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EVERYTHING YOU'VE ALWAYS WANTED TO KNOW ABOUT TOF-SIMS

Among the lesser-known analytical techniques that can provide very useful information, Time-of-Flight Secondary Ion Mass Spectrometry (generally referred to as TOF-SIMS) is definitely worth considering. Although the name may sound complex, the basic principles behind this method are simple: the sample is bombarded by a beam of primary ions (generally bismuth or gallium) and secondary ions are ejected from the first atomic layers. They are then collected by a spectrometer that determines their mass to charge and time of flight ratios (from the surface of the sample to the detector). Since more massive ions move more slowly, it is possible to differentiate them with a 0.0001 atomic mass unit resolution.

To simplify, the reaction is similar to what happens when a projectile hits a layer of water: some material is ejected and a crater is formed. The size and mass of the incoming object obviously affects the size and shape of the depression and the amount of material ejected (a ping pong ball will penetrate more than a beach ball but will create less splatter). This phenomenon explains the advantage of being able to use different primary ions (bismuth or gallium). Also, the speed of the ejected particles depends on their mass and by analyzing their time of flight and polarity, a lot of information can be obtained about the sample.

Furthermore, one of the advantages of TOF-SIMS is that it can give different types of information:

- The molecular and elemental composition of the sample (including light elements like oxygen)
- A depth profile for the chemical composition
- Surface imaging

The first feature is similar to what can be obtained using another technique available at the GCM, the XPS, but the detection limit is significantly lower (part per million or part per billion vs. 0.1 atomic percent) allowing the detection of trace amounts of elements or molecules. However, as opposed to the XPS, the results are semi-quantitative and are precise within approximately one order of magnitude. For example, ***Figure 1*** shows the distribution of different chemical species in Al-Mg intermetallics coming from mine tailings. The results indicated that small amounts (ppm) of iron, manganese and beryllium were present and had the tendency to agglomerate in the same regions, confirming the heterogeneous nature of the sample.

Also, ***Figure 2*** shows two red lines produced with different pens. Although it is impossible to differentiate them using optical microscopy, using TOF-SIMS to image the concentration of potassium (ink 1 – red line) and $C_5H_{10}OF$ (ink 2 – purple line), the difference is obvious. This is possible because the chemical composition of commercial inks is extremely variable and TOF-SIMS is able to measure the concentration of an extremely wide range of chemical species.

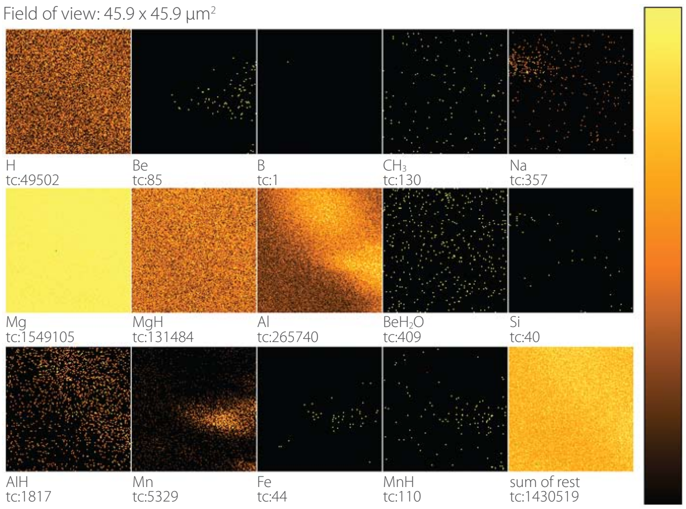

***Figure 1 :** Distribution of different elements in Al-Mg intermetallics from mine tailings.*

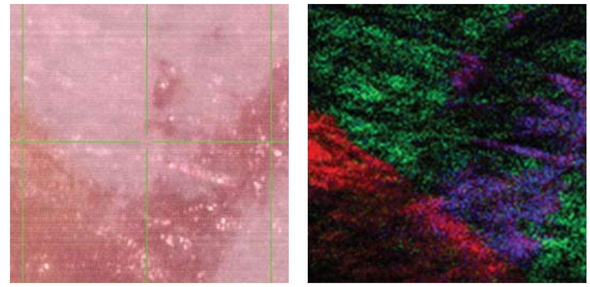

***Figure 2 :** Images of two different red inks using optical microscopy (left) and TOF-SIMS (right). On the TOF-SIMS image the paper is shown in green and the inks in red and purple.*

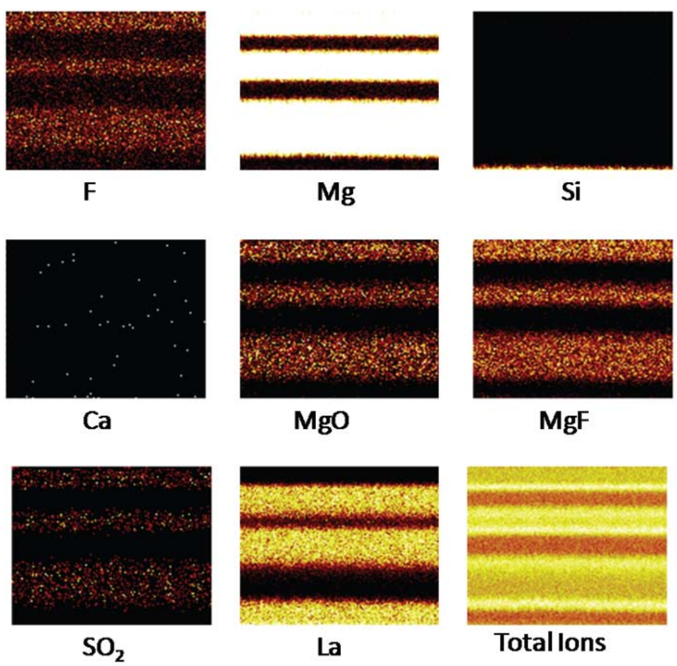

***Figure 3 :** TOF-SIMS images of a fluorine and lanthanum based optical treatment on a silicon surface (depth of the analysed layer: 300 nanometers).*

Finally, by bombarding the same region in a continuous manner, a progressively deeper crater can be formed, yielding a chemical depth profile up to 1 micron deep. As shown on ***Figure 3***, it is thus possible to see in two or three dimensions the distribution of elements or molecules, something impossible with most analytical techniques.

To conclude, TOF-SIMS an extremely sensitive and versatile analytical method that can used alone or in tandem to obtain complementary information. Among the projects performed at GCM with the help of this technique we note the analysis of:

- Alloys and corrosion products
- Contamination of integrated circuits
- Biomaterials
- Toxic elements in materials
- The structure of polymers
- Optical fibres
- Different types of inks (for legal or industrial applications)

If you want more information or need help for your project do not hesitate to contact:
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