Suggestions for improvement based on Feasibility Study of Passive Thermal Control using Temperature sensitive materials and Durability in Space Environment.

Department of Applied Science for Integrated System Engineering,
Graduate School of Engineering, Kyushu Institute of Technology
Hiroshi Ishihara

1. Research background

The satellite in space is exposed to very severe thermal environment under the influence of sunshine and shade. In particular small satellites, because the heat capacity of the small satellite is small compared to the large satellite, the satellite receives a large thermal changes depending on the thermal environment.

Typical thermal control is a heater or heat pipe. However, they are an active thermal control method. Therefore, there is a problem requiring more power or the space. In the thermal control, passive thermal control which does not consume power are preferred. In particular, normal emittance variable element normal emittance varies with temperature change has attracted attention as a passive thermal control material for the next generation. And various elements will be developed in future.

2. Purpose

We are developing a new thermal control system using temperature sensitive material the amount of light absorption varies with temperature change. Under high temperature environment, since the solar absorptance of the thermal control material is reduced, heat input drops. In contrast, under high temperature environment, since the solar absorptance of the thermal control material is increased, heat input rises. It is possible to control the heat input of the satellite without using the power and complex systems.

In this study, in order to propose a new passive thermal control system using a temperature sensitive material, the purpose is to show the utility of space utilization.

3. Temperature sensitive material

Temperature sensitive material is a paint of the ink color changes depending on the temperature of the environment. In this study, we have used a temperature-sensitive material that is based on the ink of friction ball-point pen that has been developed by PILOT Corporation.

This ink is called Metamo color. In the microcapsules of ink, leuco dye (color former), developer (component for color), discoloration temperature adjusting agent is uniformly mixed and Encapsulated. Leuco dyes cannot color by itself, ink can color by binding with developer. Coupling of the developer is changed to discoloration temperature adjusting agent from the leuco paint, as a result the color changes. Fig. 1 shows the principle of Metamo color. Fig. 2 shows Sample at the time of coloring of the temperature-sensitive material. Fig. 3 shows Sample at the time of discoloring of the temperature-sensitive material. Table. 1 shows Sample of color and discoloration temperature.

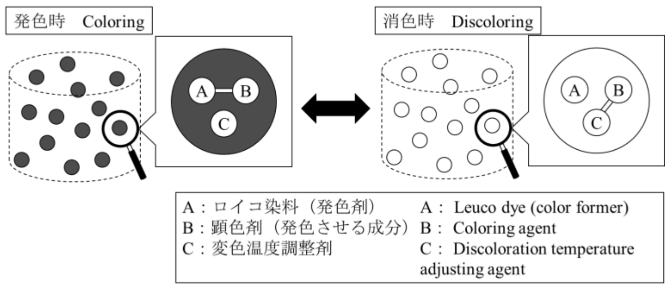

Fig.1 Principle of Metamo color

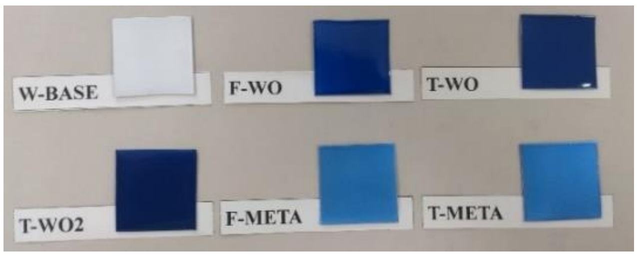

Fig.2 Sample at the time of coloring of the temperature-sensitive material

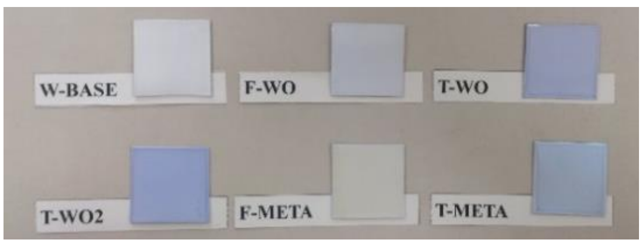

Fig.3 Sample at the time of discoloring of the temperature-sensitive material

Table.1 Sample of color and discoloration temperature

Sample	Change color	Discoloring temperature	Coloring temperature
W-BASE	White	----	----
F-WO	Blue⇔White	65℃	-20℃
T-WO	Blue⇔White	90℃	-30℃
T-WO2	Blue⇔White	90℃	-30℃
F-META	Metallic Blue ⇔White	65℃	-20℃
T-META	Metallic Blue ⇔White	90℃	-30℃

4. Durability test in Space Environment

We evaluated the durability test in Space Environment of the temperature-sensitive material in the beginning. Material is deteriorated by many external factors such as Vacuum, thermal cycling and ultraviolet rays. Therefore, we evaluated the Durability test and the Utility of the device in Space Environment.

As a result, F-based paint which can follow the abrupt temperature change is found to be a promising candidate for space. Except for temperature changes followability, the change in solar absorptance and normal emittance was not confirmed before and after each durability test. We have confirmed to have a high space environment durability. Table. 2 shows after adaptability test solar absorptance.

Table.2 After adaptability test solar absorptance

Sample	Before Test at coloring	Before Test at discoloring	Vacuum Test at coloring	Thermal cycle Test at coloring	Ultraviolet Test at coloring
W-BASE	0.36	0.36	0.36	0.36	----
F-WO	0.60	0.39	0.60	0.60	0.60
T-WO	0.60	0.42	0.59	----	----
T-WO2	0.62	0.44	0.61	----	----
F-META	0.47	0.34	0.47	0.47	0.47
T-META	0.48	0.37	0.47	0.47	----

5. The usefulness evaluation in the space environment

Then, we did the usefulness of evaluation as a new passive thermal control system. To demonstrate the utility of passive thermal control system using a temperature sensitive material, we make a comparison with other thermal control material. Then, we thought the design method of the temperature sensitive material in the thermal design of the satellite. The temperature sensitive material was F-WO and comparative material was five thermal control material. Table. 3 shows Thermo-optical properties.

Table.3 Thermo-optical properties

	Solar absorptance		Normal emittance	α/ε
Temperature sensitive materials	During cooling More than -20 ℃ 0.6	During heating More than 60 ℃ 0.42	0.93	--
Aluminum	0.5		0.06	8.33
Black anodized	0.66		0.81	0.81
Alodine	0.24		0.05	4.80
Black paint	0.92		0.83	1.11
White paint	0.25		0.83	0.30

When using the temperature sensitive material, the temperature rise is reduced when the temperature has reached 65 ℃ of a decolorizing temperature. Since the solar absorptance becomes small, heat input is reduced, so that the maximum temperature and temperature rise was suppressed. Fig. 4 shows the temperature change in each thermal control material.

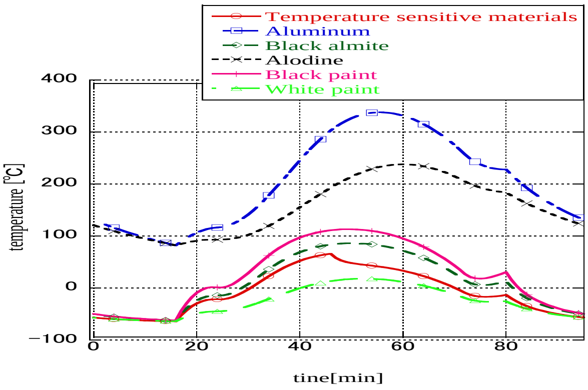

Fig.4 The temperature change in each thermal control material

6. Summary

Temperature sensitive material currently under study are still poor in practicality, problems often exist. Then, we describe happened problems in durability test and usefulness evaluation in this study, and we present the improvement plan in order to solve the problem. We mentioned the problem and presents a resolution proposal of these problems. Finally, we aim to establish as a new passive thermal control in the future.

① in shade on the orbit, since normal emittance is high, the surface temperature is lowered.

The reason is that the normal emittance was affected the white paint of the lower layer, it was higher. Since the normal emittance of the temperature sensitive material is not changed, the temperature would fall into a low temperature at the time the shade. Improvement plan is to change the underlayer material to low normal emittance material. Also, by using a variable emissivity element to the base material, there is a possibility that can establish a passive thermal control material which solar absorptance and normal emittance can change.

② Less reactive to temperature changes

This phenomenon has been confirmed in only T paint. This problem is promoting the development of high-temperature reactive paint with PILOT Corporation

7. Future tasks

If we propose a temperature sensitive material as a new passive thermal control material, normal emittance is a serious problem. In the sunshine on orbit, Characteristics of the temperature-sensitive material can be confirmed. However, in the shade, normal emittance is very high, so a lot of heat running away. Future, improvement of normal emissivity is the most important to the proposal of a new passive thermal control material.