DEVELOPMENT AND USE OF A NEW DEVICE FOR INDENTATION OF BIOLOGICAL TISSUES AND HYDROGELS

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Introduction

In the last few decades measurement of local mechanical properties of biological tissues has become an important topic in biology and biotechnology [Cross, 2007]. Recently, some nanoindentation devices have been used for this purpose because they offer suitable force and displacement range [Kaufman, 2008]. However, with the currently available nanoindenters it is complicated to deal with certain issues imposed by extremely soft and biological samples (adhesion, large depths, capillary forces, liquid media, etc.).
The goal of the presented paper is to demonstrate nanoindentation of hydrogels and biological samples using newly developed nanoindentation device. Issues such as contact point determination, adhesion and capillary forces will be shown and their effect on the measurements discussed.

Experimental methods

All experiments were performed with a new Bioindenter device, result of collaboration between biologists and instrumentation engineers. The device is based on CSM Instruments Ultra Nanoindentation Tester (UNHT) with increased displacement range and force resolution. Further, special Biochamber (CSEM) accommodates Petri dish holder, phase contrast, bright field microscope and 37°C heater. Spherical indenter (radius 100 µm) used in our experiments had specially thin shaft to diminish the capillary and buoyancy effects. The maximum indentation force in our experiments was 100 µN with hold period of typically 60 seconds. The experiments were performed in liquid on agarose, polyacrylamide and PDMS hydrogels and several biological tissues (cornea, liver).

Results and discussion

Most of the experiments involved low indentation forces with large maximum depths (up to ~57 µm, see Fig. 1). The Young's modulus was calculated using standard Oliver&Pharr (O&P) model, but other calculation approaches are also being evaluated. Nevertheless, O&P model yielded results close to values obtained by other experimental methods. All indentations were performed in liquid; the adhesion effects were therefore mostly eliminated. Some adhesion was observed only on the PDMS184 sample. There were no perturbations observed on the normal force signal that could be related to capillary forces (capillary forces can also be measured with the Bioindenter using special indentation procedure). The point of contact of the indenter with the sample surface could be easily determined due to recording of the force-displacement data before and after the contact of the indenter with the sample. The penetration depth into the sample could therefore be correctly measured.

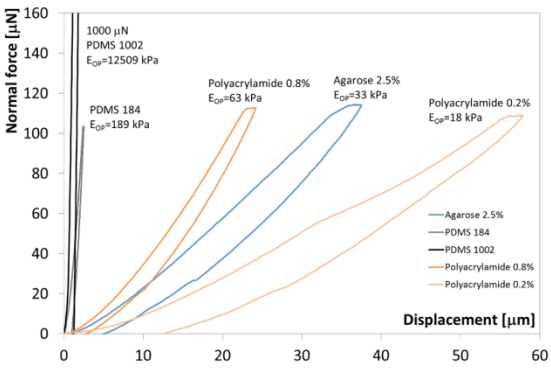

Figure 1: Comparison of average force-displacement curves from five types of hydrogels.

Conclusions

This paper presents a new nanoindentation device for application in biology and biotechnology. It was shown that this device allows for easy characterization of mechanical properties of hydrogels and biological tissues. This new device, called Bioindenter, will therefore effectively bridge the gap between the nanoscale atomic force microscope measurements and macroscopic tests.

References

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