

## i-Rheo AFM

This executable has been created by:

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## Installation

This program has been written in MATLAB and you may need a MATLAB licence to use it.

**Aim:** This program is designed to evaluate the frequency-dependent materials' viscoelastic moduli via the ratio between the Fourier transform of the time-dependent force and indentation functions.

## Modus operandi

The code analyses stress relaxation measurements performed by means of any generic indenter/AFM with a spherical tip of known diameter.

The code will automatically identify the peak force achieved during the initial indentation and before the start of the stress relaxation.

The "relaxation data" of both the force and indentation functions are highlighted in red on both the top graphs.

The first time you run the executable "i-RheoAFM" a window appears, click the "Select File" button to choose the file to read and analyse (i.e. the file containing the step-indentation measurement data). Then you can click the "Calculate" to execute the code.

The file to analyse must be of type .txt, with tab separated data. It may contain more than three columns; however the executable reads only the first three columns of the file. These must be: **{time [s], force [N], indentation [m]}**. The file may contain column headings, but it will be necessary to discard them when processing the data as explained hereafter.

Once the step-indentation measurement has been loaded, the temporal behaviour of both the force and the indentation are displayed on the top part of the application's front panel, as shown in Figure 1.

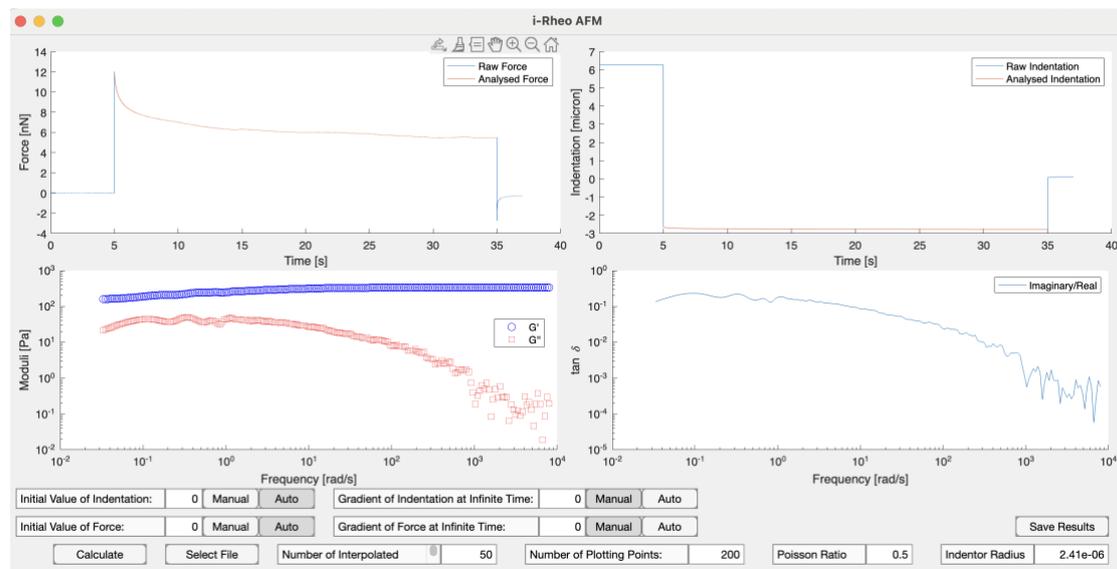
Only the force relaxation section of the measurement is analysed. This section is detected automatically by the program and it is displayed in red in both the plots showing the measured force and displacement in the top-left and right, respectively.

Additional inputs are (i) the radius of the indenter (input it in the bottom-right corner), (ii) the Poisson's ratio (usually equal to 0.5).

The program then automatically calculates and displays the following parameters:  $\omega$ ,  $G'$ ,  $G''$ ,  $\tan(\delta)$ . In particular:  $G'$  and  $G''$  are displayed on the bottom left graph as shown in Figure 1.

Note that, the default values of the four parameters  $\dot{F}_\infty$ ,  $\dot{d}_\infty$ ,  $F(0)$  and  $d(0)$  required by the analytical method are either set equal to zero (for  $\dot{F}_\infty$ ,  $\dot{d}_\infty$ ,  $d(0)$ ) or read automatically by the executable (for  $F(0)$ ). The user could change these values by switching the related controls from “Auto” to “Manual” at the bottom-left of the front panel.

The range of frequency where the complex parameters are displayed is calculated by using the time window extremes of the curtailed indentation-measurement shown in the bottom-left graph. In particular, the longest time ( $t_{max}$ ) provides the lowest frequency  $\omega_{min}$  (i.e.  $\omega_{min}=1/t_{max}$ ); whereas, the shortest time ( $t_{min}$ ) provides the highest frequency  $\omega_{max}$  (i.e.  $\omega_{max}=1/t_{min}$ ).



**Figure 1.** Front panel of the MATLAB executable ‘i-Rheo AFM’.

The displayed parameters and moduli can be saved into a text file by pressing the “Save Results” button. You are given the option to choose the name and location of the output file. The output file is composed of the Frequency Range [rad/s] and the calculated values real ( $G'$ ) and imaginary ( $G''$ ) parts of the complex moduli and is saved as a .txt file.

The virtual oversampling procedure has by default a value of 1000, which is indicated by “Number of Interpolated”. Notice that, in some cases it may actually be beneficial to reduce it significantly to minimise the undesired effect of noises, as shown in Figure 1 (showing a value of 50).

The effective number of output data points (i.e. the number of rows in the output file) for the specific range of frequency can be chosen by changing the numeric value in the “Number of Plotting Points” box (the default value is 200 points, equally spaced on a Log scale).

## Tips

All the parameters and the number of output data values can be changed while the program is running. i-Rheo AFM will adjust the results as soon as the “Calculate” button is pressed.

For further information or questions, please do not hesitate to contact me:

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## **Bibliography**

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