MONASH University

MONASH ENGINEERING

Faculty of Engineering

ASPIRE Summer Research Program 2026-2027

Project Title: Understanding and Controlling Thermally Induced Structural Color in Additively Manufactured Titanium Alloys

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Objective

The project will establish a reproducible heat treatment–color map for selected titanium alloys and identify how temperature and treatment time influence the final surface color. Quantitative color measurements will be correlated with oxide thickness, composition, crystal structure, and interfacial chemistry obtained from microscopy and spectroscopy. STEM data analysis will reveal nanoscale compositional gradients, elemental segregation, and structural changes within the oxide layer. These results will be combined to develop a mechanistic understanding of how thermal oxidation produces different colors in titanium alloys and to provide practical guidelines for controlled color design.
The work may contribute to a future journal publication..

Project Details

The introduction of titanium into widely recognized consumer products has brought renewed attention to the appearance as well as the mechanical performance of titanium alloys. For example, the iPhone 15 Pro was released in black titanium, white titanium, blue titanium, and natural titanium finishes, making the color of titanium familiar to a broad public audience. The commercial coloring route used in such products is proprietary and is not assumed to be thermal oxidation. Instead, the iPhone provides an engaging starting point for a fundamental materials-science question: why can titanium appear in so many different colors?
When titanium is heated in an oxygen-containing atmosphere, a thin surface oxide develops. Depending on the oxide thickness and composition, light reflected from the air–oxide and oxide–metal interfaces can interfere, producing vivid gold, purple, blue and other colors without the use of conventional pigments. Previous studies on Ti-6Al-4V have reported clear color changes with oxidation temperature and have related these changes to variations in oxide-film thickness, composition, and optical interference.
However, oxide thickness may not be the only controlling factor. Different titanium alloys contain elements such as Al, V, Sn, Zr, Mo, and Nb, which may alter oxygen diffusion, selective oxidation, oxide-layer stratification and the electronic structure of the film. Oxidized Ti-6Al-4V, for example,

can form chemically distinct oxide layers containing Ti-, V-, and Al-rich regions. The crystallographic orientation and microstructure of the underlying titanium can also influence the morphology and optical response of the oxide.
This project will investigate whether different additively manufactured titanium alloys develop reproducible and distinguishable colors under identical thermal treatments. Polished coupons of commercially pure titanium, Ti-6Al-4V, and one additional near-α or β titanium alloy will be thermally oxidized under controlled temperature, time, and atmosphere.
The oxide films will then be characterized across multiple length scales. Film thickness, roughness, phase constitution, and chemical composition will be measured using techniques such as surface profilometry and SEM. Selected colored conditions will be examined using FIB-prepared cross-sections and advanced STEM-EDS/EELS to resolve oxide-layer structure, titanium oxidation state and alloying-element segregation at the oxide–metal interface.
The project therefore combines an immediately visible outcome—a collection of brightly colored titanium samples—with fundamental research in oxidation, surface science, color measurement and atomic-resolution microscopy. The student will gain practical experience in titanium metallurgy, additive manufacturing, controlled heat treatment, surface and color measurement, spectroscopy, electron microscopy, quantitative data analysis, and optical modelling.

Main Activities
1. Sample preparation: prepare geometrically identical coupons from two or three titanium materials, preferably. The samples will be ground and polished using an identical procedure to minimize differences caused by initial roughness. A small number of as-built samples may subsequently be included to evaluate how additive-manufacturing surface texture affects color uniformity.
2. Thermal-oxidation experimental: Conduct a preliminary thermal-oxidation screening study over an approximate temperature range of 350–650 °C, using selected exposure times between approximately 5 and 60 minutes. The initial screening will identify conditions that produce

visually distinct gold, purple, blue, and dark-colored surfaces. Representative conditions will then be repeated to assess color reproducibility.
3. Color measurement: using standardized photography under controlled illumination. This activity will distinguish genuine material differences from variations caused by camera settings, lighting conditions, or subjective color descriptions.
4. Oxide-film characterization: using SEM, XRD, and profilometry to preliminarily characterize the oxide film.
5. Atomic-Scale STEM Data Analysis: Analyze STEM data to determine oxide composition, structure, and interfacial elemental distribution.
6. Establishing the Heat Treatment–Color–Mechanism Relationship: Correlate heat-treatment

Project Timeline

TASK	1	2	3	4	5	6	7	8	9	10
Literature review										
Sample preparation:										
Thermal-oxidation experimental:										
Color measurement:										

Oxide-film characterization:										
Atomic-Scale STEM Data Analysis:										
Establishing the Heat Treatment–Color–Mechanism elationship (Wrap up and report)										

Prerequisites

Outline any prerequisite units, degree or experience needed by students. *(If required)*

Student Placement Agreement

A student placement agreement must be signed by the project supervisor and the student prior to commencement of the ASPIRE program.

LV0554-72741 ASPIRE Program Co-Curricular-Student-Placement-Agreement-Short-term.docx

Additional Information

Relevant Literature

[1] Wang, S., Liao, Z., Liu, Y. and Liu, W. (2014). "Influence of thermal oxidation temperature on the microstructural and tribological behavior of Ti6Al4V alloy." Surface and Coatings Technology, 240, 470–477. doi: 10.1016/j.surfcoat.2014.01.004.
[2] Kumar, S., Sankara Narayanan, T. S. N., Ganesh Sundara Raman, S. and Seshadri, S. K. (2010). "Thermal oxidation of Ti6Al4V alloy: Microstructural and electrochemical characterization." Materials Chemistry

Submit as a word document - no more than one page long.