In this talk we discussed some of the scientific tools available to measure the surface of materials. We run a surface analysis lab in the materials department at Imperial College and are keen to develop collaborations.

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The talk started with the definition of our research questions, and was followed with the definition of some key terms. The hierarchical approach to the study of materials was discussed. In the limited time available we were only able to discuss two techniques, and these were chosen to highlight different ends of the hierarchical spectrum.
We started with some research questions

1. What do the Catch 22 key-words mean (especially “surface” and “damage”)?
2. What information on damage can surface analysis techniques provide?
3. Can we use surface analysis to predict (useful) lifetimes?
Some of the key words are indicated on this slide. It was not clear to us that these terms have been precisely defined in a scientific way (so that numbers and units can be assigned). For example if “damage” has not been rigorously defined then how can you measure how damage changes with time in a rigorous way?
We asked “what is the surface” and concluded it is many things to many people and has many attributes. Its something that emits light in the visible part of the spectrum, it is something that has morphology, it is something that can be described in terms of the atoms that are present, and so on.
The different descriptions continued. It is also defined by what we can measure, so the concept of surface has evolved as scientific measurement tools have developed.
We concluded that you need to define “surface” before you can define “damage”
We decided to concentrate in our presentation on two attributes of surface, namely morphology (which we measure with optical interferometry) and chemistry (which we measure with SIMS).
We volunteered a definition of damage in terms of “loss of information” and introduced for debate the idea of entropy.
Access and touch in particular might increase the rate of damage and entropy of the surface decreasing its useful life. The traditional role of conservation is to increase the durability of the object by reducing the rate of damage. The participants were asked in the subsequent discussion what is an acceptable loss of lifetime? Is it 1%, 10%, 50% of the life of the object. Opinions varied!
We then introduced the concept of an analysis hierarchy. Clearly we will start with air based non-invasive techniques first, moving to vacuum based destructive techniques last and only if absolutely necessary.
The white light interferometer is an air based microscope that works using interferometry. The key point is the information it provides – it produces digital maps of the height of the surface with incredible precision – the accuracy in the lateral dimensions are a fraction of a micron – height differences can be measured to a precision on a nanometre (a thousand millionth of a metre). This instrument can be used to measure how surfaces change with time. For example one could measure how the height of the numbers and letters on a coin were changing as the coins was handled. Thus one could predict how many contacts would lead to a decrease in height of 10% or 100% (total loss of that aspect of the information).
The build up of corrosion products on a glass vessel has been measured with the interferometer. So it can be used to monitor erosion of surface features or build up of contaminants.
Because the data is digital it can be analysed retrospectively and quantitatively.
Another example in high magnification showed the measurement of a crack.
We now moved to the other end of the hierarchical spectrum and described a vacuum based surface analysis technique in which the sample surface is irradiated with high energy ions. Ionised atoms from the sample fly off and are analysed in a mass spectrometer, telling us the chemical make-up of the surface. This technique called SIMS leads to gradual erosion of the sample.
But the amount of sample erosion is very small and usually is invisible to the naked eye. A far more serious problem for some samples is the vacuum itself. The material must be vacuum compatible. Also, there are limits on the size of the object we can analyse.
We have measured glass corrosion using SIMS. We discussed this example and showed the incredible power of this technique to study ultra-slow corrosion processes (which are quite typical in museum objects).
The SIMS technique reveals the distribution of atoms with depth. In vulnerable glasses there is a hydrated gel on the glass surface and a depletion of sodium. Slowly over time there is an ingress of moisture and an egress of sodium.
By monitoring the sodium trace in different samples aged for different periods of time it is possible to measure the rate of development of the gel type surface layer. Thus we can use SIMS to measure kinetics and mechanisms of corrosion. One key fact to observe here is the depth scale which is measured in nanometres. We are measuring incredibly slow processes preceding at a rate of 1mm in 3,000 years!
Finally some people do worry about the extra damage our analysis techniques such as SIMS introduce. I have been exploring the idea of using existing damage on the sample as the site for our analysis i.e. hiding where we have been!
The focused ion beam can be used to open up cross-sections to study the microstructure of a sample for subsequent analysis. What about putting the trench inside an existing scratch. At the lowest magnifications in an optical microscope it is impossible to see. At high magnifications the FIB trench becomes visible, but even then we can make it less visible if it runs parallel to the scratch. Basically nobody looking at “Dagman” will know we were there!!
The trench can be analysed at high magnification.
We have described two techniques at opposite ends of the analysis spectrum. Both have a role in the analysis of museum objects and can give us information on the effects of handling. If we quantify the word “damage” then we can use these techniques and the information they provide to determine the change in useful life of the object as a result of access and touch. In the case of the interferometer the damage would be associated with the morphology (smoothness, roughness, crack length, pin-hole density or similar). In the case of SIMS it would be associated with the types of atoms on the surface and how they changed with time (were depleted or accumulated).

If you are interested in these ideas or these techniques please contact us to discuss how best we might initiate a collaboration ☺.

Conclusions

Morphology
Optical Interferometry is a non-contact air based technique for studying surface morphology

Chemistry
SIMS is an vacuum based technique with nano-sampling that offers the opportunity to study surface reaction mechanisms and kinetics of ultra-slow processes. The analysis area is usually invisible and may be hidden inside or underneath existing damage sites.