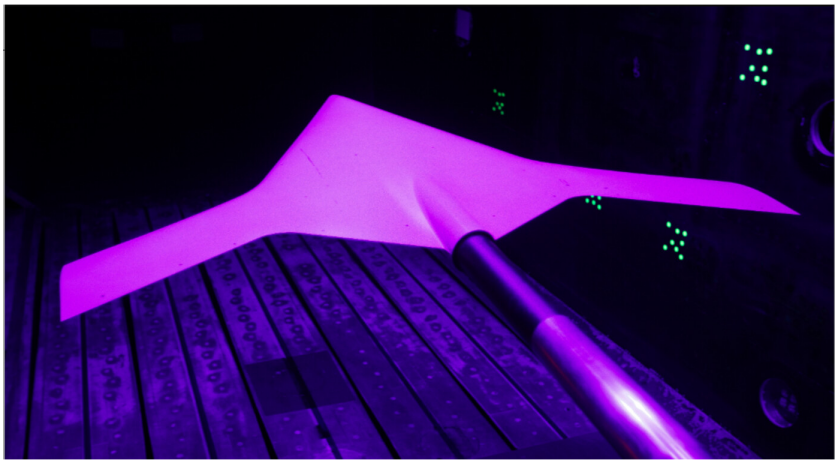
National Aeronautics and Space Administration



TECHNOLOGY SOLUTION

Materials and Coatings

Improved Unsteady Pressure Sensitive Paint Formulation

Titanium Dioxide Dispersant for High-Precision Pressure Measurements in Dynamic Testing Environments

Modern aerodynamic testing requires capturing high-resolution, unsteady pressure distributions across complex surfaces. Unsteady pressure-sensitive paint (uPSP) enables non-intrusive, full-field pressure mapping, by luminescing under excitation light. As local air pressure fluctuates across a test article, the emitted light intensity changes, allowing cameras to record a dynamic visual map of surface pressure. Traditional formulations suffer from rapid photodegradation, non-linear calibration, and high temperature sensitivity. These setbacks hinder accurate, high-frequency measurements in extreme testing environments.

In response to this issue, innovators at NASA's Langley Research Center developed an improved uPSP formulation. The invention is an advanced coating utilizing a porous binder with a high titanium dioxide (TiO2) content, which allows for highly accurate, linear, and less temperature sensitive pressure mapping. The result is a more reliable tool for pressure measurement in aerodynamic testing, achieved through careful reengineering of existing materials and processes.

BENEFITS

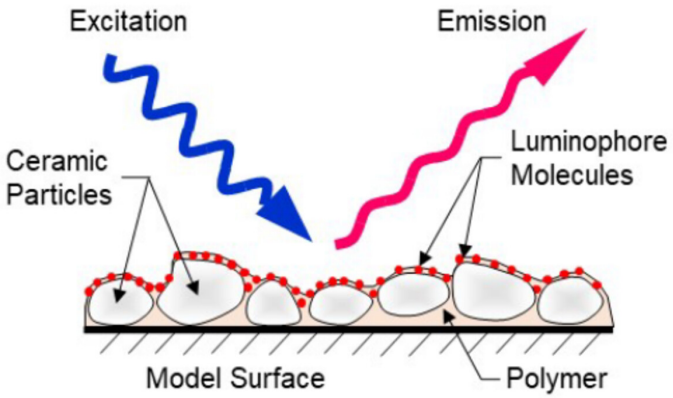
- Enhanced Durability: Reduces photodegradation which extends the operational life of the coating. This is especially valuable in environments where reapplication is difficult and daily testing impossible.
- Streamlined Calibration and Operation: Simplifies the calibration process to deliver accurate, real-time pressure data, reducing setup time and operational complexity during testing.
- High-Frequency Data Capture: Captures high-speed, unsteady aerodynamic phenomena, providing the resolution required for advanced aerospace and propulsion testing.
- Temperature Independent: Stabilizes pressure sensitivity using optimized TiO2 and dispersant combinations. Analytical testing from 10 deg to 50 deg C demonstrated a reduction in temperature-induced data variance to a 10% increase (0.85%/kPa at 10 deg to 0.94%/kPa at 50 deg).
- Easy to Implement: Eliminates the need for specialized application equipment or thermal baking by utilizing standard ambient spraying techniques. The formulation requires only a one-hour cure time prior to operational testing, minimizing facility downtime.

THE TECHNOLOGY

The improved uPSP relies on a specific combination of TiO2 particle grades and dispersants. The formulation improves the dispersion of the TiO2 particles within the polymer/ceramic binder, reducing particle agglomeration and allowing thinner, smoother coatings to be applied. The new coating exhibited linear calibrations and retained the fast pressure response required for unsteady measurements while reducing surface roughness and coating thickness compared to traditional uPSP formulations. The improved formulation also provides greater stability with age, allowing the coating to retain its pressure sensitivity for longer periods after application.

Calibration chamber testing conducted from vacuum conditions to 100 kPa, highlights substantial improvements over baseline formulations. Compared to traditional mixes, the optimized formulation delivers highly linear oxygen sensitivity, enhanced overall responsiveness, and superior thermal stability. Frequency response characterization confirms the uPSP reliably captures high-speed transient aerodynamic phenomena up to 12 kHz.

While NASA's Langley Research Center originally developed this uPSP for testing launch vehicle buffeting, rotorcraft, and transonic fluid dynamics, it offers value across multiple industries. Automotive and wind energy sectors can utilize this stable, thin-profile coating to map high frequency aerodynamic loads on vehicle prototypes or turbine blades, and its ability to capture dynamic pressure changes makes it ideal for structural monitoring and real-time pressure mapping in commercial machinery. This technology is currently available for patent licensing.



A graphical representation of the uPSP binder formulation on application surfaces. Credit: NASA

APPLICATIONS

The technology has several potential applications:

- Aerospace Testing: Launch vehicle scale models, rotorcraft blades, and high-speed transport craft requiring precise, high-frequency surface pressure mapping to capture transient aerodynamic phenomena like buffeting and unsteady flow.
- Automotive Testing: Vehicle prototypes, commercial truck designs, and motorsport aerodynamic packages where non-intrusive, full-field dynamic pressure measurements enable faster design iterations and drag reduction without altering the vehicles critical surface profile.
- Commercial Aerodynamics R&D Facilities: Full-scale wind tunnels and optical diagnostics centers requiring highly stable, temperature independent data to improve CFD correlation and reduce costly test reruns.
- Commercial Turbomachinery: Compressor blades, industrial fans, and wind turbine rotors demanding high-frequency pressure mapping to assess unsteady aerodynamic loading and structural fatigue during operation.

PUBLICATIONS

Patent Pending

More Information

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