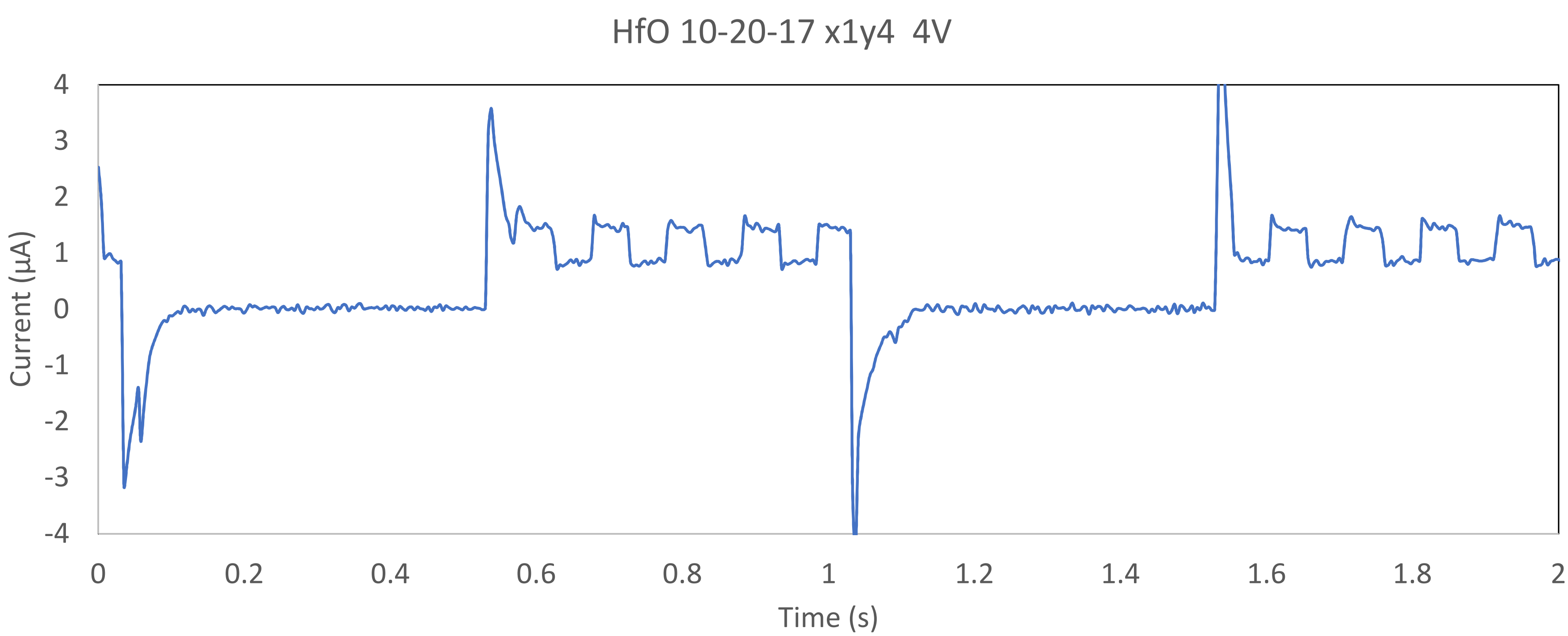


12 min x 1.4 x 0.8 = 13.4 nm Sputtering in Oxygen T = 360 °C
4 min x 17.3 x 0.8 = 55.4 nm Sputtering in Ar T = 330 °C
3.67 min x 1.4 x 0.8 = 4.1 nm Sputtering in Oxygen T = 280 °C

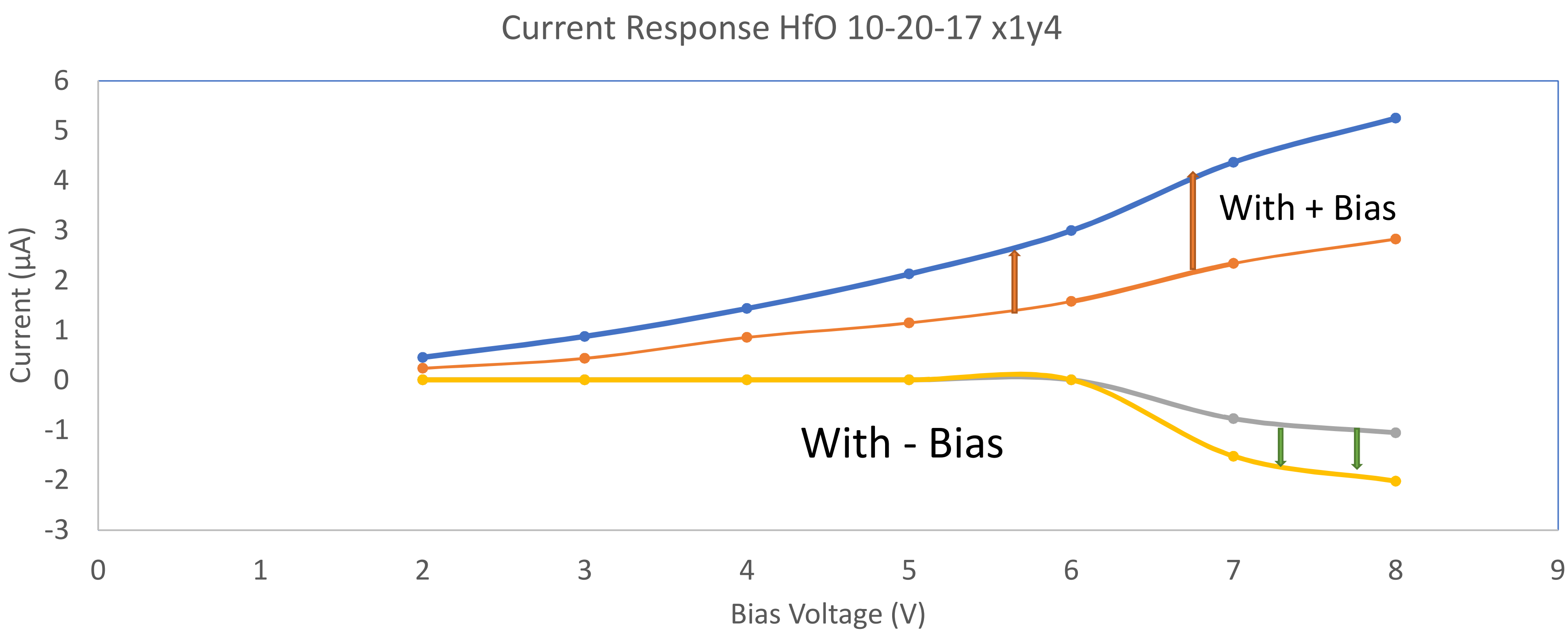
Total Thickness = 73 nm



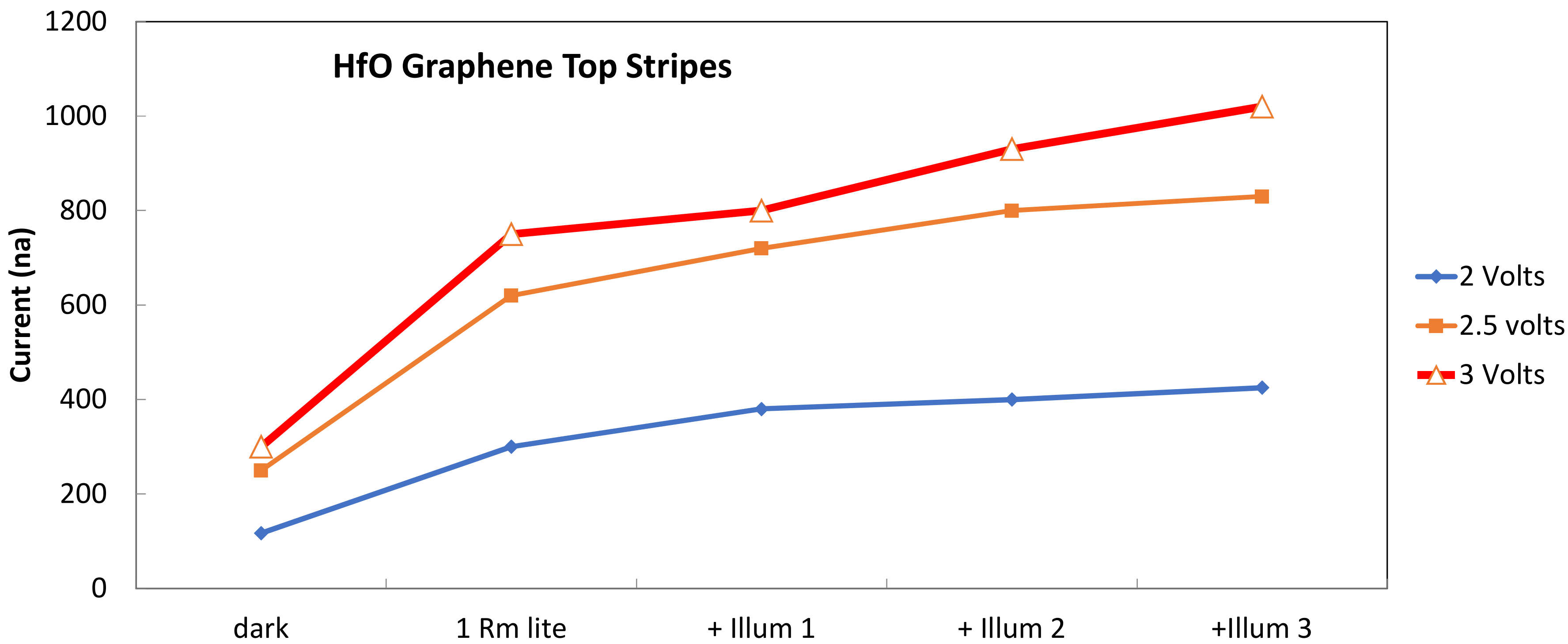
HfO layers with only 2 minute Hf Ar deposition also exhibit high junction resistances



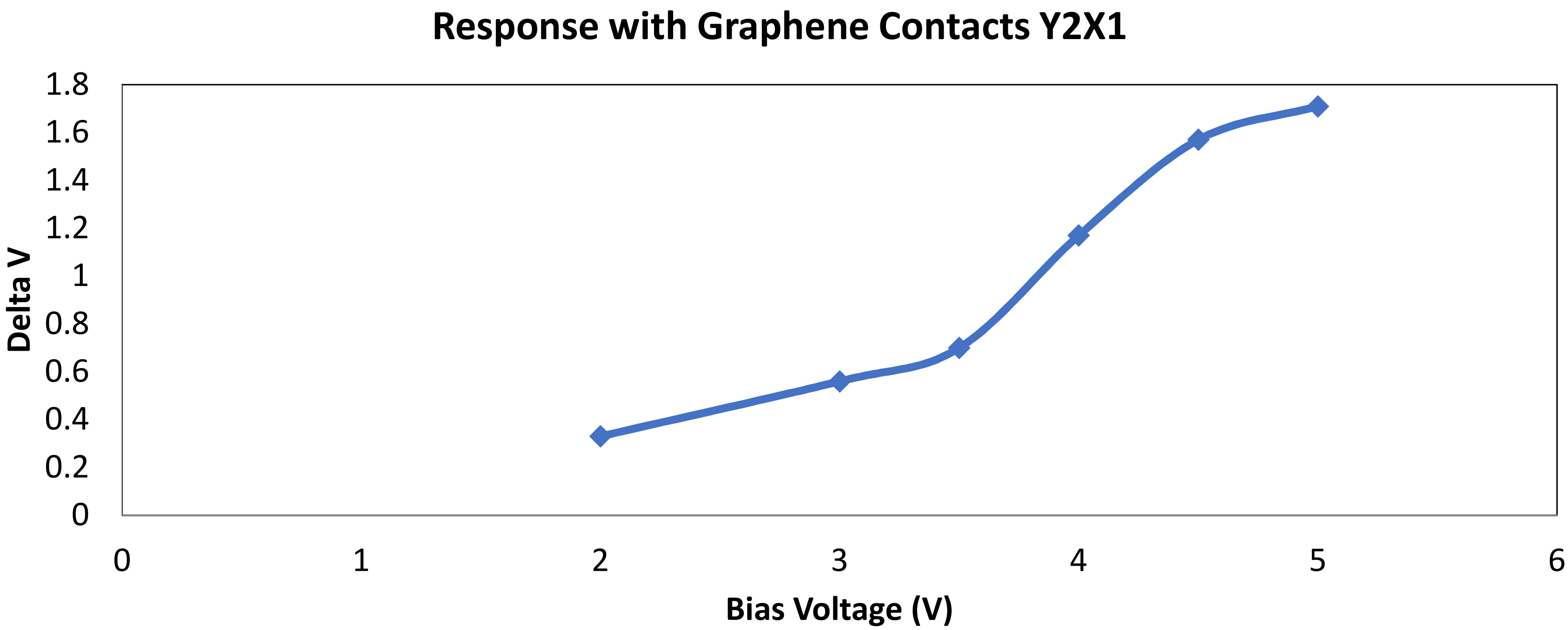
HfO Laminate Thickness 58 nm – Junction Resistances ≈ MΩ



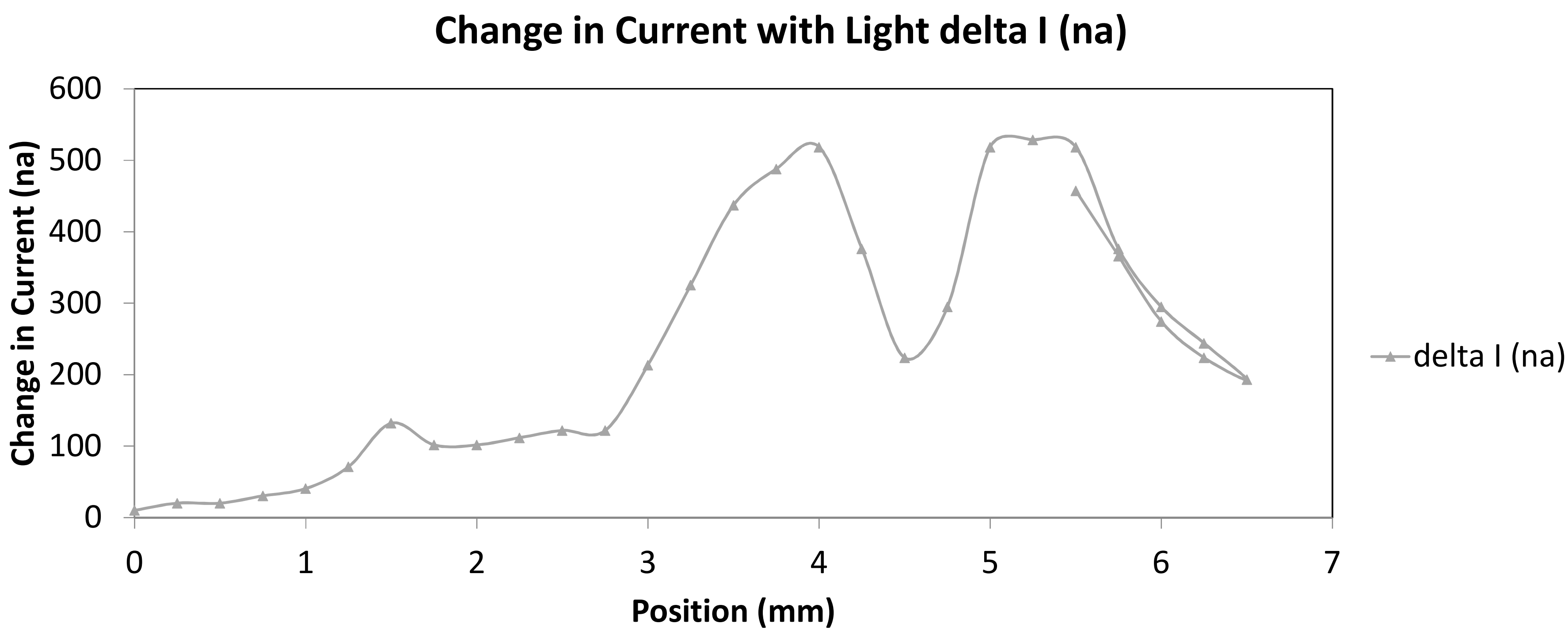
Transparent Graphene conducting cross stripes have also been demonstrated usable as top contacts.



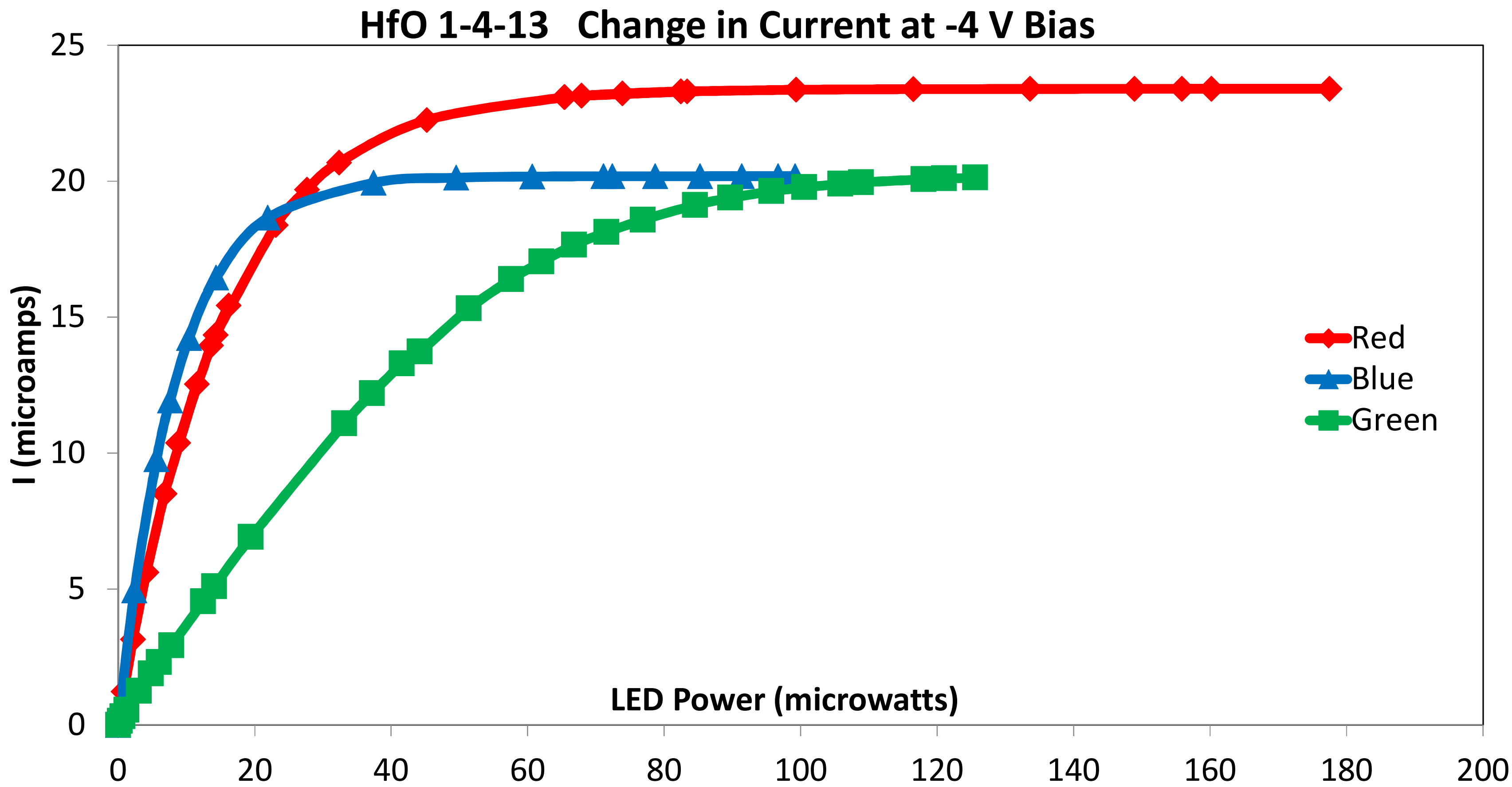
Transparent Graphene contacts do not exhibit shadowing



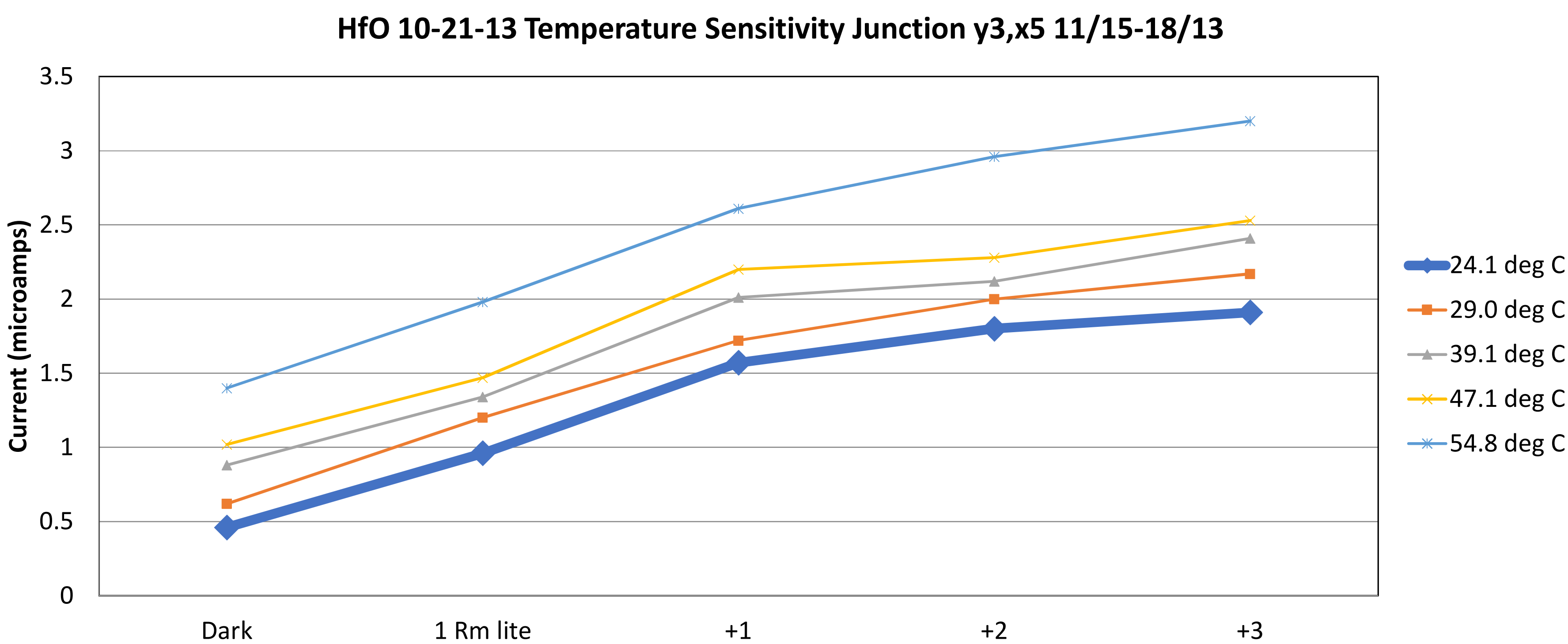
Shadowing across 1 mm wide opaque Aluminum top contacts.



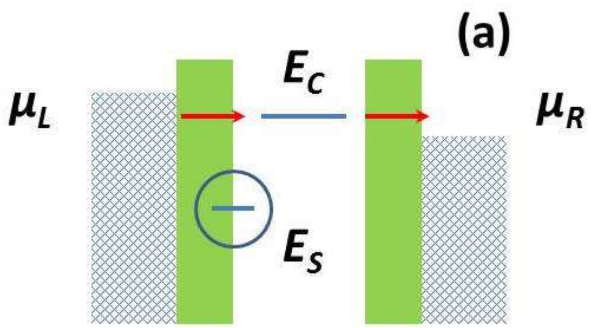
Junction Response for Red, Green, and Blue LEDs

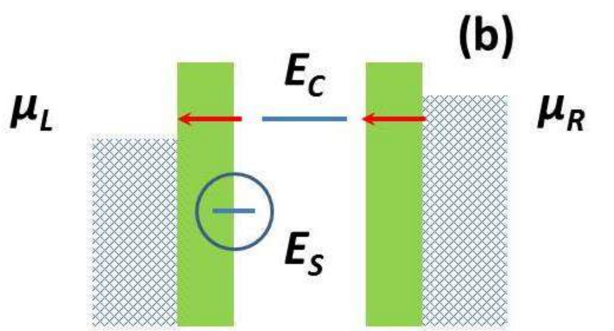


Response Increases With Increased Temperature



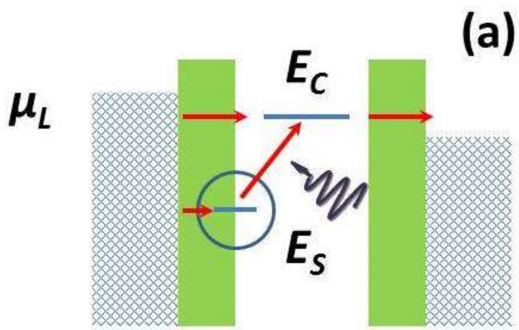
Electron transport without light illumination

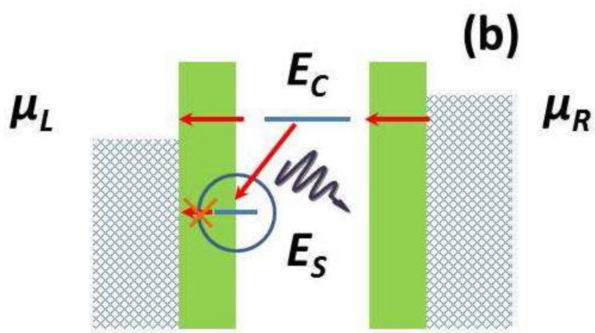




1. During the sample growth, the oxygen dangling bonds lead to the appearance of the interface states, E_S, on the upper metal-oxide interface.
2. Electron transport occurs in the conduction window between the chemical potentials of the leads when the states with corresponding energies are filled at the one of the lead and empty at the another one.
3. The interface states are well below the chemical potential of the leads, so they do not contribute to electron transport ***without the light illumination***.
4. Consequently, the current-voltage characteristics are symmetric with the direction of the applied voltage.

Electron transport with light illumination



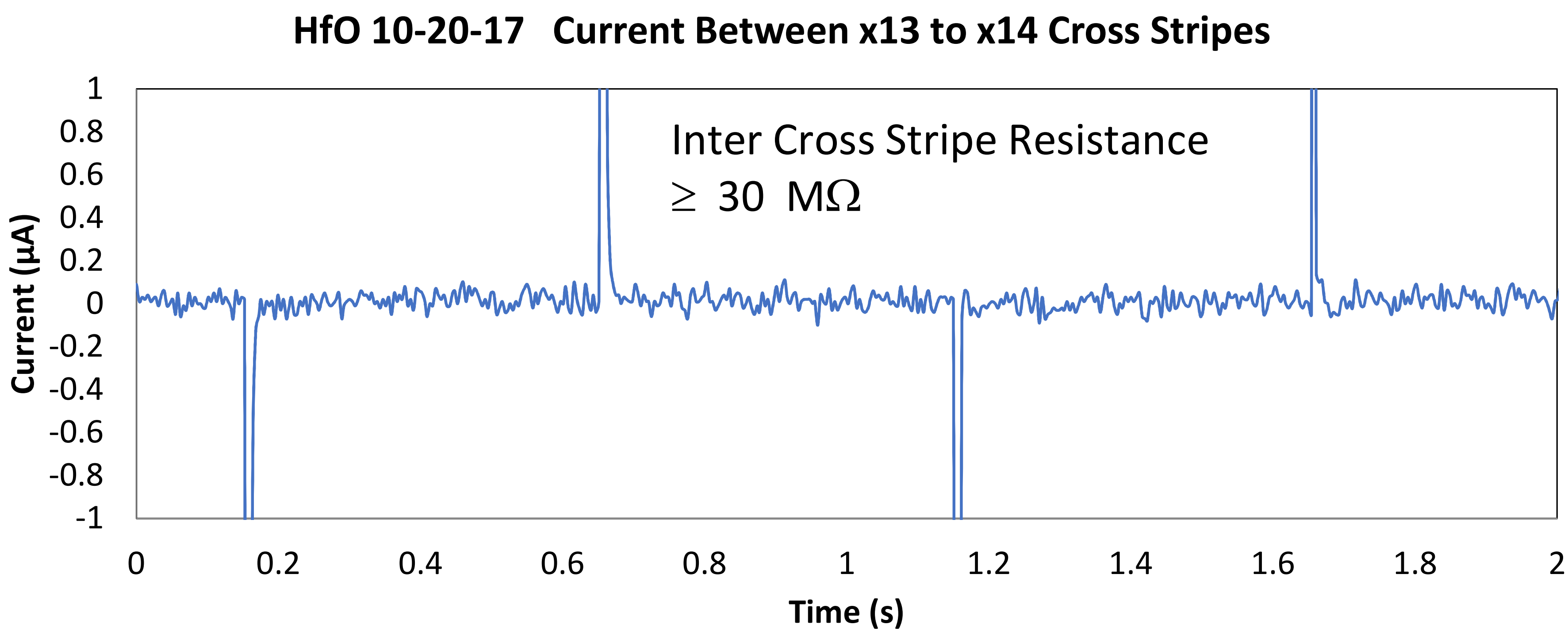


1. ***With the light illumination,*** electrons can be promoted from the interface states to the states in the conduction window after the light absorption.
2. This leads to the additional conduction channel for the left-to-right current, as the interface states are populated from the left lead, depopulated to the conduction channel, and the electrons subsequently proceed to the right lead. This gives rise to significant left-to-right current enhancement.
3. Electron transport via the interface states in the right-to-left direction is blocked at moderate voltages because these states cannot be depopulated to the left lead as all the states at this energy are already filled.
4. At high voltages, when the chemical potential of the left lead becomes comparable to the energy of the interface states, small enhancement of the right-to-left current occurs.

Summary

- Sputtered Film Laminates With Nanometer Thicknesses Have Been Synthesized That Exhibit Light Sensitivity For Through the Film Thickness Electrical Resistances.
- Metal Oxide – Metal – Metal Oxide Laminates Made with Aluminum, Titanium, and Hafnium have been synthesized that exhibit a large light sensitivity for one bias polarity, but no response when biased with an opposite polarity bias Voltage.
- The observed light response has been modeled in terms of interface states that explain the behavior for optimally synthesized film laminates.

The Top Contact Strips Deposited Onto Oxide Layer Are Highly Insulated From Each Other



Isolation of Long y-Stripes Dependent on Si Resistance or an Oxide Overcoat Layer