Spectroscopic Ellipsometry Application in Life Science

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Introduction

Spectroscopic ellipsometry (SE) is a non-destructive optical technique based on the measurement of polarization state change, using linearly polarized white light beam reflected from the sample surface. The set up of SE is shown in Figure 1. Information about sample properties and structure, like layer thickness (d) and optical constants (refractive index (n) and extinction coefficient (k)) values is obtained from the analysis of ellipsometric angles (Ψ&Δ) using modeling approach.[1]

SE is widely used in academy and industry in the following application fields: semiconductors, displays, solar cells, chemistry and metallurgy. In the semiconductor industry, especially, SE is used for about 30 years. In addition to measurement of layer thickness and optical constants, SE can also determine materials band gap, composition and electrical properties (resistivity, carrier density and mobility). SE measurement could be performed on variety of different solid substrates, like semiconductors, glasses, metals and plastics films. SE measurement could be also performed in the liquid ambient. In recent years, SE application is extended to the life science. In this article, we introduce two examples from this field.

Application in Life Science

Biocompatibility of DLC films[2]

This work was done in collaboration with Tokyo Denki University. The purpose of this study was to find the correlation between optical properties of diamond-like carbon (DLC) films and their biocompatibility, using spectroscopic ellipsometry.

DLC films structure could vary from diamond-like to graphite-like, depending on the ratio of diamond bonds (sp^3) to graphitic bonds (sp^2). DLC films are known for their excellent mechanical, tribological and chemical stability properties. Recently, DLC films biocompatibility opened new fields for applications in biology and medicine, as protective coating which modify surface of implants like artificial blood vessels or heart valves, for example. However, the biocompatibility of DLC films is strongly affected by their structural properties, which are changing due to film deposition methods and conditions. Depending on

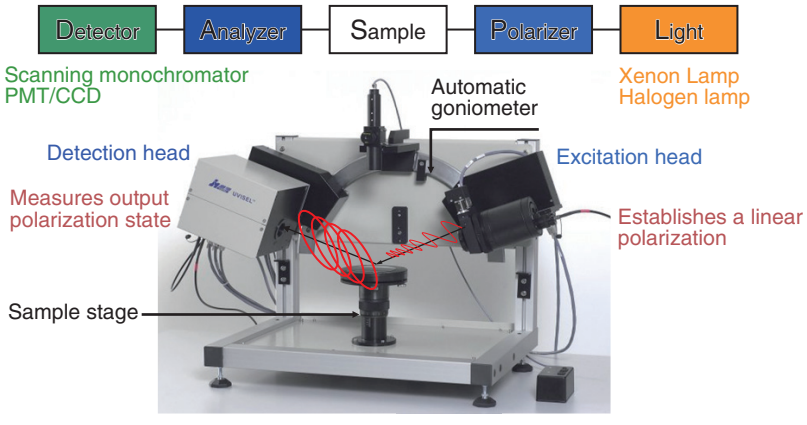

Figure 1 Setup of spectroscopic ellipsometer (UVISEL)

the method of preparation, DLC could be hydrogen free (a-C) or hydrogenated (a-C:H). As a result, it is important to evaluate correctly the property of DLC films.

In this work, various DLC films were deposited by chemical vapor deposition (CVD) methods on polyvinyl chloride (PVC), dimethyl polysiloxane (PDMS) and polystyerene (PS) dishes.[3] The cells were grown on these dishes using mouse-derived fibroblasts. The cell proliferation rate was evaluated by absorbance measurement. The DLC films were measured by SE, to determine refractive index. In Figure 2, cell proliferation rate is shown as function of refractive index.

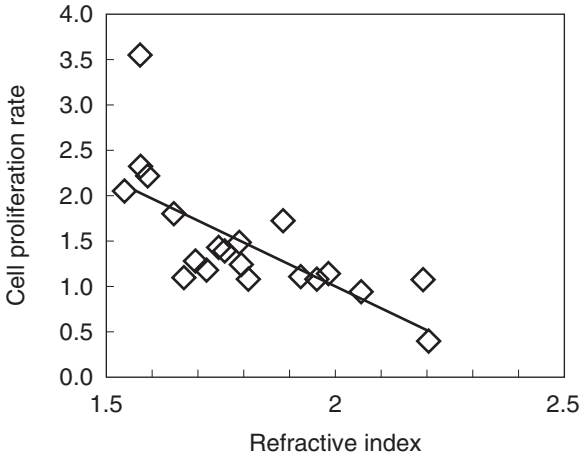

Figure 2 Correlation between refractive index and cell proliferation rate[3] (Correlation coefficient "r" = 0.71, Significant difference "P" = 0.0004)

In the case of base material, dish without DLC coating, the cell proliferation rate is defined as 1. It was found that the cell proliferation rate increases for the lower refractive index. In this work, films with the high hydrogen concentration have lower refractive index. So it is considered that the high hydrogen content of DLC films accelerates the cell proliferation on their surfaces. This result shows that SE can be used to evaluate the biocompatibility of DLC films.

Demineralization and remineralization process of tooth surface[4]

This work was done in collaboration with Tokyo Medical and Dental University. The purpose was to demonstrate demineralization and remineralization process of tooth surface due to exposure to acid and saliva respectively. SE used to measure the tooth effective surface roughness, using model described in Figure 3, and calculate the difference before and after exposure to saliva. Toothbrushing was introduced to demonstrate weakness of the demineralized tooth surface after exposure to acid.

The experiment procedure of this study was as following. Firstly, teeth were exposed to acid to introduce the demineralization on the tooth surface. SE used to measure the initial effective roughness. Secondly, each tooth was dipped into saliva for different periods of time to follow the remineralization process. Thirdly, after brushing each tooth, thickness of teeth effective surface roughness was measured by SE after dip into saliva. The difference of effective roughness was calculated.

As shown in Figure 3, with increasing dip time in saliva, the difference of

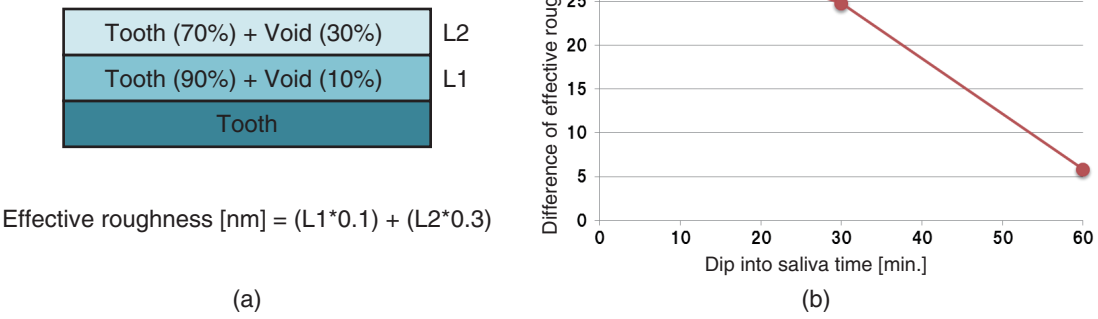

Figure 3 (a) Optical model of tooth and (b) difference of effective roughness after brushing as function of dip into saliva time..

effective surface roughness was decreasing. This result demonstrates the remineralization effect of saliva on demineralized tooth surface. From this result, it could be suggested that toothbrushing after meals should be done not immediately, but after some time, to allow saliva repair the tooth surface. The above result shows that SE can be used to evaluate the demineralization and the remineralization process of tooth surface.

Summary

SE is relatively inexpensive and quick method for characterization and optimization of DLC film properties to match relevant biomedical application. SE could be used to study the demineralization and the remineralization process of tooth surface. It also could be used for other medical application like development of artificial saliva. We hope to increase life science application of SE in the near future.

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