Materiali avanzati
Advanced Materials

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Investigation conducted in collaboration with
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Main research topics:

- Nanoparticles and nanopowders for functional applications.
- Functional and structural thin coatings via wet chemistry.
- Ceramic based nanocomposites.
- Nanostructured materials for gas sensors

Functional biomaterial based on silk fibroin-titanate nanocomposites

After being used for millennia as a luxury fabric, silk, and in particular silk fibroin, the protein extracted from the silk fibers is experienced a second youth thanks to outstanding applications as a biomaterial.
Thanks to its high transparency, mild processing conditions and pushed by the development of several fabrication and nanofabrication methods, silk fibroin has been proposed as a platform for biocompatible optics, high tech application like resorbable electronics, and implantable and biofunctional optical devices.
To enhance the performances of silk as a material for optics a strategy to increase its refractive index while preserving all the properties of silk is needed. We developed a new nanocomposite made of silk and titanate nanosheets (TNSs). TNSs are 2D layered materials made of nano sheets with a $Ti_{(1-x)}O_2^{4x-}$ composition that are one unit cell thick and 3-5 nm wide (see figure 1a). TNSs have small size, high refractive index and are easily synthesized via sol gel chemistry. They are also water-soluble which makes the integration with the silk processing very easy to implement. TNSs have been homogenously dispersed in silk (see figure 1b) obtaining both unsupported flexible thick film (see figure 1c) or thin film supported on proper substrate, with refractive index varying from 1.45 to up 2.00 depending on the concentration of TSNs.
A wide variety of fabrication techniques were developed to create optical devices and interfaces with silk: e-beam lithography to make photonic structures, photolithography, thin coatings, inkjet printing. The high refractive index TNSs/silk nanocomposite was successfully processed with all these fabrication techniques.
In Figure 2a a thin film of 75% TNSs 25% silk patterned with e-beam lithography is shown. 270 nm holes with 700 nm lattice constant were successfully written. TNSs:silk nanocomposite was used as a resist for UV lithography. Figure 2b shows a pattern of 400 µm wide features that were made by UV exposure of a 300 nm TNSs:silk coating made with 80% TNSs and 20% silk. High refractive index silk solution was successfully used as a functional ink for inkjet printing as reported in figure 2c.

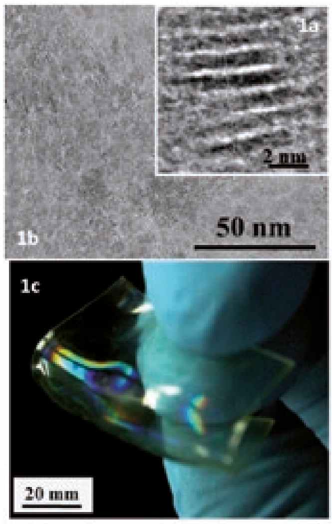

Figure 1. a) TEM picture of a single TNS particle made of 6 nanosheets. b) TEM picture of TNSs silk-TNSs composite, TNSs are evenly dispersed in the silk matrix. c) a freestanding film made flexible by simple hydration with water

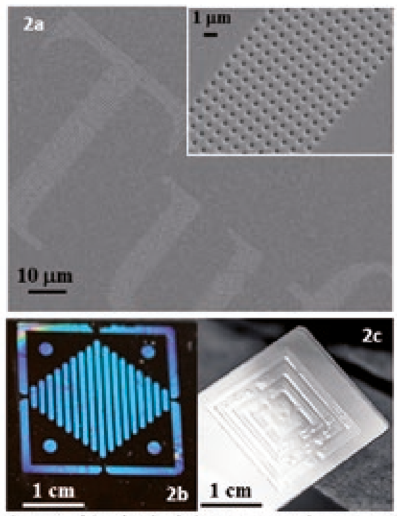

Figure 2. High refractive index nanocomposite processed with different techniques. a) SEM picture of 270 nm holes e-beam lithographed on a 300 nm film. The inset shows a higher magnification picture. b) film patterned using UV lithography; lines are 400 µm in width. c) ink jet printed solution on a glass slide