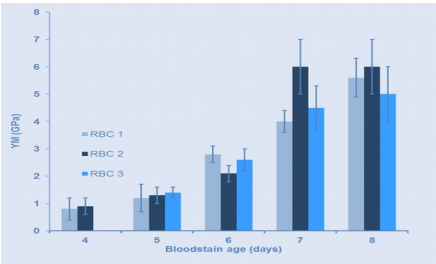
Physics MSc Project (6 months, starting September 2019)

ATOMIC FORCE MICROSCOPY FOR CRIME SCENE INVESTIGATION: NANOMECHANICAL STUDIES OF POST-MORTEM RED BLOOD CELLS FOR AGE DETERMINATION OF BLOODSTAINS.

Background

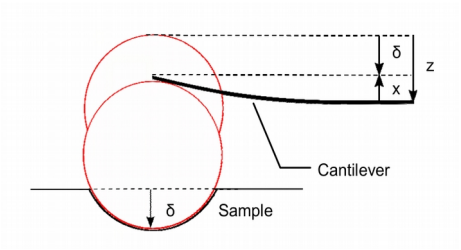
Analysis of biological traces, in particular bloodstains, are of crucial importance at a crime scene. Bloodstains are regularly used for DNA-profiling, however if the age of a bloodstain could be determined this type of trace could also identify the time of the crime. Age determination of bloodstains at a crime scene has attracted much scientific attention in forensic science as up to now there are only a few methods to determine the time of the crime based on trace evidence, and these do not have high time resolution (1).
In Leiden we have done a Atomic Force Microscopy (AFM) pilot study in collaboration with the Netherlands Forensic Institute (NFI) which has shown the potential of this nanotechnology tool to address this problem. This study has proven a correlation between red blood cell (RBC) elasticity data and the age of the corresponding bloodstain in laboratory conditions (2). Nevertheless realistic "crime" conditions can vary a lot, and can also be completely unknown. A complete AFM study that would result in a usable forensic application will have to explore several environmental and victim conditions, like health, gender, medicines etc. This large data set could be analyzed by Machine Learning algorithms for identification of patterns.

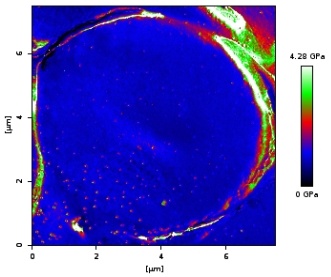


Young Modulus measured by AFM of different RBCs in one bloodstain measured in different days in the same drying conditions (2). Graph show clear increase of the "dead" RBCs in time. This trend can potentially be used to determine the age of the bloodstain.

Project description and aim

AFM is a very versatile and powerful technique that not only outputs extremely high resolution images of specimens in several environmental conditions but it is also capable of studying material properties as material dissipation, adhesion, local surface electrical property mapping and especially elasticity mapping (3). The latter can be measured with an AFM on a very wide range from very soft materials (kPa) to extremely stiff materials (100 Gpa).
The technique used for this purpose is called AFM Nano Indentation. For the forensic application, AFM elasticity maps can be measured on the same RBCs which have been drying in a given bloodstain in different laboratory conditions. As the pilot study was limited to one specific condition (temperature and humidity) the goal of this project is to explore at least 2 very different conditions from the ones of the pilot study and to begin the study from the first day after bloodstain deposition (pilot study started at day 4). This approach will also bring more understanding of the mechanisms of the drying processes of the RBCs after death.





Left: Cartoon representation of the AFM probe performing "nano indentation" on a flexible specimen. Right: pixel-by-pixel YM map ("elasticity map") or a RBC obtained by AFM (2).

The main phases of this project are 3:

- to determine the optimal statistics needed to infer the elasticity of the RBCs under study in the quickest way possible. The faster the AFM measurement can be performed the better for the time accuracy of the age determination of the bloodstain.
- to explore the main processes of the drying of the RBCs outside the body from the moment of the cell death (day 1) to 10 days after in the same conditions of the pilot study. This will be done by AFM Nano Indentation supplemented by high resolution optical microscopy.
- to determine a correlation between elasticity and time for 2 very different drying conditions than the pilot study: higher humidity and lower temperature.

During this project you will master AFM imaging in advanced modes of operation, like Quantitative Imaging, and you will learn basics of cell biology, (nano)-mechanics, inter-molecular forces and adhesion. The focus is on AFM measurements, careful environmental control and data processing with commercial AFM software and Python.

Project team

Dr. Federica Galli, supervisor. Contact if you are interested: galli@physics.leidenuniv.nl
Hosting group: Prof. Jan van Ruitenbeek

References

(1) Edelman G. et al., *Hyperspectral imaging for the age estimation of blood stains at the crime scene*, https://www.ncbi.nlm.nih.gov/pubmed/22938693
(2) T. Smijs et al. https://pdfs.semanticscholar.org/031d/4b2dc4ed80bcf41b4184d8e1efe7efc13251.pdf
(3) H-J Butt et al. Force measurements with the atomic force microscope: Technique, interpretation and applications. Surface Science Reports 59 (2005) 1-152