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Raman spectroscopy for petrology : recent scientific milestones, technological trends and challenges

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Over the last two decades, Raman microspectroscopy has known a spectacular development in various research fields of petrology opening new avenues for studies in sedimentology, metamorphism or magmatism and cosmochemistry. This has been made possible thanks to major technological improvements (e.g., Raman hyperspectral mapping) and a better theoretical approach (e.g., data processing and interpretation). Raman spectra are actually sensitive to even minor (chemical or structural) perturbations within chemical bonds in (even amorphous) solids, liquids, and gases. They can, thus, help identify, characterize, and differentiate between individual minerals, fluid inclusions, glasses, carbonaceous materials, solid solution phases, strain in minerals, and dissolved species in multi-component solutions. Such sensitivity and versatility make Raman a unique tool for petrology. Yet, it relies on a weak and subtle signal and a cautious approach is required to avoid pitfalls during the analysis and/or the interpretation of data. Some recent scientific milestones will be presented and discussed in various fields like geothermobarometry of metamorphic rocks, geochemistry of meteorites, speciation of deep fluids involved in fluid-rock interactions or the characterization of organic/mineral assemblages of astrobiological interest. For the particular c ase of petrology, Raman microspectroscopy has the immense advantage that it requires minimal sample preparation, thus it can be performed in situ preserving the original microtexture of the sample with a rather high spatial resolution for analysis, typically 1 mm at 532 nm for modern systems. Therefore, this technique is now increasingly used to study poorly crystalline and chemically heterogeneous materials involved for instance in geochemical processes occuring at Earth surface. But it faces numerous challenges due to the reactivity of such phases making them fragile under the laser beam, or due to the quasi-systematic presence of intense backgrounds in the spectra overwhelming the Raman signal. The source of this background can be multiple as it can be observed with fine-grained samples and/or it can be generated by the presence of luminescence/fluorescence emission centers. More generally such background is not well understood although it is a major issue for Raman spectroscopy in many petrological applications. However, there too, recent technological developments, sometimes based on old ideas, offer new possibilities to investigate safely and accurately such materials : time-resolved spectroscopy and surface-enhanced Raman spectroscopy (SERS) will be presented as well as some applications for petrology of complex samples.