– STEFANO FARRIS –

INTERVIEW

Stefano Farris earned his Ph.D. degree in Food and Microbial Biotechnology in 2007. From 2007 to 2008 he was a postdoctoral fellow at Rutgers University (NJ) in the Food Packaging lab led by Prof. K. Yam, where he worked on the use of hydrocolloids as biopolymer coatings. In 2011 he joined Prof. M. Hedenqvist's group at KTH in the Department of Fibre and Polymer Technology, where he worked on the development of hybrid materials. At present he is Associate Professor in the Department of Food, Environmental and Nutritional Sciences (DeFENS) of the University of Milan, where he coordinates a team of approximately ten people.

His research activity deals with fundamental aspects to provide new suitable practical solutions, especially for the food packaging sector. In practice, his work mainly focuses on the design and development of new high-performance packaging materials, using different approaches such as soft chemistry and nanotechnology. In addition, he is actively involved in the exploitation of green strategies (e.g. enzymatic routes) to obtain high-value products (molecules, biopolymers, additives) from waste recovery. The ultimate goal is the generation of new hybrid materials (i.e. that include an organic and an inorganic phase) with enhanced performance, especially in terms of barrier (against gases and vapors), wettability, and optical properties. To achieve this goal, Stefano Farris' research is focused on the design and characterization of surfaces and interfaces using a broad range of analytical techniques that include, among others, atomic force microscopy (he works with a Tosca 400 from Anton Paar), optical contact angle, zeta-potential characterization of solid surfaces, X-ray photoelectron spectroscopy for elemental analysis as well as small- and wide-angle x-ray scattering for structural organization.

Which part of your research do you cover with atomic force microscopy (AFM)? Which samples and properties do you measure and what insights can you get from it?

We use the atomic force microscope (AFM) mainly for the characterization of functional coatings in terms of roughness, topography, phase miscibility, and nanomechanical performance. For example, we have extensively used AFM to investigate the impact of the nanotexture of biopolymer coatings (made of natural polymers such as chitosan, pectin, gelatin, and pullulan) on the wettability properties of the final material (i.e. plastic-coated film) for the generation of anti-fog surfaces. Fog is the term used to indicate the formation of tiny water droplets on the surface of plastic films upon change in temperature (e.g. fog is typical for freshly-cut salads placed in the shelves of retailers). Though the fog formation has no impact on the consumers' health (it does not affect the nutritional and microbiology properties of packaged food), it affects negatively the display of the food because the fog formation prevents consumers from seeing a clear image of the food due to scattering of the incident light.

Another example is the analysis of the surface morphology of nanocomposite coatings with high gas barrier properties. AFM has been used to quantify the reaggregation phenomenon of nanoparticles once the coating formed on the surface of the plastic film. In other words, while nanoparticles can be well dispersed in the coating solution, they tend to reaggregate during coating deposition and solvent (water) evaporation because they are forced to a confined space (the coating thickness). Unfortunately, the higher the reaggregation, the higher the negative impact on both permeability and optical properties of the final material, which, in turn, may affect the shelf life of the product (due to a higher permeability to gases, such as oxygen) and the aesthetic properties of the ultimate package.

Furthermore we perform AFM analysis to check the successful obtainment of nanofillers (e.g. exfoliation of graphene from graphite, cellulose nanocrystals for the hydrolysis of macrosized cellulose fibrils, etc.) and determine the size distribution of these fillers (e.g. length and thickness). In this case, we use AFM to check how good we are in the obtainment of nanoparticles starting from macro-objects. For example: the obtainment of cellulose nanocrystals (CNCs) from cellulose, graphene from graphite, or chitosan whiskers from chitosan. In turn, this will enable the generation of nanocomposite materials (that is, nanoparticles/nanofillers loaded into a main polymer/biopolymer phase).One of the latest applications is the detection of microbial spoilage through the morphological characterization of bacteria and the influence of the resistance through nanomechanical characterization of the bacterial cell wall. More specifically, we first checked for the contamination by surface analysis in contact mode. Afterwards, we switched to a nanomechanical test that allowed us to discriminate between bacteria as a function of their mechanical resistance (expressed as stiffness).

How do these results influence the next steps in the research?

These results are of outmost importance for two reasons. First of all we can assess the validity of the processes used in the previous steps. Also, it is possible to better address the next steps of material development. Just to provide you with an example, by AFM we found out that pullulan (an exopolysaccharide produced by the fungus-like yeast Auerobasidium Pullulans) is by far the most wettable biopolymer amongst many (e.g. gelatin, chitosan, pectin, wheat gluten, zein, etc.). Starting from this finding, we have been able to fabricate pullulan coatings laid on plastic substrates (e.g. polypropylene) with anti-fog features. Water droplets will never stand on this surface, rather they will wet the surface due to extensive spreading of water molecules, which has been demonstrated to be due to the combined effect of surface chemistry (high polarity) and morphology (roughness of pullulan coating being in the order of 3 nm).

How do the properties on the nano-scale relate to the polymer properties?

The properties on the nano-scale actually have a great impact on the large-scale properties of materials. For example, phase-separation at the nanoscale level is one of the main reasons for heterogeneous performance in terms of e.g. wettability and friction properties. Moreover, nanoparticles aggregation is a clear evidence of unsuccessful exfoliation, which is reflected in the presence of micron-scale aggregates in the final material (e.g. coatings), leading to a lower performance in e.g. gas barrier properties.

What is the ultimate research goal and how does the AFM help?

The ultimate goal is to gain knowledge at the nanoscale level of the systems obtained with a macro-scale approach. We aim to adjust the large-scale performance by controlling the nanoscale features. AFM is an essential tool for nanoscale characterization.

Finally, which features of Tosca are especially important or beneficial for you? Which features do you or your students appreciate, which help them in their research?

The main appreciated feature is the ease-of-use, which leads to high efficiency. Tosca is extremely user-friendly, from the tip mounting up to the execution of the analysis. This is extremely important to make the instrument available to young scientists and students. The possibility to place several samples on the stage before observation is another important feature, because this enables the user to shift rapidly from one sample to another.