Jose Almirall is perfecting a laser-based materials analysis technology for forensics

Prachi Patel

The words of wisdom Jose Almirall has for his students are not about career choices or life values. In fact, they sound ominous, but on the slim chance that someone has to use them, they could make or break a young person's future. "Once you leave the scene of an accident, it becomes a felony," he advises. "There's always evidence left behind."

Almirall knows from years of experience. For 12 years, Almirall was a forensic scientist with the Miami-Dade Police Department, in Florida, USA. His job involved analyzing and identifying physical evidence found on the victim or at a crime scene—glass fragments, paint, or fibers—and comparing it to evidence found on the suspect. Often, he had to testify on his methods and findings in court. In fact, he has provided expert testimony in over 100 cases, in some of which his analysis provided the crucial piece of evidence in incriminating an offender.

Almirall left his crime-fighting days behind in 1998 when he became a professor of chemistry and biochemistry at Florida International University. But now, as the director of the university's International Forensic Research Institute, he is having a more far-reaching impact on law enforcement. Almirall is involved in training practicing forensic scientists, and is also helping to educate future generations who will do behind-the-scenes work at the hundreds of forensic laboratories in the United States and around the world.

Education is only one part of Almirall's mission to improve forensics. He leads cutting-edge research on the tools that are used to investigate material evidence, such as x-ray fluorescence spectroscopy and laser ablation inductively coupled plasma mass spectroscopy (ICP-MS). However, he has a special interest in laser-induced breakdown spectroscopy (LIBS), a technique that uses lasers to vaporize materials to analyze their chemical composition. LIBS is commonly used in the mining industry to determine ore composition, but is now being tested for forensics in research laboratories. "How does this emerging technology perform in comparison to the more established techniques? That's the question we're trying to answer," he said.

Almirall unexpectedly chanced upon his career 25 years ago when, as a graduate student in physical chemistry at the University of Miami, he saw an advertisement in the newspaper from the Miami-Dade police department looking for a forensic chemist. "It looked pretty interesting and I thought I'd do it for a couple years," he said. "Twelve years later I was still there."

He started with analyzing controlled substances such as drugs and explosives. Even though he had to learn forensics on the job, Almirall's basic chemistry background provided a solid foundation. The hardest part about working as a forensic scientist, he said, was "having to deal with a lot of different kinds of people. You have to develop ways to converse with detectives, attorneys for both the defense and prosecutors. You have to testify in court."

He soon became interested in trace analysis. This involves using analytical chemistry tools to determine the elemental composition of evidence and tracing it back to its origin. Glass, for instance, contains tiny quantities—less than 10 parts per million—of metal impurities that serve as a fingerprint: the type and amount of these metals is unique to the manufacturer and the time period it was made. Analyzing glass was a routine part of Almirall's work. Many times, the analysis directly impacted the verdict.

One such case is etched in his mind. It was a hit-and-run accident in which the driver fled the scene, leaving his damaged car behind. When the police went to his house later, he said the car was his but he did not possess it at the time of the accident. However, detectives found flecks of glass on the suspect's person that they sent in for tests. Almirall proved that the glass came from his car's shattered windshield, providing irrefutable evidence that the suspect was in the car at the time of the accident.

The slivers of glass found were less than a millimeter in dimension, Almirall said. This is typical of the material evidence detectives might find at crime scenes and send in to a crime laboratory for analysis. To determine chemical compositions, scientists need fast, highly sensitive chemical analysis techniques that can detect a range of elements at parts per billion concentrations or even less.

Laser ablation ICP-MS is the cur-

https://doi.org/10.1557/mrs.2011.324 Published online by Cambridge University Press

rent state-of-the-art technique used in dozens of forensic laboratories around the world. It involves focusing a laser beam on the sample to be analyzed. A small amount of the material is removed and introduced into an argon plasma at temperatures of around 10,000 K. The plasma converts the ablated atoms into ions, which are separated and detected by a mass spectrometer.

This technique is suitable for forensics, but it is also cumbersome and requires a fair amount of equipment, Almirall said. "It requires a highly trained operator and expensive instrumentation that is also expensive to maintain," he said. "It requires calibration, and days' worth of data collection and analysis."

LIBS, by comparison, is faster and easier to use without requiring much equipment, only a high-power laser—typically a solid-state Nd:YAG laser—and a spectrometer. When the laser is focused on a specimen, it not only ablates tiny particles of the material but also atomizes and ionizes them, creating a plasma with a temperature over 10,000 K. The atoms and ions become excited at these temperatures and emit light at certain characteristic frequencies.

The technique gives results in seconds, and the emitted light spectra are easy to interpret. But the biggest advantage, according to Almirall, is that LIBS could potentially be miniaturized to make portable, low-power systems. "You could take a LIBS detector out in the field," he said. "It could make a lot of new things possible, say if you're in a clandestine lab that's making drugs and want to know quickly what a chemical sample contains."

Almirall and his fellow researchers have done groundbreaking work to see if LIBS has what it takes to investigate trace evidence. With a grant of nearly $300,000 from the National Institute of Justice, they are analyzing how LIBS compares with laser ablation ICP-MS. They have shown that LIBS can detect many different elements at low parts per million concentrations, and have determined its detection limits. "LIBS has a lot of the characteristics that make it an amenable alternative to laser ablation ICP-MS," Almirall said.

In late 2009, Almirall and his group of researchers introduced LIBS in a court case. The case involved an attempted bank robbery in Maryland. Police intercepted two men fleeing in a van, but needed evidence to prove that these suspects were the robbers. As it turned out, when one of these men had fired a shot through a vestibule glass, some specks of the shattered glass had ended up on his clothes. Almirall's LIBS analysis was able to provide the conclusive link.

Almirall is now pushing to standardize the technique so that it can be taken outside research laboratories for real-world forensic analyses. He said that there is a need for standards for LIBS instrumentation as well as analytical methods to make LIBS easy to adopt and be used consistently across all laboratories.

"Instrument manufacturers are all over the place," Almirall said. "You have a lot of choices in the lasers and detectors that you can use. There are too many choices. No manufacturer has stepped up and said, 'OK, we'll sell this as an optimized forensics instrument.' Right now, you have to get it tailor-made."

Almirall and his colleagues are hosting groups of practicing forensic scientists, training them on how to use LIBS, and getting their feedback. This is helping Almirall's group write standard methods for LIBS forensic analyses. "There have to be lot of good reasons for accepting something new," he said. "People are slow to change from established methods. They have to be convinced that there are many advantages."

That is exactly what Almirall hopes to show through his work. He predicts that the use of LIBS at crime laboratories will increase over the years. By standardizing LIBS and illuminating its forensic analysis benefits, he hopes to speed up that process and make it easier for law enforcement agencies to catch criminals. □

https://doi.org/10.1557/mrs.2011.324 Published online by Cambridge University Press