Quantitative Analysis of Electrolytes in Microliter-size Blood Drops Congealed via HemaDrop™ using Ion Beam Analysis and SIMNRA

This project tests the viability of HemaDrop™ to accurately determine quantitative blood compositions via vacuum-based techniques such as Rutherford Backscattering Spectrometry.

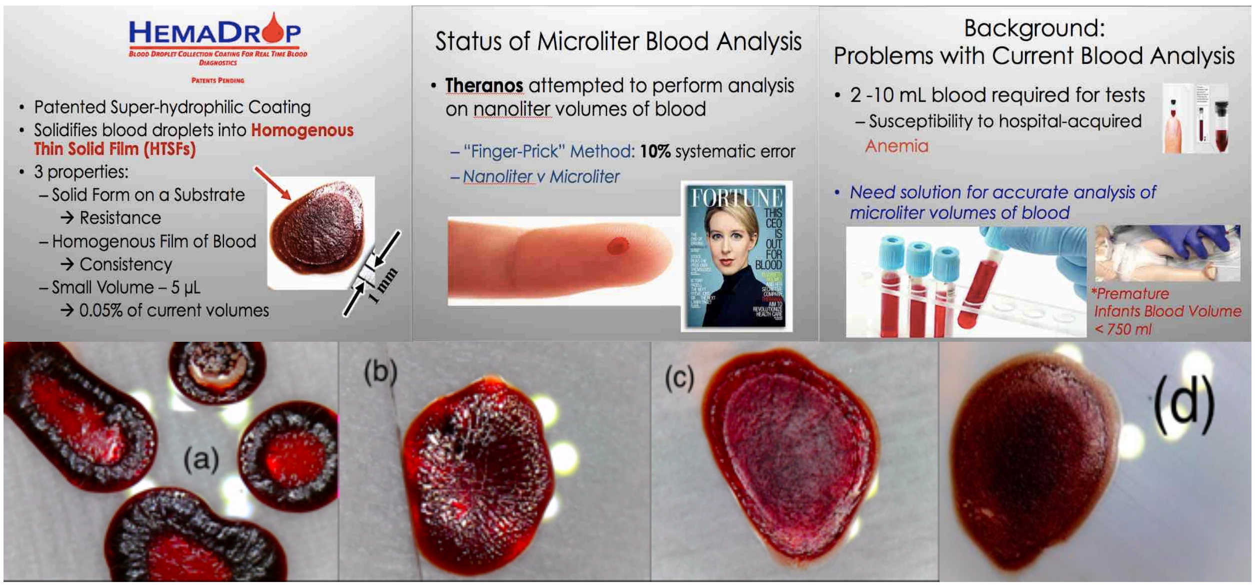


Figure 1: *Optical microscopy images captured with the Opti-tek Scope OT-V1 Digital Microscope at the 1600 x 1200 resolution for uncoated and coated substrates. (a) 4 human blood drops on uncoated microscope slides 20 minutes after application, with clear cratering, phase separation, and non-smooth topography. (b) A human blood drop on a HemaDrop-coated microscope slide 20 minutes after application. No significant phase separation, cratering, and semi-smooth topography. (c) The same blood drop 2 days after application has no cratering or phase separation and smooth topography. (d) The same blood drop 1 week after application. No hysteresis or cratering is observed.*

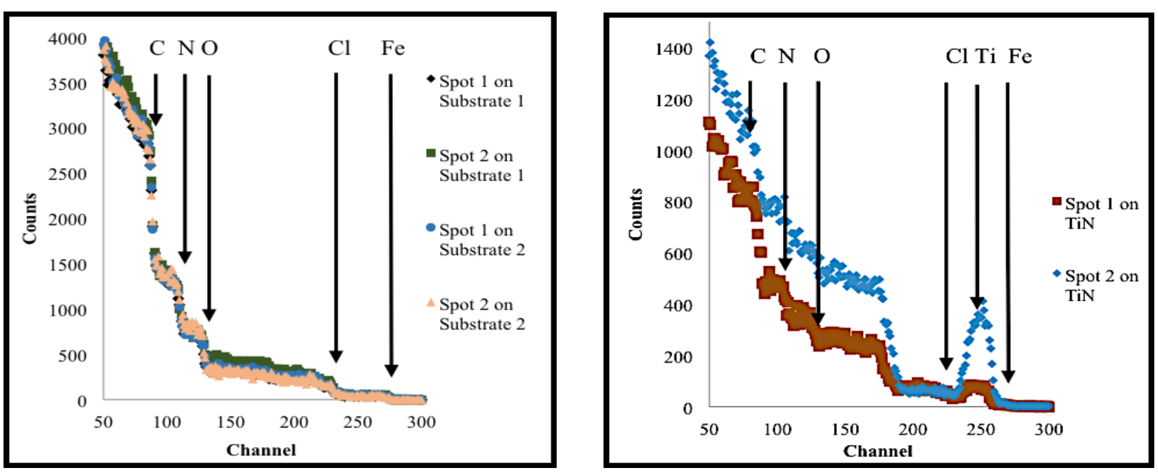
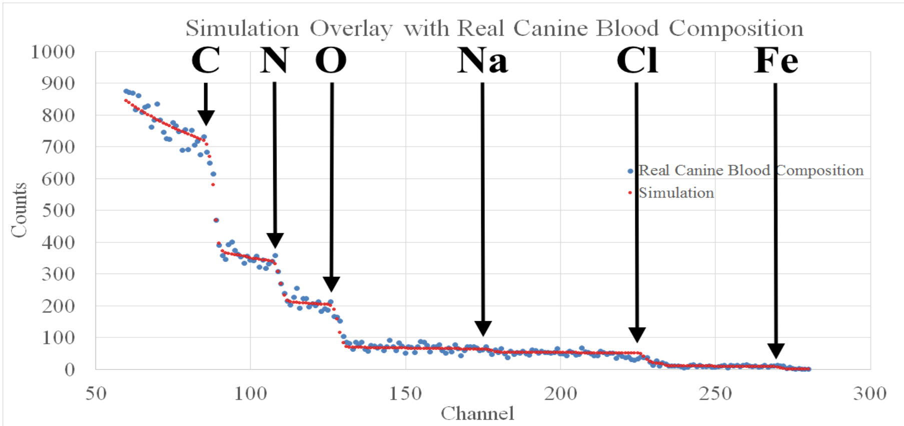


Figure 2: *(a) Four RBS Spectra taken with 400,000 counts on two separate areas of blood prepared with HemaDrop™ on two different substrates. (b) Two RBS spectra taken with 100,000 counts on two separate areas of blood prepared without HemaDrop on TiN. We can discern each element's signal as a plateau. The leading edge of each plateau represents the signal from surface atoms of that element. Each channel represents ~5 keV of energy.*

The RBS spectra of HemaDrop™-coated substrates are first compared to those of the uncoated substrate. As shown in Fig. 2a, the elemental composition of blood has higher precision and consistency for blood samples on HemaDrop™ substrates than for those on uncoated substrates. Because leading edges of signals in Fig. 2a have widths of 4 channels while those in Fig. 2b have widths of 20 channels, signals for elements are highly resolved and more accurate in spectra of coated substrates. In addition, because the films are uniform, spectra taken at different locations (spots) on different HemaDrop™ substrates (Fig. 2a) are highly consistent (3%, 1%, 2%, and 5% sampling error for Carbon, Nitrogen, Oxygen, and Iron respectively) compared to the two spectra in Fig. 2b, which have large differences in composition, showing that HemaDrop™ allows for precise and consistent measurements of elemental blood composition.



For the successful identification of quantitative blood compositions, RBS simulations from SIMNRA are compared to real RBS data from blood drops. Using the simulation, the original blood composition is corrected element by element, starting with the Iron composition. The error is calculated by summing Iron counts for both the simulation and the RBS data. The difference in the number of counts gives error, which is found by dividing the two sums. The compositions are iteratively adjusted based on the error to give very accurate elemental composition.

Once the elemental values are corrected for, the new concentration is then processed through SIMNRA to simulate new spectra. The process is repeated again for Chlorine, Sodium, Oxygen, and Nitrogen, resulting in +/- 1% error for each element. Both optical and quantitative results demonstrate the uniformity and smoothness of samples prepared via HemaDrop™ .

The film created with HemaDrop substrates is analyzable with any vacuum-based technique. For example, while the specialized Ion Beam Analysis was performed in a controlled environment, hospitals and medical labs have the resources necessary to implement our analysis: ion sources such as Americium^{241} (found in smoke detectors), electromagnets currently used for nuclear testing and cancer therapy that can guide ion beams, and a controlled environment for testing. Other techniques, such as Fourier Transform Infrared (IR), Terahertz Time-Domain (THz-TD), Nuclear Magnetic Resonance (NMR) spectroscopies, use similar sample preparation techniques as RBS. Because HemaDrop™ forms a homogenous, uniform thin film on a substrate, applying HemaDrop™ to these other spectroscopic techniques and even to other biological fluids is promising for future research, especially because IR and NMR spectroscopies can provide quantitative information about the molecular and biological contents, such as protein and leukocyte concentrations, of a blood sample.

HemaDrop™ can revolutionize blood analysis by significantly decreasing the volume of blood needed for accurate, qualitative measurements in the biomedical and forensic fields. Smaller volumes required for blood testing will help prevent hospital-acquired anemia, reduce discomfort experienced by patients, and allow for more accurate and regular monitoring of conditions.