講演番号	037

文献番号	20226037

Relationship between Coefficient of Variation of Island Area and Millimeter-Wave Transmittance in Island-Shaped Indium Sputtered Film for Millimeter-Wave Radome Decoration

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KEY WORDS: **Safety, Surface treatment/plating,** Millimeter-wave, Radome [C1]

Autonomous driving and advanced driver assistance systems (ADAS) use cameras, radar, sensors, and additional tools to detect vehicles, people, and additional elements of the neighboring environment. Millimeter-wave (MMW) radar is a type of radar that utilizes electromagnetic waves in the frequency band 30 – 300 GHz. Currently, 76 – 77 GHz MMW is mainly used for automotive radar. Radar is frequently mounted behind the emblem because a good mounting location is in the middle of the front of the car.

While metallic luster is necessary for vehicle emblems in terms of design, a metallic film is an element that significantly lowers MMW transmission efficiency for emblems for MMW radar, which require high MMW transmission performance. The technique used to produce both metallic luster and MMW transmission performance, which elements contradict each other, is the deposition of indium thin films by sputtering or vacuum evaporation. When sputtering or vacuum evaporation is used to create metal thin films, these films do not form a continuous film in the first stage, but rather a discontinuous structure like islands. The lower the melting point of the metal during the sputtering, the easier it is to form island structures, and indium is particularly easy to form island structures. Metallic films with island structures are used to adorn emblems because they have a metallic luster and are more easily transmitting MMW than continuous films. MMW transmittance is significantly influenced by the island structure of the metal film, but it is unclear which specific parameters are relevant. This research aims to clarify which structural parameters of indium films are connected to MMW transmittance.

A DC magnetron sputtering machine is used for laying down of film. Indium was used as the sputtering target, and Argon gas was used as the sputtering atmosphere. Polycarbonate (PC) plates were used as sputtering substrates. Compressed air with the water removed by a compressor opened the load lock, which is the entrance and exit of the chamber, to the atmosphere, and nitrogen gas was used to power additional equipment. In some tests, the substrates were dried using a dryer before the sputtering. In this study, different sputtering conditions were used to perform the sputtering by changing the sputtering time, Argon gas flow rate, target–sample distance, and pre-drying substrate circumstances. After the sputtering, MMW transmittance at the 76.5 GHz was measured by a QAR quality automotive radome tester. A nonsputtered PC flat plate was used in measurements as a control sample, and the MMW transmittance of the indium film was calculated by subtracting the MMW transmittance of the control sample from the MMW transmittance of each sample. The indium film's island structure was captured on a camera using a scanning electron microscope (SEM) at a magnification of 30,000x, and in the island structure, the size of each island was calculated analyzing the SEM images using ImageJ, an image analysis software.

The relationship between the coefficient of variation of island area and MMW transmittance is shown in Fig. 1. In statistics, the coefficient of variation is an index that shows the variability of data relative to the average. The coefficient of variation increases as the degree of variability increases, whereas the coefficient of variation decreases as the variability decreases. The coefficient of variation was calculated by dividing the island's standard deviation by the average island area. The graph demonstrates a distinct relationship between the coefficient of variation of the island area and the MMW transmittance, and the MMW transmittance decreases with an increase in the coefficient of variation. Alternatively, the relationship between the average island area and the thickness of the indium film and MMW transmittance could not be confirmed. Taking into account the fact that conductivity affects MMW transmittance, it is considered that the coefficient of variation of the island area is connected closely to the factor that determines conductivity. In the island's architecture, the conductivity of between-island spaces is significantly lower than that of the islands, and the overall conductivity of the film is dependent on the conductivity of the gaps rather than the islands. The coefficient of variation of island area is a criterion that shows the state of the island structure, but due to the relationship between the state of the gaps between islands and island structure, it is expected that it may indicate the amount and the condition of the spaces separating the islands.

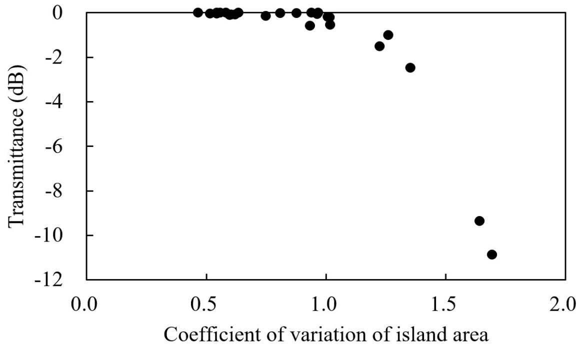

Fig. 1 Relationship between the coefficient of variation of island area and MMW transmittance at 76.5 GHz

2022 JSAE Congress (Autumn) - Summarized Paper
Issued on October 7, 2022