BIOSILICA STRUCTURE FROM MARINE SPONGES: OPTICAL FIBER PROPERTIES OF SPICULES

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Introduction

Biosilica is an intriguing example of natural order and complexity. Siliceous sponge spicules, in particular, are characterized by a large variety of dimensions and shapes, with an ultrastructure based on silica nanoparticles strictly packaged around an axial filament constituted by a family of proteins called silicateins. These proteins are also directly involved in the biological construction of spicules and they are a fundamental consitutent of silica nanoparticles [1, 2]. This biosynthesis scheme determine the production of a peculiar composite material with remarkable technological properties, like high flexibility and the amazing property to transmit light along its axis [3, 4].
The main consituent of these biological fibers are basically made of the same material of common telecommunication fibers (silica), but, differently from the commercial ones, they are much more resistant to fracture. This is due to their ultrastructural organization into lamellae connected by organic glue in their external region. These highly ordered and unique structures are produced under strictly genetic control in mild environment conditions, drastically different from the industrial process, where high temperatures of manufacture are needed.
In this work, we have characterized the optical properties of the spicules of the Antarctic sponge *R. racovitzae* respect to their suggested biological functions [3]. Indeed, given the remarkable transmission properties of biosilica, this material can reveal strategic for the realization of novel fiber-optics systems and for embedment in composites structures based on silicon oxides compounds.

Experimental

Silicoeus spicules used in this work were extracted from a dry specimen of *R. racovitzae* collected during the Italian Antarctic expedition of dicember-january 1995 at Ross Sea (Terranova Bay). Before the light transmission analysis the 10-12 cm long spicules were cleaned with Na hypochlorite and then extensively washed with distilled water to remove the external organic materials. In order to assess the performances of the *R. racovitzae* spicules in terms of light transmission, a Tungsten lamp and a He-Ne laser (λ=633 nm, maximum power 15 mW) were mainly employed as light source, whose power can be tuned in the range 0.1-15 mW by using neutral density absorption filters. The laser beam is coupled, by a set of metallic mirrors, to an objective lens (N.A. 0.15-0.5), used to inject the laser light into the spicule. The careful coupling of the spicules with light generally requires alignment of the waveguide axis with the wavector (**k**) of the laser beam with sub-μm resolution. To this aim, the spicules were mounted on a 6-axis piezo-stage, allowing the translation of the samples in X-Y-Z with sub-100 nm spatial resolution and the fine adjustment of the waveguide plane by the tilt angles Θ_X-Θ_Y-Θ_Z. The light transmitted by the waveguide was collimated by an objective lens (N.A. 0.55) and detected by a Si photodiode. The waveguide propagation losses can be calculated by measuring the incident (P_{in}) and transmitted (P_{out}) light power.

Results and discussion

Spicules from *R. racovitzae* are able to transfer both red light (Fig. 1 A) and white light (Fig. 1 B). In our experimental conditions it is clearly evident the light trasmission properties of this biosilica structure is remarkably different from the commercial optical fiber. In the sponge case, in fact, light is widely diffused along spicule axis, while in the industrial fibers light is trasported along the cable without appreciable loss of intensity.
These results confirm that glass sponges spicules have specific optical characteristics, and the peculiar structure of this composite material is able to determine the different transmittance properties compared to the industrial ones. Moreover, the amazing correspondence of the maximum of transmittance of this natural fiber with the wavelength interval of light irradiance throughout the water column at this depth in the Antarctic seas (data not shown) together to the previously documented presence of diatoms along their axis [3] and their capability to distribute light along the hole spicule body in our opinion suggest a direct action of evolution to select specific biomaterial specialized in light transmission to supply the photosynthetic activity of symbionts.

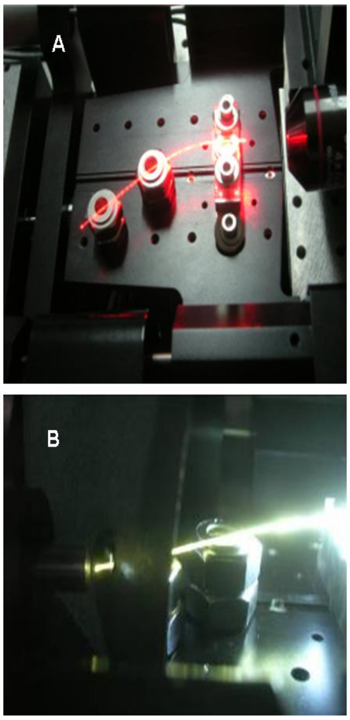

Fig. 1 Optical fiber performances of *R. racovitzae* spicules. Light transmission at 633 nm (A) and with white light generated by a Tungsten lamp (B).

Conclusions.

In future, a better understanding of the biological and functional working mechanisms of the biosilica spicules will greatly help in designing and realizing composites materials made by polymer matrices embedding spicules or spicules fragments. This will aim at the in-depth tailoring of both the resulting structural properties and of the optical properties of the composites, possibly approaching the light-transmission performances of commercial silica optical materials (Fig. 2).

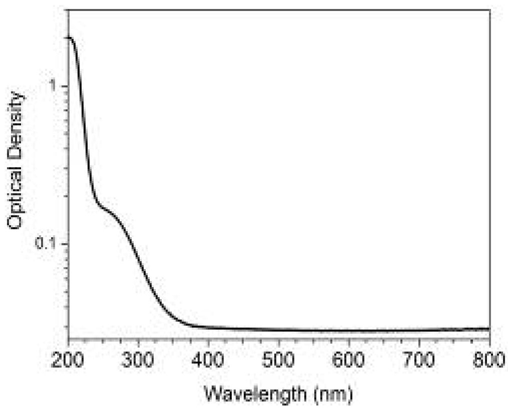

Fig. 2 Absorption spectrum of commercial silica optical materials, evidencing almost complete light-transmission in the visible range.

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