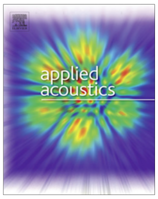
Applied Acoustics 82 (2014) 23–27

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust



Technical Note

Improvement of sound absorption characteristics under low frequency for micro-perforated panel absorbers using super-aligned carbon nanotube arrays

Y.J. Qian [a,b,*], D.Y. Kong [b], Y. Liu [a,b], S.M. Liu [a,b], Z.B. Li [a,b], D.S. Shao [b], S.M. Sun [c]

[a] *Department of Automation, University of Science and Technology of China, China*
[b] *State Key Laboratory of Transducer Technology, Institute of Intelligent Machines, Chinese Academy of Sciences, Hefei 230031, China*
[c] *State Key Laboratory of Transducer Technology, Institute of Advanced Manufacturing Technology, Changzhou 213164, China*

ARTICLE INFO

Article history:
Received 24 January 2014
Received in revised form 11 February 2014
Accepted 25 February 2014
Available online 27 March 2014

Keywords:
Super-aligned carbon nanotube (SACNT) arrays
Micro-perforated panel (MPP)
Acoustic performance

ABSTRACT

Super-aligned carbon nanotube (SACNT) arrays are grown on the surface of micro perforated panel (MPP) in the hope of improving the acoustic performance of MPP absorbers by virtue of their unique properties. Scanning electron microscopy reveals that SACNT arrays did not block the perforations of MPPs or changed the perforation diameter due to their "super-aligned" nature, although MPPs are thickened. The absorption effect of SACNT arrays which are of the same and different lengths with different incident side on MPP absorbers are investigated, and standing wave tube method is used to determine the normal sound absorption coefficient. Results show that both of the lengths of SACNT arrays and the incident side have effects on the sound absorption performance of MPP absorbers. And generally SACNT arrays help to improve the sound absorption capacity of MPP absorbers in low-frequency regions only when the SACNT arrays surface is the incident side. SACNT arrays decrease absorption performance of MPP absorbers when the MPP surface is used as the incident side. Moreover, SACNT arrays are found to increase the acoustic ability of MPP absorbers with the same structure parameters monotonically at lengths up to 600 μm in the condition that the SACNT arrays surface is used as the incident side.

1. Introduction

Nowadays the noise pollution has become a serious problem, the demand for a better environment and more diversified life styles is increased. Thus thin, light weight and low-cost absorption constructions that will absorb sound in wide frequency range are strongly desired. Micro-perforated panel (MPP) absorbers have been widely used in noise control engineering since they were first proposed by Maa in 1975 [1]. MPP absorbers are friendly environment, low cost, simple structure and high safety. Based on the above advantages, MPP absorbers have been always regarded as promising as a basis for the next generation of sound absorbing constructions and the study on their absorption characteristics has become a hotspot research. However, compared with the traditional porous sound absorption materials, MPP absorbers have one very notable unpleasant property—its narrow sound absorption bandwidth, normally 1–2 octave, which restricts it becoming a general sound absorber. In order to achieve optimal enhancement in the sound absorption properties of MPP absorbers, a lot of improvement approaches have been proposed. Lin et al. [2] attempted to improve the sound absorption performance through adding porous sound-absorbing materials in the cavity. According to the position of the porous materials, the corresponding theoretical prediction models were built and experimental results agreed well with the prediction results. Sheng [3,4] obtained composite sound-absorbing constructions by covering a thin film in the front side or the back side of MPPs, and their sound absorption properties were theoretically and experimentally studied. Variable section of orifice was used to widen the absorption bandwidth of MPP absorbers by He et al. [5]. Sakagami et al. [6] and Randeberg [7] also focused on enhancing the absorption performance through orifice design. A new type of MPP absorber with holes of multiple sizes instead of uniform size was experimentally studied by Misasa et al. [8] aiming at obtaining a wide band sound absorber. A double-layer MPP absorber [1] was also proposed by Maa to broaden the absorption bandwidth, but at the cost of occupying more space. Moreover, a lot of other research efforts have been directed towards optimization design of the cavities to improve the acoustic

---

[*] Corresponding author at: Department of Automation, University of Science and Technology of China, China. Tel.: +86 0551 65591163.
E-mail address: qyj1987@mail.ustc.edu.cn (Y.J. Qian).

http://dx.doi.org/10.1016/j.apacoust.2014.02.014

performance of MPP absorbers, such as cellular cavities [9], irregular cavities [10], and subdivided cavities [11]. However, all the improvement approaches increase weight and the complexity of structure or occupy more space which will limit widespread use of MPP absorbers. According to Maa [12], a straightforward method to broaden the absorption bandwidth of MPP absorbers is to reduce the perforation diameter, namely, ultra-micro MPP absorbers [13], but experimental results show that such MPP absorbers are just good in high frequency region ranging from 2000 Hz to 6000 Hz.

Furthermore, all the approaches mentioned above about improving sound absorption performance of MPP absorbers involve no nanomaterials which have been adopted widely in porous sound-absorbing materials for getting many desired properties. Verdejo et al. [14] found that low loading fraction of carbon nanotubes (CNT's) in flexible polyurethane foams have relatively high effect in sound absorption; even 0.1% CNT's can enhance the acoustic absorption dramatically, which leads the peak absorption coefficient to increase up to 90% from 70% for the pure polymer foam especially in the high frequency region. Gayathri et al. [15] showed that sound absorption coefficient of polyurethane foam modified with nanosilica, nanoclay and crumble rubber fillers were found to demonstrate an increase up to 80% from 52% for the pure foam in the frequency range of 100–200 Hz. Thus nanomaterials may have great potential to improve the absorption ability of sound-absorbing materials. But so far study on improving acoustic performance of MPP absorbers based on nanomaterials has not been reported yet. The purpose of this study is to examine the effects of surface modification on acoustic properties of MPP absorbers by nanomaterials. Ordinary nanomaterials may block the holes of MPP absorbers, and given that super-aligned carbon nanotube (SACNT) arrays are selected. It is generally known that compared to ordinary CNT, SACNT arrays are a kind of high-quality and ordered carbon nanotube arrays and in a SACNT array, CNTs possess a high density and very clean surface. SACNT arrays can be easily grown on the surface of silicon or glass substrate, as a matter of convenience, a non-template chemical vapor deposition (CVD) method was used to synthesize SACNT arrays on the surface of MPPs made out of silicon based on MEMS technology. Ferrocene was used as a catalyst, xylene as the carbon source. An obvious trait of the SACNT array is that it can produce an ordered array parallel to the drawing direction and the CNTs will not block the holes of MPPs because there is no catalyst in the position of holes. Moreover, SACNT arrays have high surface area; in this case, they are expected to offer proper impedance matching between air and MPP absorbers when the SACNT arrays surface is used as the incident side. At the same time the acoustic resistance of MPP absorbers will increase as a result of the increased panel thickness. By these considerations the possibility of achieving a wideband sound absorber with surface modification of MPP absorbers using SACNT arrays is discussed. Finally, the influence of the incident side on the sound absorption characteristics of the composite structure of MPP absorbers with SACNT arrays is also explored. The normal sound absorption coefficient of MPP absorbers are measured according to standard: ISO 10534 10534-2:1998 "Acoustics – determination of Sound Absorption Coefficients and Impedance Tubes-part 1: Method using standing wave ratio" [16].

2. Experimental results and discussion

2.1. Specimens

For the experimental investigation, MPPs were made out of silicon based on MEMS technology since the SACNT arrays were easily grown on silicon substrate. The MPPs were made with various hole sizes, various arrangements and various perforation ratio, but the same panel thickness and cavity depth. SACNT arrays with different lengths were grown on the surface of MPPs. The structure parameters of MPP absorbers are listed in Table 1. In Table 1, d is the diameter of the perforations, t is the panel thickness, b is the distance between centers of adjacent perforations, D is the depth of the cavity, σ is the perforation ratio (the ratio of surface area of the perforations to the total surface area of the panel), and l is the length of SACNT arrays. Each group of the structure parameters is non-optimized. Note that the MPP absorber with SACNT arrays 0 μm in length (specimen #4) means that there is no SACNT arrays on it. The surface micro structure was observed using Scanning Electron Microscope (SEM) for MPP absorbers before and after surface modification using SACNT arrays and pictures of some of the specimens are shown in Fig. 1. It is evident from Fig. 1 that the perforations have not been blocked by SACNT arrays but the total panel thickness is increased. To facilitate the understanding, the cross section schematics of silicon MPP with

Table 1
The material and structural parameters of MPP absorbers.

Specimen	d (μm)	t (μm)	b (μm)	D (mm)	σ (%)	l (μm)
1	45	200	106	20	14.14	600
2	66	200	216	20	7.33	600
3	84	200	277	20	7.21	600
4	54	200	156	20	9.41	0
5	54	200	156	20	9.41	100
6	54	200	156	20	9.41	300
7	54	200	156	20	9.41	600

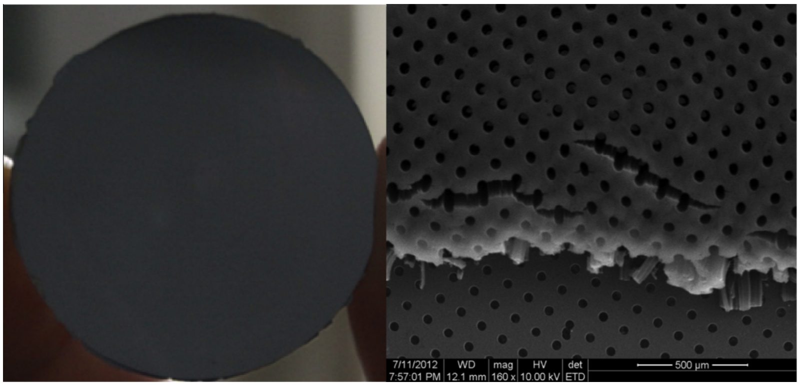


Fig. 1. Photograph and SEM micrograph of No. 4 MPP before and after surface modification with SACNT arrays.