# Optical Signatures in Reflective Polarimetry from Titanium Nanostructures

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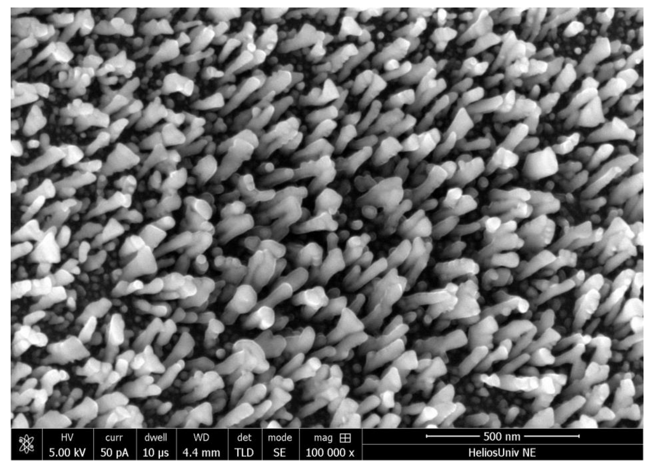
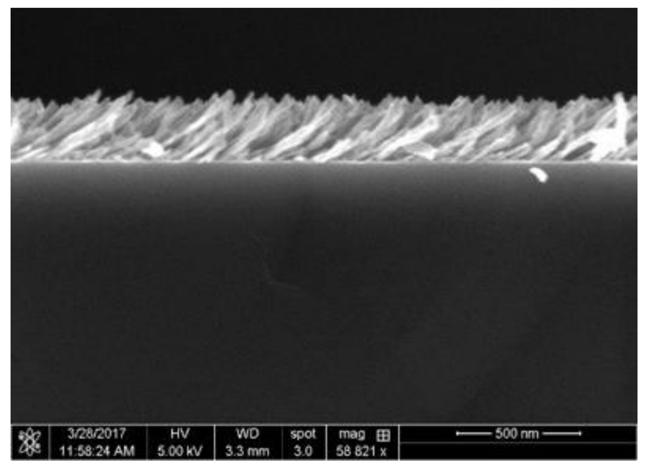
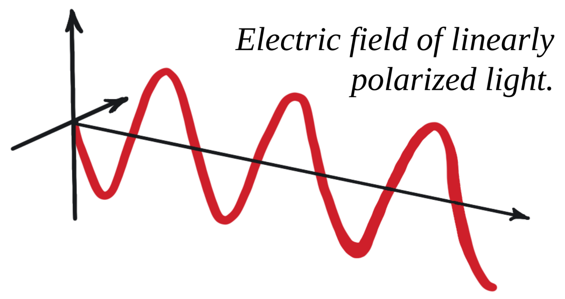
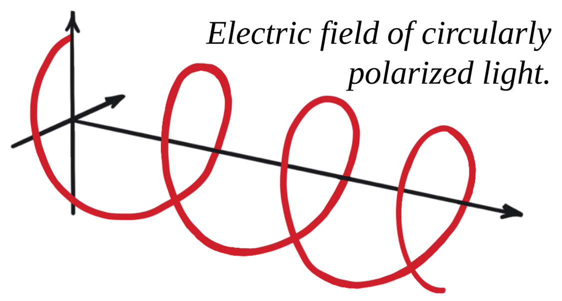
## INTRODUCTION

In the work reported here, we reflect both linearly and circularly polarized light from "tilted rod" anisotropic titanium nanostructures (shown below). By measuring differences in the intensity of the reflected polarized light, i.e. dichroism, we hope to identify optical signatures of metallic structures of a size comparable to the wavelength of the laser light we use to study them.





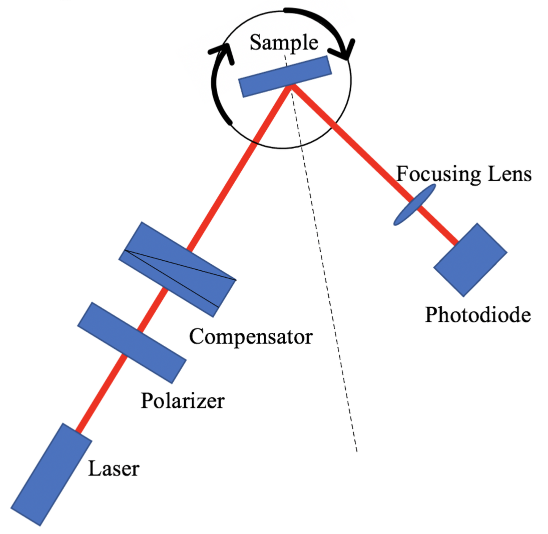


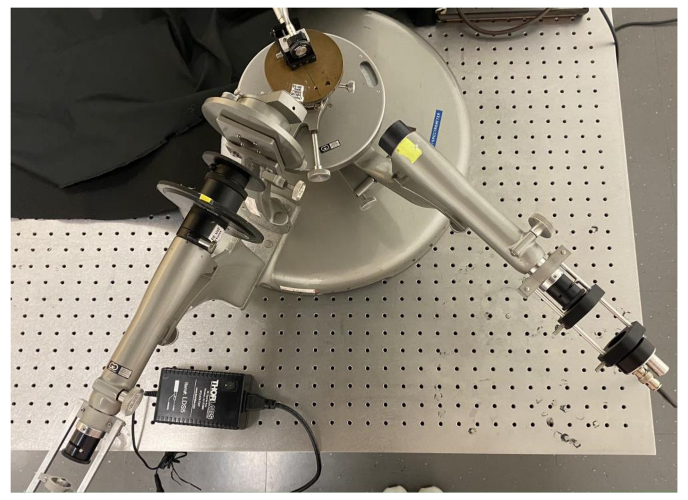




Polarization is defined by the electric field vector of a light wave. When the light is linearly polarized, the electric field oscillates in a single geometric plane. If, however, the magnitude of the electric field vector is constant and rotates around the propagation direction of the light, tracing out a "corkscrew," the light is circularly polarized.

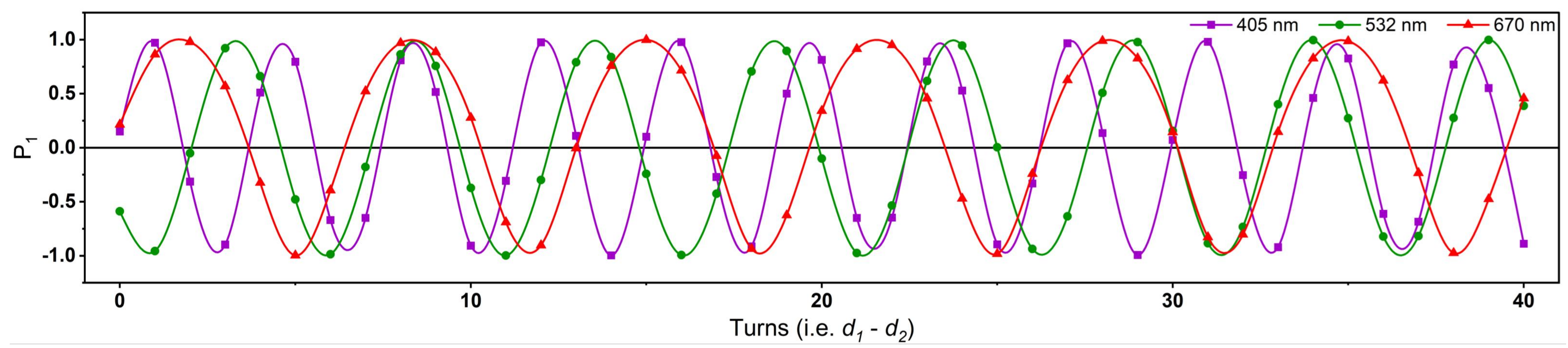
## EXPERIMENTAL SETUP

The experimental set-up is shown below. It is based on a Gaertner L119 ellipsometer and L119A Babinet-Soliel compensator. Polarimetric measurements are made upon reflection from the sample using lasers of two wavelengths (λ = 405nm and 635nm). A linear polarizer and a compensator are used to define the polarization state of light incident upon the sample. The setup shown allows for angles of incidence between 20° and 70°. The sample can rotate a full 360° in a plane perpendicular to the plane of incidence. A photodiode is used to measure the intensity of the light reflected from the sample.



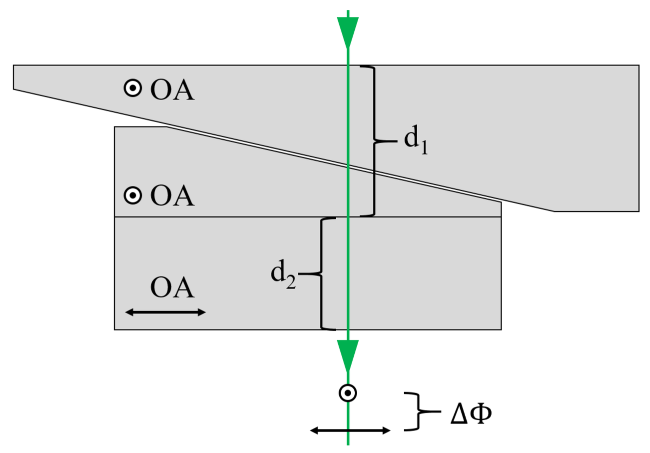



## OPTICS CHARACTERIZATION

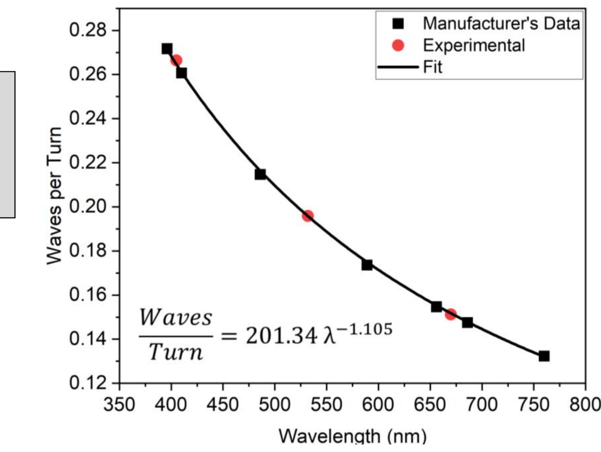



Great care is taken to characterize the optics used to define the polarization of the incident light. Measurements of the transmitted linear polarization ($P_1$) as a function of the thickness of the birefringent plates in the compensator (above) allow us to fully characterize the resulting phase shift, ΔΦ, in the transmitted light (described below). This, in turn, allows us to produce light of any desired polarization state.

$$\Delta\Phi = \frac{2\pi}{\lambda}\left|n_\perp - n_\parallel\right|(d_1 - d_2)$$

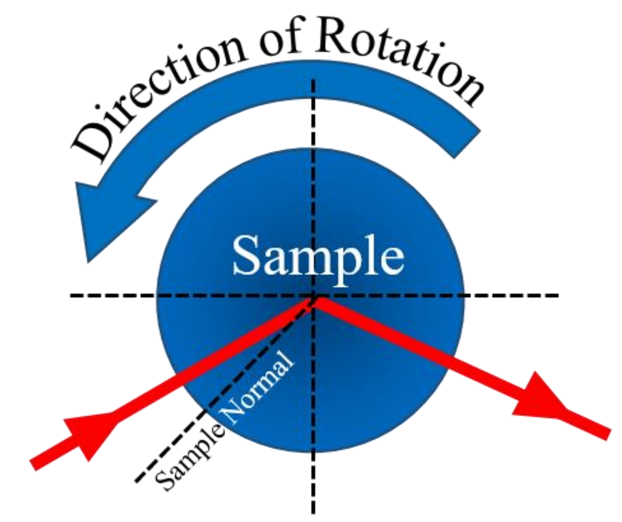


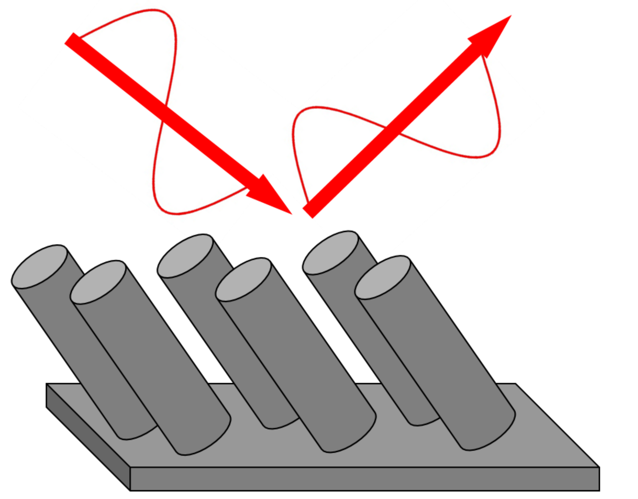

*The compensator is comprised of birefringent plates with perpendicular optical axes (OA) of indices of refraction $n_\perp$ and $n_\parallel$. The relative thickness of the plates, $d_1$ and $d_2$, determines the net phase shift in the transmitted light.*




*Careful measurements of the net phase shift per plate thickness ("turns") as a function of wavelength allows us to choose any polarization state for any wavelength.*

## AZIMUTHAL ROTATION

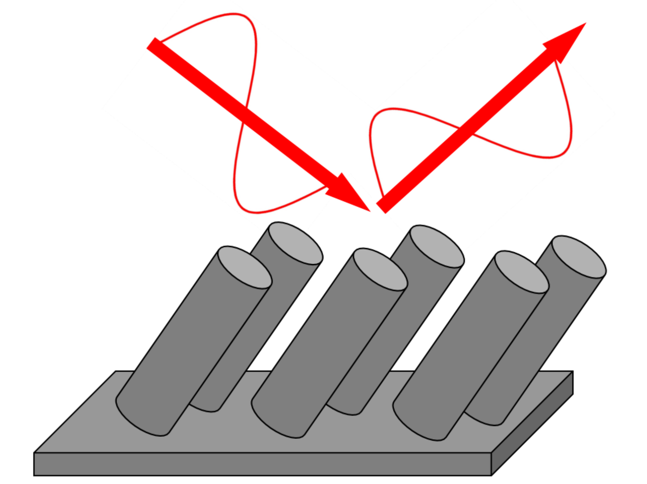


*90° Azimuth*

The clear azimuthal-orientation- and wavelength-dependent signals can be modeled by envisioning the titanium nanostructures as nano-scale antenna.

As the azimuthal orientation changes, the nanostructures align with the plane of polarization of the incident light.



*270° Azimuth*

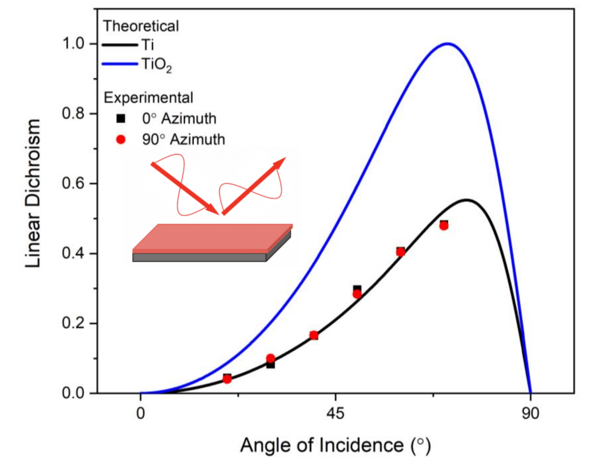
## DICHROIC RESPONSE

The dichroic response from both anisotropic and isotropic (optically flat) titanium is shown here.

Dichroism is calculated by:

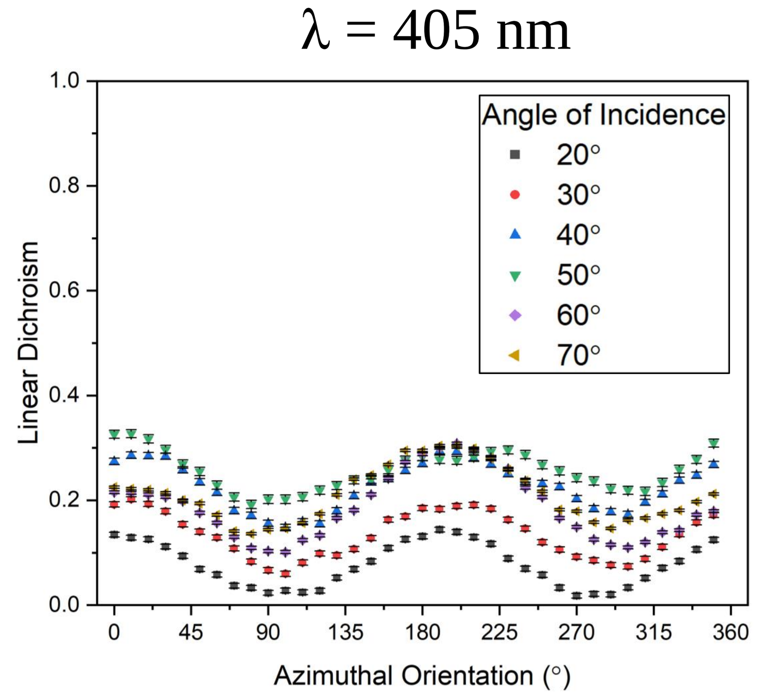
$$D = \frac{I^{V,R} - I^{H,L}}{I^{V,R} + I^{H,L}}$$

where $I^{x,y}$ is the normalized intensity of the reflected vertically ($V$), horizontally ($H$), right-handed circularly ($R$), and left-handed circularly ($L$) polarized light.

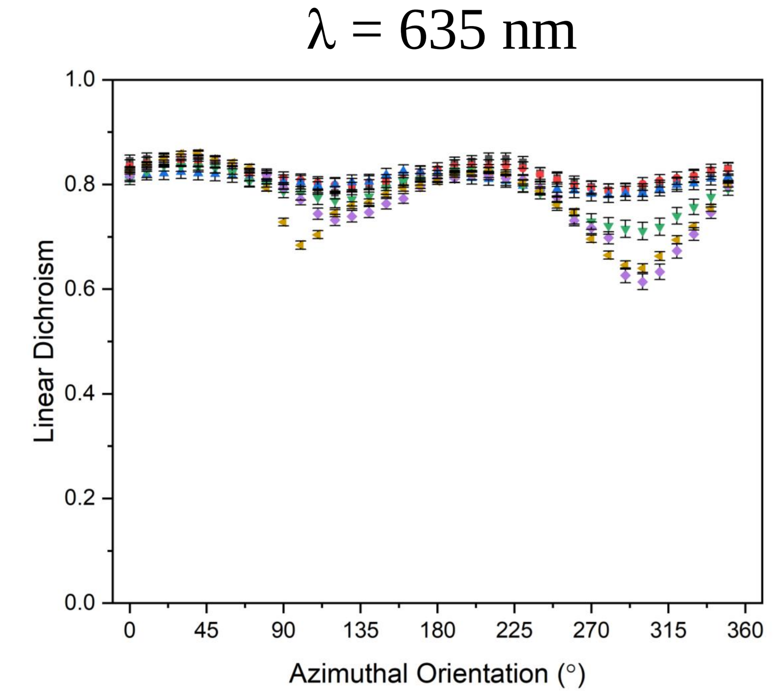


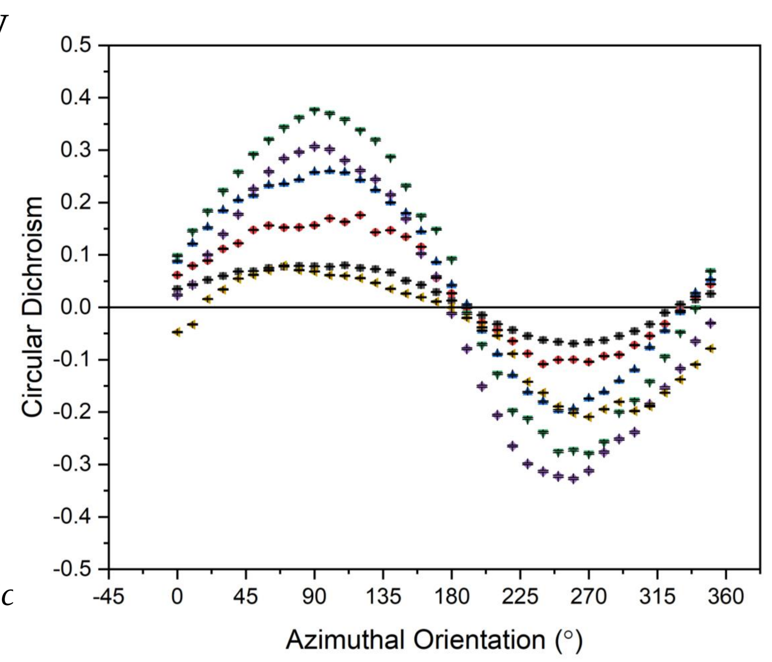

*Linear dichroism signal from isotropic (smooth) Ti film[1,2].*

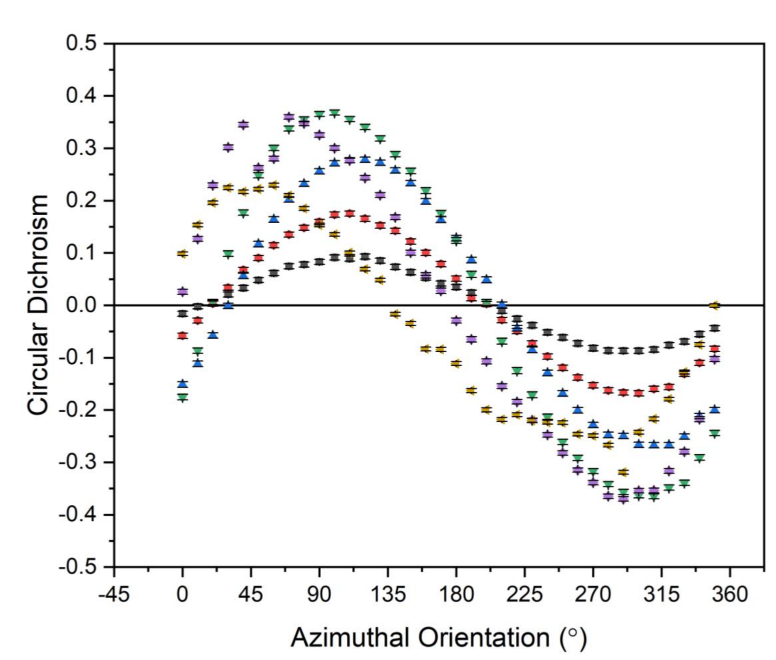
λ = 405 nm




λ = 635 nm




## CONCLUSIONS

- Anisotropic titanium nanostructures show a clear azimuthal-orientation- and wavelength-dependent dichroic response.
- The periodicity of the circular dichroic response is 360° *vs.* 180° for the linear dichroic response.

**FUTURE WORK**

- Measure linear and circular dichroic response from chiral titanium nanostructures.
- Develop a model to explain the periodicity of circular dichroism.
- Shine high intensity polarized laser light on chiral samples and investigate polarization of thermally and/or photoelectrically emitted electrons.

**REFERENCES**

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2. P.B. Johnson, R.W. Christy, Optical constants of transition metals: Ti, V, Cr, Mn, Fe, Co, Ni, and Pd, Physical Review B. 9 (1974).

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