



Material properties of photomechanical infrared receptors in pyrophilous *Melanophila* beetles and *Aradus* bugs

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ARTICLE INFO

Article history:

Received 18 January 2012

Received in revised form 18 May 2012

Accepted 18 May 2012

Available online 27 May 2012

Keywords:

Insect cuticle

Mechanical properties

Nanoindentation

Infrared receptor

Mechanoreceptor

ABSTRACT

Jewel beetles of the genus *Melanophila* and some pyrophilous species of the flat bugs genus *Aradus* show a pyrophilous behaviour and have developed so-called photomechanical infrared (IR) receptors. In a spherical photomechanical IR sensillum incoming IR radiation is converted into micromechanical action, finally stimulating the dendritic tip of a mechanosensitive sensory cell. The tip is located inside a tiny cuticular sphere with a diameter of about 12 μm . The material properties of the different cuticular components of this sphere are of great importance for stimulus generation. We measured the modulus and hardness of the outer exocuticular shell of the sphere and the mesocuticle inside the core. Measurements were made by nanoindentation at sensilla which were partly cut open under dry as well as under rewetted (i.e. quasi-natural) conditions. We found that in the rewetted sensilla the outer exocuticular shell of the sphere in the *Melanophila* sensillum is about 50% harder and 20% stiffer than reference exocuticle, and that in both species especially the rewetted mesocuticle of the inner core of the IR sensilla is significantly softer (about 80% in *Melanophila*) and more compliant (about 90% also in *Melanophila*) than the reference mesocuticle. The findings can be interpreted as special adaptations of the cuticular microdomains of photomechanical infrared sensilla to enhance thermomechanical performance and, thereby, sensitivity.

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1. Introduction

Jewel beetles of the genus *Melanophila* belonging to the acuminata, or “flattened type”, such as *M. consputa*, *M. notata*, *M. opaca*, *M. atropurpurea* and *M. acuminata*, are widely known to approach forest fires [1]. Similar pyrophilous behaviour has been observed in a few flat bug species of the genus *Aradus* (Heteroptera, Aradidae).

In both groups photomechanical infrared (IR) receptors have been found [2,3]. This unique type of sensillum is innervated by a mechanosensitive cell and is strikingly similar in beetles and bugs (see Fig. 1). In brief, the functional component of the photomechanical IR sensillum is a spherical IR-absorbing cuticular apparatus with a diameter of about 12–15 μm . The sphere consists of an outer shell made of hard exocuticle, which is reinforced by many layers of chitin fibres. Inside the sphere is a core of softer mesocuticle. In contrast to the solid shell, the mesocuticle has a spongy texture comprising a three-dimensional system of liquid-filled microlacunae and nanocanals (Fig. 1c and d). The tip of the mechanoreceptor enters the sphere through a pore in the shell and terminates inside the mesocuticular core (cf. Fig. 1c and d) [4,5].

According to the photomechanical model, IR radiation is absorbed by the organic molecules (i.e. proteins and chitin) as well as by the water inside the mesocuticular lacunae of the sphere. The corresponding increase in temperature mainly results in a thermal expansion of the core, consisting of mesocuticle and the liquid enclosed by the shell of the sphere. However, omnidirectional expansion is restrained by the outer shell. Thus the dendritic tip of the mechanoreceptor, as the only compliant element, is compressed. This is enough of a stimulus to activate the mechanosensitive neuron.

Electrophysiological experiments have shown that the IR receptors of *Melanophila* beetles rapidly transform IR radiation into a micromechanical event. Latencies were in the range of a few milliseconds [6,7]. Although the precise sensitivity of the photomechanical receptors is still unknown, there is some evidence that the IR receptors in *Melanophila* beetles may have a high sensitivity. One can postulate that *Melanophila* beetles and *Aradus* bugs use their IR sensilla for fire detection, as a number of anecdotal reports in the entomological literature suggest that *Melanophila* beetles can detect distant fires by IR radiation [8–10]. Large numbers of *Melanophila consputa* were observed at a large burning oil storage tank close to Coalinga in California [11]. Because Coalinga is situated in the arid San Joaquin Valley, it is unlikely that the majority of beetles had already been close to the tanks before the outbreak of the fire. Great numbers of beetles were also attracted by a large

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