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Applications of surface analytical techniques in Earth Sciences

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Abstract

This review covers a wide range of surface analytical techniques: X-ray photoelectron spectroscopy (XPS), scanning photoelectron microscopy (SPEM), photoemission electron microscopy (PEEM), dynamic and static secondary ion mass spectroscopy (SIMS), electron backscatter diffraction (EBSD), atomic force microscopy (AFM). Others that are relatively less widely used but are also important to the Earth Sciences are also included: Auger electron spectroscopy (AES), low energy electron diffraction (LEED) and scanning tunnelling microscopy (STM). All these techniques probe only the very top sample surface layers (sub-nm to several tens of nm). In addition, we also present several other techniques *i.e.* Raman microspectroscopy, reflection infrared (IR) microspectroscopy and quantitative evaluation of minerals by scanning electron microscopy (QEMSCAN) that penetrate deeper into the sample, up to several μm, as all of them are fundamental analytical tools for the Earth Sciences. Grazing incidence synchrotron techniques, sensitive to surface measurements, are also briefly introduced at the end of this review. (Scanning) transmission electron microscopy (TEM/STEM) is a special case that can be applied to characterisation of mineralogical and geological sample surfaces. Since TEM/STEM is such an important technique for Earth Scientists, we have also included it to draw attention to the capability of TEM/STEM applied as a surface-equivalent tool.

While this review presents most of the important techniques for the Earth Sciences, it is not an all-inclusive bibliography of those analytical techniques. Instead, for each technique that is discussed, we first give a very brief introduction about its principle and background, followed by a short section on approaches to sample preparation that are important for researchers to appreciate prior to the actual sample analysis. We then use examples from publications (and also some of our known unpublished results) within the Earth Sciences to show how each technique is applied and used to obtain specific information and to resolve real problems, which forms the central theme of this review. Although this review focuses on applications of these techniques to study mineralogical and geological samples, we also anticipate that researchers from other research areas such as Material and Environmental Sciences may benefit from this review.

Keywords: Surface analysis; Microspectroscopic analysis; Spectromicroscopic analysis; Elemental mapping; Grazing incidence; Synchrotron techniques

Contents

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