Unique imaging uncovers the invisible world where surfaces meet

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Hoping to find new ways of addressing environmental pollution, a physicist at the University of Wisconsin-Milwaukee (UWM) has developed some novel ways to observe what happens inside a cell when it comes in contact with contaminants or when toxic substances touch soil and water.

An object's molecules and electrons are always in motion, vibrating and wiggling.

Carol Hirschmugl, an associate professor of physics, tracks what happens to molecules when they meet the surface of a particular material or move around in a living cell by taking advantage of these vibrations and using them to map the movement of chemicals within the molecules.

Before she can witness any action, though, she has to detect all the parts involved. Using a device called a synchrotron, Hirschmugl can probe what she could not with a normal microscope. The synchrotron emits energy at all spectral frequencies, from infrared (IR) to X-rays. The light emitted by IR, which is what Hirschmugl uses, is intense, but not visible with the human eye.

IR reveals the vibrations of molecules in a cell, which act as "signatures," allowing Hirschmugl to identify the material she's working with. She is using the technique to observe how algae digest carbon dioxide (and give off oxygen), something that has implications for controlling air pollution.

In her work with algae, she studies the distribution of proteins, lipids and carbohydrates, molecules that play a major role in metabolizing the organism's food (photosynthesis). It's important in fully understanding a process that is so vitally linked to human respiration and environmental health.

"Since the alga uses up a lot of CO_2," she says, "what we're interested in is what happens when you change its environmental conditions. We want to look at how its biological makeup changes when exposed to say, runoff pollution."

Recently funded by the National Science Foundation, Hirschmugl will be developing new ways to "see" how alga reacts to its environment.

"Then, I'm taking the question one step further and seeing how the distribution of its parts changes because of interactions with nitrates or ammonium, which come from fertilizer runoff or sewage."

Her ultimate goal is to see the internal changes actually take place in a living sample.

Electrons behaving madly

In a second imaging project, Hirschmugl observes the arrangement of specific molecules on a solid surface, again enlisting the wave properties of electrons.

"What we are looking at is way smaller than the wavelength of light," says UWM physicist Dilano Saldin, who collaborates with Hirschmugl. "It can't be seen with the eye. So we need to study the energy distribution from electrons scattered from the surface."

The technique Hirschmugl uses is a modified method of low-energy electron diffraction (LEED). By shooting a minute beam of electrons onto a surface, and using a sensitive detection plate, she creates a visual picture of the electrons as they are spread out in all directions and eventually hit the plate. After sophisticated analysis, the resulting pattern can reveal the structure of the surface material.

Why go to all this trouble? To reveal the workings of the atomic world, says Saldin, whose expertise includes the interpretation of the patterns made by the scattered electrons. Since something as tiny as a molecule cannot be seen, it's is difficult to observe its behavior under various conditions.

And changes are happening. And at the atomic level, the interplay of materials at the surface can cause unusual molecular rearrangements that alter the way the materials behave. And most interactions of a solid with its environment take place at the surface.

This kind of transformation is behind the process of corrosion in metals, for example.

The aim of Hirschmugl's surface studies is to examine the behavior of water molecules when they come in contact with an oxide surface, such as soil. The dynamics of this are not well understood, but could be valuable in determining how contaminants flow through soil.

Driving Hirschmugl's inquiry is the fact that water and soil interactive in unpredictable ways, depending on which atoms in the water are touching the oxide surface.

"Water and soil present a really different interface," she says. "I want to know what happens next. Do the water molecules break down or do they remain intact?

"With these techniques, we're getting access to the dynamics of the molecules and the statics (location) at the same time."

Source: University of Wisconsin - Milwaukee