Application note

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Analysing industrial coatings with the Virsa™ Raman analyser

Analysing materials

Renishaw's Virsa Raman analyser is a transportable, fibre-coupled system that is well suited to assessing the chemical, phase and structure of materials.

The Virsa Raman analyser can be used to determine both ceramic and polymer coatings, enabling you to investigate coating coverage, thickness and homogeneity, as well as the chemical and mechanical properties of the coating.

Studying coatings with the Virsa analyser

The Virsa Raman analyser has several features that make it ideal for analysing coatings

- The Virsa Raman analyser's high performance makes it suitable for studying both bulk coatings and thin films
- It can be equipped with a video unit and motorised stage that enable Raman mapping so you can study homogeneity and target specific areas of interest
- The Virsa Raman analyser's flexible fibre-optically coupled probes are ideal for measuring large hard-to-handle samples
- It is transportable and does not need to be operated in laboratory conditions, allowing you to take it to the sample or use it in an industrial type environment
- The Virsa Raman analyser can be used to collect both Raman and photoluminescence data which can provide additional information for specific materials

Figure 1 - A Virsa fibre-probe on its motorised stage, being used to analyse a turbine blade from an aircraft engine. The blade measured approximately 200 mm × 100 mm × 80 mm.

Coatings on aircraft engine blades

Here we illustrate the power of the Virsa Raman analyser by investigating the properties of life-cycled thermal barrier coatings (TBCs) on aircraft engine parts. These coatings protect turbine blades from oxidation and corrosion. They are vital to ensure safety and longevity. TBCs typically consist of tetragonal zirconium oxide, partially stabilised by yttrium oxide, deposited on a bond coat of MCrAlY (where M is Co or Ni). The bond coat protects the underlying base metal against oxidation by forming an aluminium-rich thermally grown oxide layer (TGO). The TBC can degrade and ultimately fail during aircraft operation. Knowledge of this process is of vital importance in accurately estimating the lifetimes of the coated parts.

Analysing awkward samples

The size and shape of a turbine blade makes it difficult to analyse using a microscope-based Raman system. The Virsa Raman Analyser was designed to be versatile and is ideal for measuring large awkward samples, such as those often found in industrial applications. In this case, the sample was placed under one of the Virsa's probes that was mounted on a SB100 motorised stage base (Figure 1). For even larger samples, the probe can be oriented horizontally, enabling the analysis of samples of any size and shape. In addition, the Virsa system is easily transportable and can be taken to the sample if it is too large or heavy to move.

Assessing chemical properties

A Virsa Raman unit equipped with a 532 nm general purpose probe was used to collect Raman spectra from the coating on the turbine blade (Figure 2). The Raman bands allow us to verify that this is tetragonal zirconium oxide, as expected. In addition, a weak band attributable to monoclinic zicronia oxide is present. Monoclinic zirconium oxide has different mechanical properties to the tetragonal form and occurs in coatings that are deposited incorrectly or have degraded, and its presence is an indicator of reduced coating lifetime.

The same configuration was used to collect a fluorescence spectrum from the underlying TGO (Figure 3 a). This highlights a key strength of the Virsa Raman analyser that, as well as being able to collect Raman spectra, it can also collect fluorescence and photoluminescence spectra.

Assessing mechanical properties

Typically, coatings are applied to the turbine blades using a spray technique which results in an uneven or undulating finish. This undulation results in a repeating tensile-compressive stress pattern in the coating layer. The presence of this pattern can indicate whether a coating is pristine or degraded.

The position of the fluorescence bands can be used to determine stress in the coating. Figure 3b shows a Raman map of the band position superimposed over an optical image of the sample. At the bottom of the mapped line, we can clearly see that the band position alternates between high (red) and low (black) which is indicative of a healthy coating. However, we see less variation at the top of the line which suggests that this region is becoming stress-relieved. This process, which can only occur if the coating cracks or delaminates from the surface, is a sign of mechanical failure in the layer. This shows that we can observe and characterise the degradation in these coatings using the Virsa Raman analyser. This is a vital part of the material science knowledge required to understand and predict the lifetimes of blades.

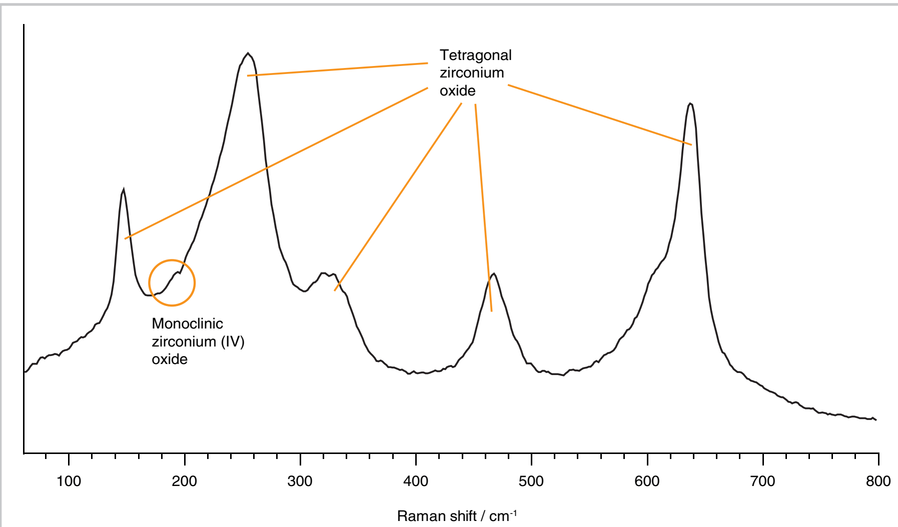

Figure 2 - A spectrum from the TBC, showing the presence of tetragonal zirconium oxide. The Raman band for monoclinic zirconium oxide is also highlighted.

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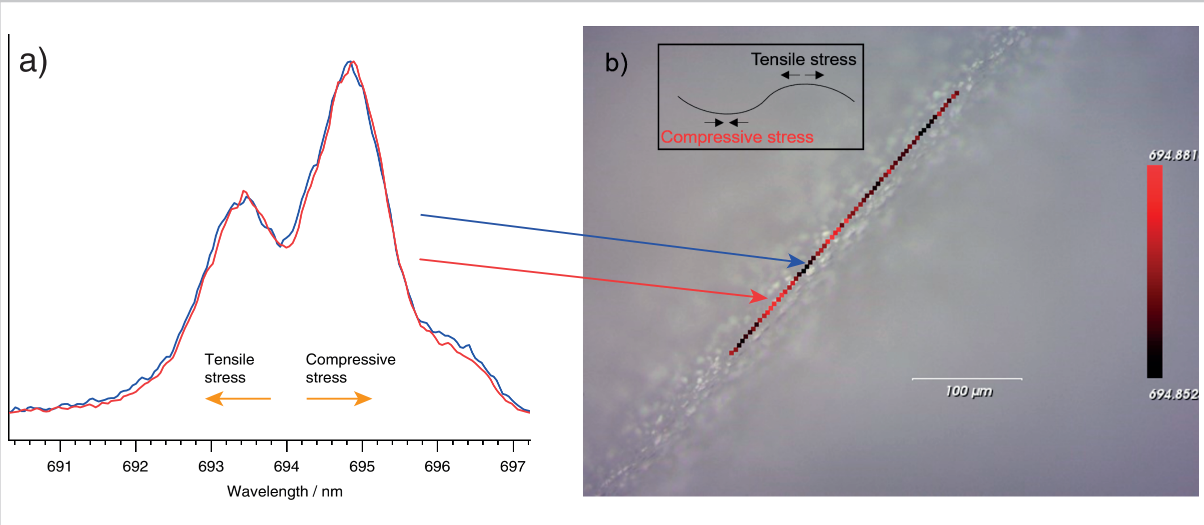

Figure 3 - a) Fluorescence spectra from different points of the sample. The blue spectrum is under increased tensile stress when compared to the red spectrum. b) Raman image illustrating the peak position of different parts of the sample; this is an indicator of stress. The collection area for spectra in 3 a) are highlighted. Note the undulating pattern red and black at the bottom of the line indicating good coating adhesion and the less varied region at the top suggesing this region is degraded.

Summary

- This work highlights how Renishaw's Virsa Raman analyser can be used to characterise the chemical and mechanical properties of complex coated systems
- The Virsa system, when combined with the SB100 motorised stage, enables measurements from large and awkward samples in or away from the laboratory
- The Virsa unit can collect both Raman and photoluminescence spectra, providing more information for coating analysis
- Correlated Raman and photoluminescence data can be overlaid on an optical image to highlight the part of the sample that may be damaged or failing

A range of related Renishaw literature is available. Please ask your local Renishaw representative for more information.

Renishaw. The Raman innovators

Renishaw manufactures a wide range of high performance optical spectroscopy products, including confocal Raman microscopes with high speed chemical imaging technology, dedicated Raman analysers, interfaces for scanning electron and atomic force microscopes, solid state lasers for spectroscopy and state-of-the-art cooled CCD detectors.

Offering the highest levels of performance, sensitivity and reliability across a diverse range of fields and applications, the instruments are designed to meet your needs, so you can tackle even the most challenging analytical problems with confidence.

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