Fabrication and performance analysis of MEMS-based Variable Emissivity Radiator for Space Applications

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Abstract. All Louver was typically representative as the thermal control device. The louver was not suitable to be applied to small satellite, because it has the disadvantage of increase in weight and volume. So MEMS-based variable radiator was developed to support the disadvantage of the louver MEMS-based variable emissivity radiator was designed for satellite thermal control. Because of its immediate response and low power consumption. Also MEMS-based variable emissivity radiator has been made smaller by using MEMS process, it could be solved the problem of the increase in weight and volume, and it has a high reliability and immediate response by using electrical control. In this study, operation validation of the MEMS radiator had been carried out, resulting that emissivity could be controlled. Numerical model was also designed to predict the thermal control performance of MEMS-based variable emissivity radiator.

1. Introduction
MEMS based sensor and actuator technology have come to stage of commercialization. Active efforts have been made to apply to aerospace, JAXA, NASA and ESA of advanced aerospace countries attempt to graft MEMS technology onto the aerospace application[1-6]. If MEMS technology applies to the satellite, which would be having the ability such as weigh lighting, miniaturization, low power consumption by high integration. The satellite operated additional thermal control systems to maintain allowable temperature of electrical device. Because the satellite carried out mission at space environment To control temperature of satellite[7], Louvers are usually used. Louvers have good thermal control ability but they have a disadvantage of becoming weight heavier[8-9]. So MEMS based variable radiator was developed to support the disadvantage of the louver. Table 1 shows a characteristic of louver and variable emissivity radiator. Microscopic device with MEMS technology could be produced in bulks. So it could be developed at low cost. Also MEMS technology applied to aerospace, it expected to have leading technology and intellectual property. Therefore this study carried out thermal performance analysis using a numerical method, calculation based EM was fabricated, temperature of EM radiator was measured by 00000 camera. CFD model was verified by comparing experiment value. Based on verified CFD model, the performance characteristics of variable emissivity radiator and fixed emissivity were examined by orbit analysis commercial tool. When variable emissivity radiator was applied, temperature could be controlled without additional

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Table 1. Comparison of the variable emissivity radiator with the louver

| Results | characteristics |
|---------|-----------------|
| Louver  | • Weakness by launch environment
|         | • Increase in weight and volume
|         | • Low operation reliability
|         | • High thermal control performance |
| MEMS radiator | • High strength by environment
|         | • Light weight and miniaturization
|         | • Good response
|         | • High operation reliability |

heater and power consumption. Even if variable emissivity radiator used a half area than fixed emissivity radiator, efficiency of variable emissivity radiator was superior to fixed emissivity radiator.

2. CFD model design and experiment

Operation principle of variable emissivity radiator was that emissivity was controlled as bead with low emissivity and low thermal conductivity moved between radiation plates by electrical discharge. CFD model was proposed to analyse performance of radiator as shape and material properties. Also Ansys fluent was used to analyse heat transfer which conductivity and radiation was occurred simultaneously. EM variable emissivity radiator with identical CFD model properties was fabricated for verification of analysis results. Variable emissivity radiator consists of the radiation plates with high emissivity and low emissivity, Electrodes for discharging bead and cover. Figure 2 shows schematic diagram of test device for thermal control test. EM radiator was placed on the heating plate for copying the generation of heat of box temperature. In the temperature range of 30°C ~ 70°C, Cover temperature was measured as bead location. When low temperature range is a copy, EM radiator model was placed in the low temperature chamber, temperature changes about both materials were measured by IR camera.

Figure 1. Variable emissivity radiator

Figure 2. Experiment setup for thermal test
3. Analysis result verification

In the low-temperature range, after placing the EM radiator in a low-temperature chamber, an IR camera was used to measure the temperature change for two materials with time. Figure 4-5 shows the radiator’s heat data measured through the experiment and its analysis result. The reason why the thermal diffusion velocity was increased in the open state is that a large amount of radiant heat was transferred directly toward the outer side to increase the thermal diffusion velocity. On the other hand, for the closed state, the bead is on the high-emissivity radiation plate, so for the heat transfer on the high-emissivity radiation plate, the heat is complexly transferred in the order of radiation-conduction-radiation, and the temperature of the outer side was measured about 3°C lower due to the low heat transfer characteristic of the bead. For the low-emissivity radiation plate, the temperature rose by about 2°C, and it is considered that the temperature rose because the heat is transferred only by thermal radiation for the outer side. The temperature change in the open and closed states obtained through the analysis and experiment has the same tendency, so it could be considered that the result of the analysis is consistent with that of the experiment.

Based on the CFD model result analysed earlier, the heat control performance was verified in the deep space environment. To carry out the analysis, the SINDA, which is a commercial tool, was used to conduct the orbit thermal analysis of the fixed and variable emissivity radiators. As a result of the thermal analysis, the fixed emissivity radiator requires the electric power of more than 10 W for driving the heater because it reduces the equipment’s temperature due to its high heat emission performance even in the low temperature condition, but the variable emissivity radiator performs heat emission like the fixed emissivity radiator in high temperature and changes into low emissivity in low temperature, so it could keep the equipment’s allowable temperature without using a heater. Should not be inserted using Word’s footnote command because this will place the reference in the wrong place—at the bottom of the page (or end of the document) rather than next to the address. Ensure that any numbered superscripts used to link author names and addresses start at 1 and continue on to the number of affiliations. Do not add any footnotes until all the author names are linked to the addresses. For example, to format

4. Results

The MEMS variable emissivity radiator is a heat control device using electrical discharge. Because there is no attempt to apply the MEMS technology into the space in Korea, this study was carried out
to apply the MEMS technology. The CFD analysis was carried out based on a mathematical model, and an EM of the variable emissivity radiator was made to verify the validity of the analysis model. As a result of analyzing the verified CFD model in the space environment, it was found that the heat could be controlled more efficiently than the existing heat control device.

(1) It was found that the EM variable emissivity radiator could control the emissivity to radiate and cut off heat in the temperature range (-25 ~ 70 ℃).

(2) For the existing studied radiator, its variable emissivity is 0.74, and for the variable emissivity radiator in this study, its emissivity could be changed up to 0.84.

(3) It was found that the variable emissivity radiator could keep the allowable temperature without using a heater in the deep space environment by using only the 50 % area compared to the fixed emissivity radiator.

The variable emissivity radiator made in this study is a space heat control system applying MEMS, which would be a basic study for the development of heat control devices applying MEMS in Korea, and if a sufficient space verification and heat control test is completed in the future, it could be expected to use it as a small satellite component for a satellite heat control system.

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