Abstract

For centuries, humans have studied biological systems. At the beginning of the 20th century, the Wright brothers developed a rudimentary model of an airplane inspired by birds. Today, design concepts derived from biological systems have become an effective and widely used approach to solve human challenges. These include responsive materials that change their characteristics in response to external stimuli (such as light, electricity, magnetism, or heat) and layered/composite materials that demonstrate exceptional mechanical properties, such as high strength and toughness.

Although many biological systems have been extensively studied and have inspired numerous applications, from the mechanics point of view, most research has primarily focused on their static or quasi-static properties. In recent years, only a few studies have delved into the dynamic significance of these systems or drawn inspiration from their dynamic behavior, which is important for understanding dynamic performance and advancing the development of wave manipulation technologies.

Seashells, well-known for their advanced composite microstructures, exhibit diverse morphologies that are related to the environments in which they live. Therefore, by studying their global structure-related properties and geometrical characteristics, we may gain a deeper understanding of the significance behind their varied and sophisticated forms. The *gastropod* sea snails, *Turritella terebra* and *Turritellinella tricarinata*, were chosen as the object of my study. They feature a hierarchical, conical-spiral shape, similar to that of a drill, that is believed to help the organism to burrow under the mud.

A combined experimental and numerical study was conducted on the seashells structure, in which the micro-computed tomography scans were used to obtain the geometry, atomic force microscopy and nanoindentation were used to characterize the local mechanical properties, resonant ultrasound spectroscopy was used to determine the global modal behavior with the help of finite element analysis simula-

tions. The results show that the special geometric characteristics of the *Turritellidae* family seashells, i.e., their conical-spiral structure, can be linked to their vibration attenuation behavior.

By further observing the structure of these seashells, it can be further noticed that they feature similar geometric characteristics, such as graded cross-sections and curvature, found in another biological system, the cochlea of mammals. The cochlea, the core of the auditory system of mammals, is responsible for the identification of sounds, which depend on their frequency content and intensity. An interesting phenomenon, named tonotopy, can be observed in the cohlea. It consists in the fact that there is a one-to-one relationship between the frequency of the impinging signal and the spatial location of the maximum response on the cochlea basilar membrane.

Therefore, inspired by the common geometrical features existing in both *Turritellidae* seashells and cochlea, a set of geometrical equations was used to develop a meta-sensor that displays a tonotopic behavior and sensitivity to the polarization of the input or output signals. The 3D meta-sensor allows for simultaneous tonotopic characterization in both planar and axial orthogonal polarization modes. This characteristic, along with polarization capabilities, make the design promising for applications in artificial cochlear implants and the field of non-destructive testing sensors.