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# Achieving good infrared-radar compatible stealth property on metamaterial-based absorber by controlling the floating rate of Al type infrared coating

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In order to realize the infrared stealth ability for the metamaterial-based EM absorbers, the polyurethane(PU)/aluminum (Al) composite coating with low infrared emissivity is successfully applied on its surface. The influences of the floating rate of Al particles on the infrared emissivity and their compatibility feature with metamaterial-based EM absorbers have been systematically investigated. Infrared emissivity values are measured using IR-2 Infrared Emissometer in the wavelength range of 8–14 μm and the electromagnetic wave absorption properties of the metamaterial-based EM absorbers with or without infrared coatings are measured by the arch method. When the content and floating rate of Al powders are 20% and the 90%, respectively, the metamaterial-based EM absorber with infrared Al/PU coating displays not only a lower emissivity but also good electromagnetic wave absorbing properties which means the good infrared-radar compatibility condition can be achieved. The results indicate that, after coating with this PU/Al infrared layer, the infrared emissivity of metamaterial absorbers can be greatly lowered from 0.65 to below 0.204 and meanwhile its good radar absorbing performance can still be maintained without much reduction.



## 1. Introduction

In recent years, especially after the successfully application of radar absorbing materials to B-2 and F117 deceptive airplanes, stealth materials have received extensive attention because of the rapid development of detection equipment, which may pose a great threat to the military targets [1–3]. Stealth technology involves the radar, infrared, visible light, laser and so on. At present, radar and infrared stealth are the most widely used in the military. Previous available camouflage materials are generally designed to be used only in the infrared ranges of the electromagnetic spectrum or in the radar range [4]. However, with the development of detection technology, more and more military applications need to have both radar and infrared stealth functions simultaneously. Therefore, the preparation of high performance radar and infrared compatible materials is an important means to improve the survivability of weapon equipment [5].

According to the radar absorbing and infrared stealth mechanism, radar absorbing material requires high absorption and low reflection while infrared stealth needs low absorption and high reflection [6–10]. So far, there are two methods that have been proven to solve the problem of infrared and radar compatibility. One of them is to develop a material with both infrared stealth and radar absorption. Lv et al. have fabricated FeAl flake mixtures by ball-milling technique that have a narrow microwave absorption bandwidth of 1.7 GHz and a far-FR emissivity of 0.15 [11]. However, even the sample pose the proper infrared emissivity, its relatively narrow microwave absorption bandwidth makes it be difficult to meet the requirements of engineering application. Another way is to make a multi-layer coating, which is to coat a layer of infrared stealth coating on the radar absorbing material [12]. Xie Guohua et al. have prepared the radar and infrared compatible material by spraying a low infrared emitting layer on the surface of the Fe-Ni radar absorbing material and at the same time, a matching layer is placed between these two layers [4]. The results show that the infrared emissivity of the material can be reduced to 0.3 while its microwave absorption properties are not changed too much. Therefore, the second method can be expected to be an effective

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method to solve the problem of infrared and radar stealth compatibility.

Currently, metamaterials have attracted wide attention in the field of electromagnetic wave. Compared with the traditional electromagnetic wave absorbing materials, the metamaterial has been proved to be a promising electromagnetic wave absorbing material because of its low surface density and high electromagnetic response tunability [13–16]. Many pervious investigations have reported that metamaterials with specially designed patterns show the superior electromagnetic wave absorption properties. However, because the patterns on the surface of metamaterial are commonly made of copper metal, the infrared emissivity of metamaterials is relatively high which is usually higher than 0.6. And meanwhile, the poor environment-resistance property of metamaterial has also restricted its application on the military platform. Therefore, the preparation of highly efficient radar and infrared compatible metamaterials has become a difficult problem to be solved. Due to the low infrared emissivity of metal fillers, infrared stealth materials are mostly silver particles, Cu and Al pigment coatings [17,18], among which aluminum flake pigment has received considerable attention due to its low price and excellent performance in reducing infrared emissivity [19,20].

In this work, in order to solve the high infrared emissivity of the metamaterial-based radar absorbing materials, the aluminum type low infrared emissivity coating with proper floating rate was applied on the surface of the metamaterial-based radar absorbing material. The floating rate is a reflection of the floating performance of the Al powder and is one of the important indicators to measure the Al powder. The floating rate is closely related to the shape and processing technology of the Al powder. Commonly, the method which has been widely used in the coating industry to determine the floating rate of Al powder is the steel sheet test method. According to our previous studies, the floating rate is also found to be a key factor which can significantly affect the emissivity of coating [21,22]. Therefore, in this study, the shape of aluminum powder can be changed by ball milling method, and then the floating rate of aluminum powder will be adjusted. Therefore, in this study, the shapes of the Al powder will be changed through the ball milling technique and their corresponding floating rates will be adjusted as well. By exactly controlling the shape of the Al powder through ball milling process, the Al powder with different floating rates can be obtained. The effect of floating rate of aluminum powder in this infrared coating on the infrared emissivity and electromagnetic wave absorbing property of metamaterial will be systematically studied.

## 2. Experimental

### 2.1. Materials

Al particles with the particles size ranged from 15 to 25 μm and floating rate of 60% was purchased from Nanjing Stell Coating Co., Ltd. The white spirit (WS) and stearic acid (SA) were purchased from Nanjing chemical agent limited company, China. Polyurethane resin(PU) and curing agents(CA) were obtained from NanJing Steer Coating Co., Ltd, China. All the solvents were A.R. grade and used without further purification.

### 2.2. Preparation of leafing Al powders

The flaky Al particles with different floating rates were fabricated by a high performance ball milling technique. In a typical procedure, the as-purchased 5 g Al powders, 20 g WS and 0.5 g SA were ball milled in a planet-type grinding mill with 50 g $ZrO_2$ ball milling media at a rotation speed of 200 rpm. Ball milling process was performed for 10–80 h and the as-prepared flaky Al powders were washed and dried under vacuum at 60 °C for 6 h. Finally, flake like Al powders were obtained.

### 2.3. Preparation of low infrared emissivity coatings

The metamaterial with good electromagnetic absorption properties was prepared by our research group. As shown in Fig. 1 (a) and (b), the metamaterial is formed from dielectric layer, patterned layer and metal ground. The dimensions of the metamaterial are 30 cm in length, 30 cm in width and the thickness is 17 mm. The surface of the metamaterial was properly cleaned at room temperature by ethyl alcohol and distilled water, and then the infrared coatings with different floating rate and Al powder content were sprayed on it. In a typical procedure, the fixed amounts of PU and Al powders with four different floating rates were mixed (10%, 20%, 30% weight percentage, respectively) under continuous ultrasonication for 10 min, then the curing agents were added into the mixtures and stirred adequately. As displayed in Fig. 1 (c) and (d),

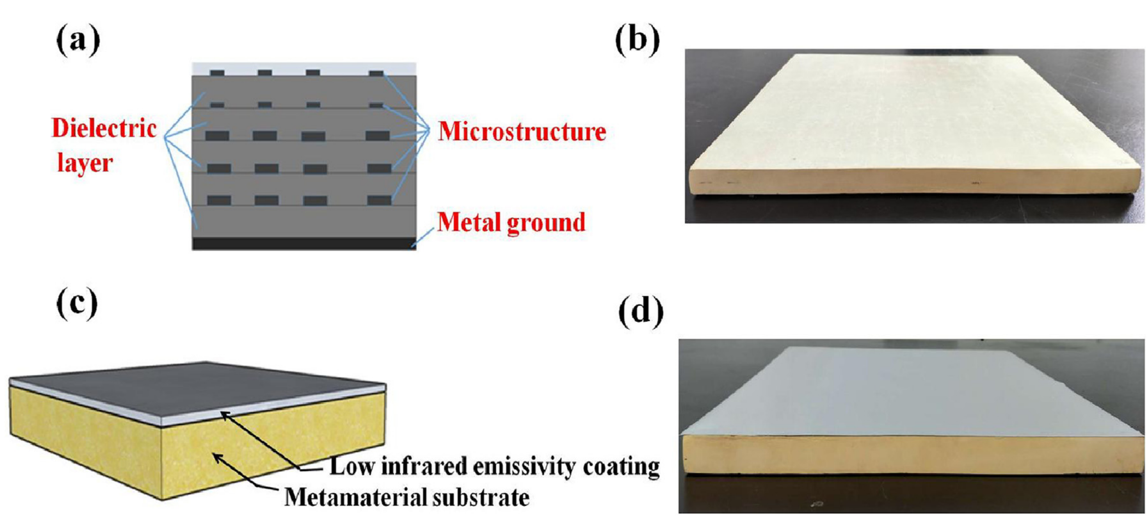


**Fig. 1.** (a) Structure diagram of the metamaterial-based EM absorber; (b) the picture of metamaterial-based EM absorber; (c) model diagram of the metamaterial with low emissivity coating system; (d) the picture of the metamaterial-based EM absorber with low emissivity coating.