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How to Use DCTS Software

2007/1/23

Contents

Download the DCTS software.

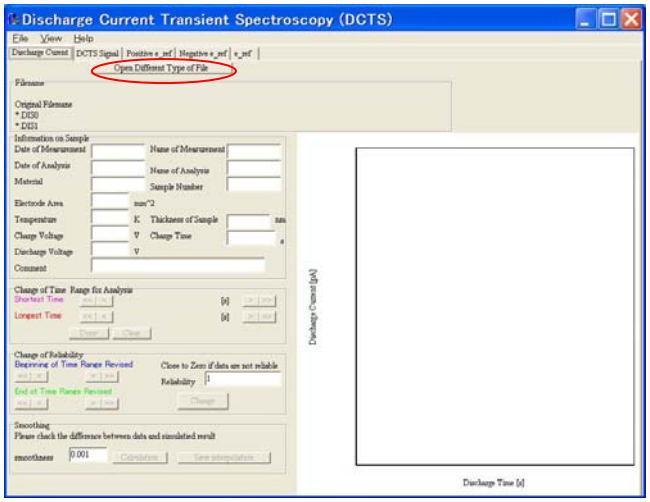
I. Example A　(File: TransientCurrent1.txt)

A. Creation of data file for DCTS analysis

1. Double-click the “DCTS_1_0.exe” file.

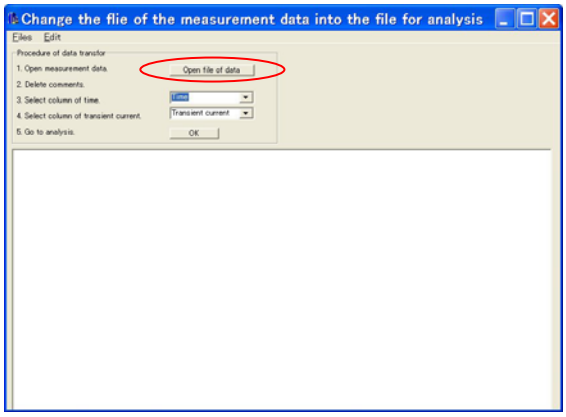
   The following main frame appears.

2. Click the “Open Different Type of File” button



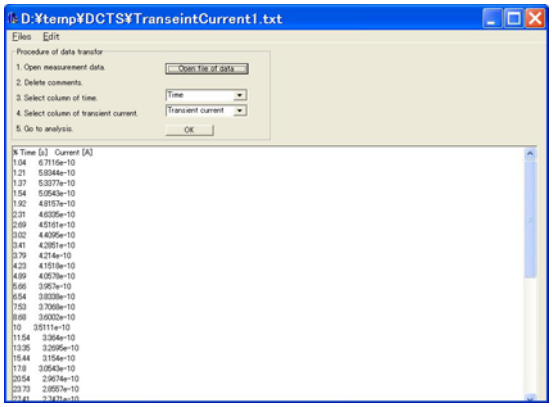
   Another frame appears as follows.

3. Click the “Open file of data” button.

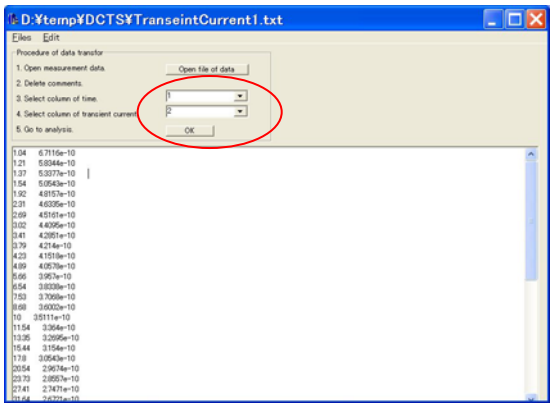


4. Select the file you want to analyze in your holder.

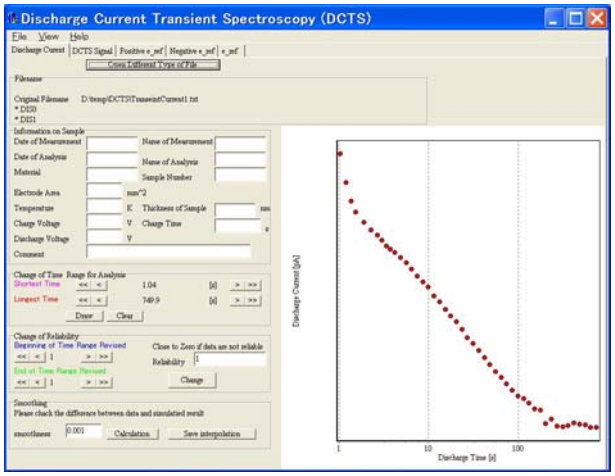
   After that, the content of the text file appears in the edit pane.



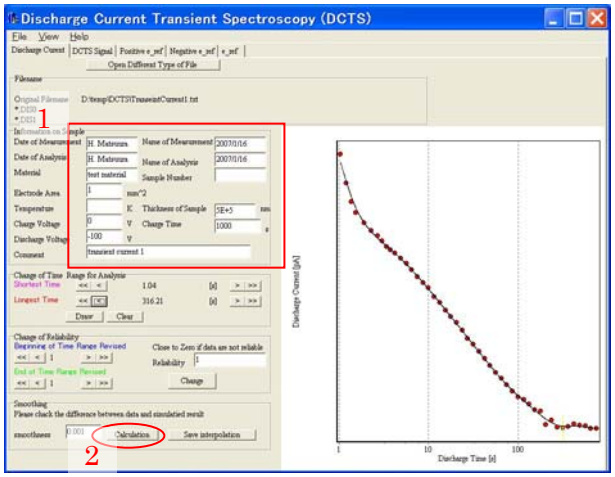
5. Delete the comments, and select the numbers of “time” and “transient current” columns.
6. Click the “OK” button.



The following appears.

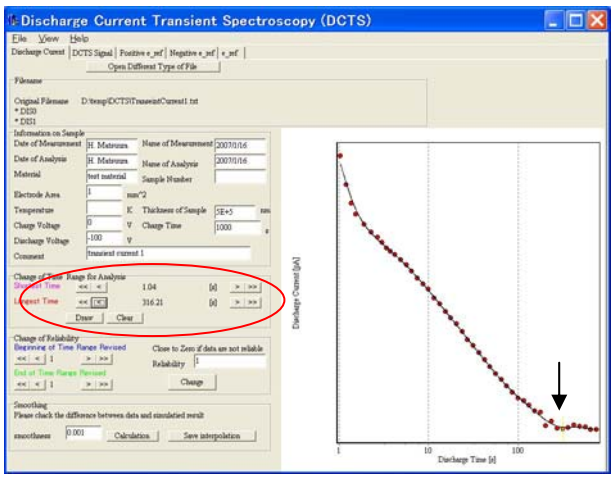


7. Input all the information, and then click the “Calculation” button.

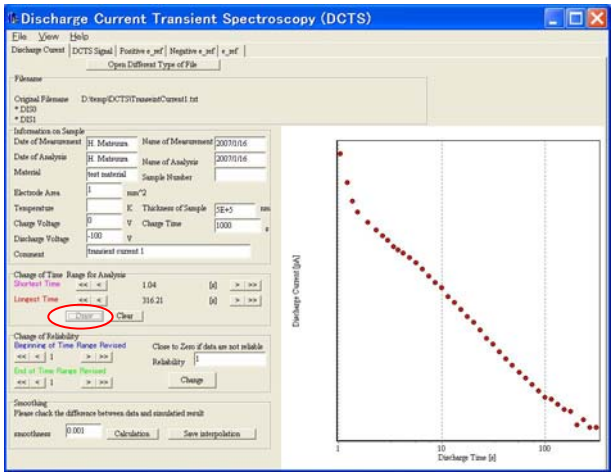


The solid line represents the transient current interpolated by a cubic smoothing natural spline function.

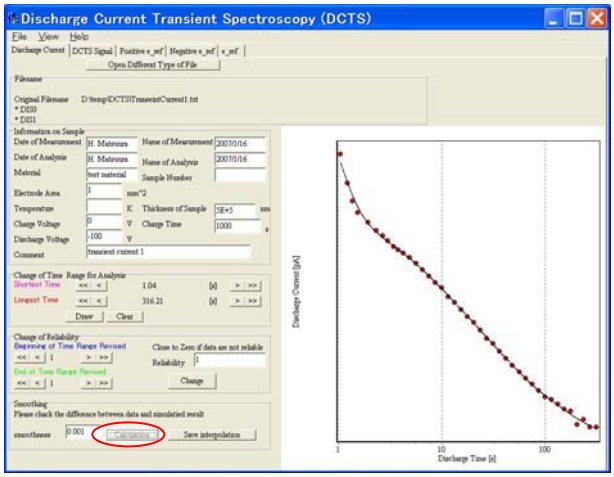
8. In order to change the time range for analysis, click the “<<” or “<” or “>>” or “>” button, and stop the “+” where you want.
   In the following figure, 316.21 s is chosen as “longer time” because the leakage current at longer than 316.21 s seems constant.



9. Click the “Draw” button.



10. Click the “Calculation” button.



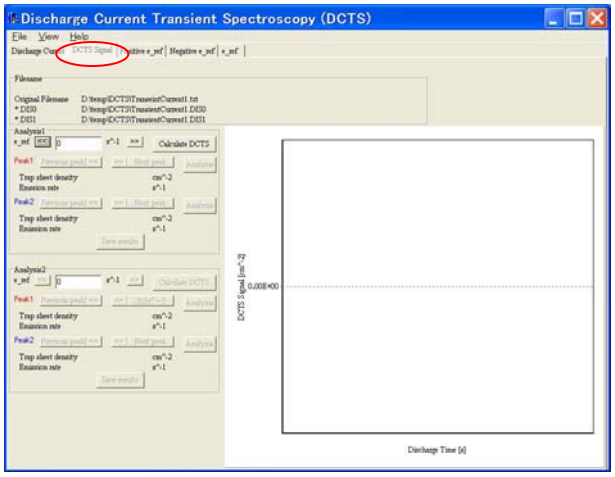
The reliable interpolated values, denoted by the solid curve, are obtained.

11. Click the “Save interpolation” button. This process produces “*.DIS0” and “*.DIS1” files, which contain the experimental transient current with reliabilities and the interpolated transient current, respectively.

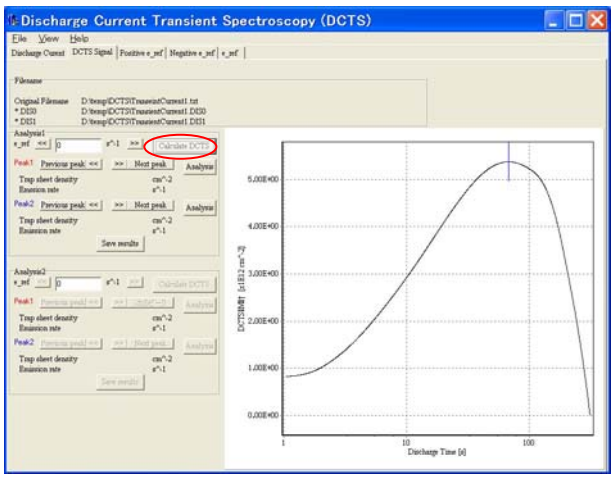
Note: Since the input of the value of temperature was forgotten, the “Alarm Dialog” of “Input temperature” appears. In this case, input the value, and click the “Save interpolation” button again.

B. Determination of trap sheet density and emission rate for $e_{\mathrm{ref}} = 0\ \mathrm{s}^{-1}$

12. Click the “DCTS Signal” tub.



13. Click the “Calculate DCTS” button.



The DCTS signal is calculated from the experimental transient current using

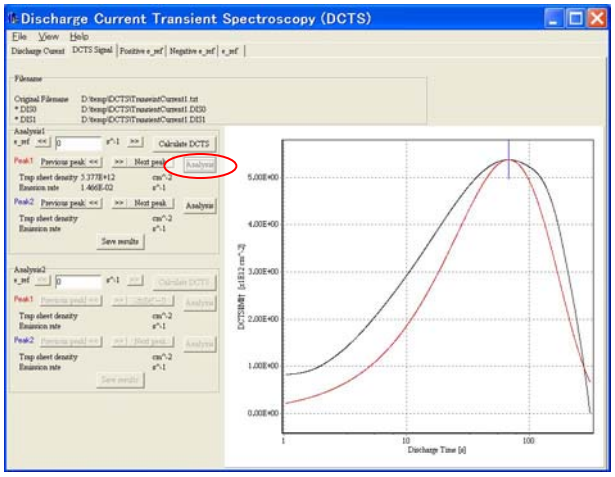
$$D(t, e_{\mathrm{ref}}) \equiv \frac{t}{qS}\left[I_{\mathrm{dis}}(t) - I_{\mathrm{leak}}(V_{\mathrm{dis}})\right]\exp\left(-e_{\mathrm{ref}} + 1\right),$$

where q is the electron charge, S is the electrode area, $I_{\mathrm{dis}}(t)$ is the transient current, $I_{\mathrm{leak}}(V_{\mathrm{dis}})$ is the steady-state leakage current at the applied voltage V_{dis}, and e_{ref} is the parameter that can shift the peak of the DCTS signal.

In the figure, e_{ref} is the selected value of $0\ \mathrm{s}^{-1}$, $I_{\mathrm{leak}}(V_{\mathrm{dis}})$ is 1.77×10^{-10} A at the longest time, which is automatically calculated.

One peak, which is denoted by “+”, appears.

14. Click the “Analysis” button.



The values of trap sheet density (N_T) and emission rate (e_T) are determined.

And also the component of the DCTS signal for this trap, which is denoted by the red line, is simulated using the obtained N_T and e_T, and the following equation.

$$D(t, e_{ref}) = N_T e_T t \exp\left[-\left(e_T + e_{ref}\right)t + 1\right] .$$

If the traps are uniformly distributed in the film, the trap density (n_T) can be calculated by

$$n_T = \frac{N_T}{d},$$

where d is the film thickness.

15. Click the “Save results” button.

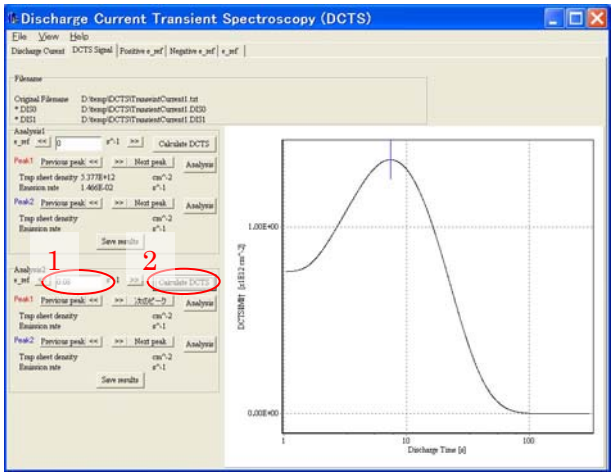
By this process, a “*.DCTS0” file is created.

C. Determination of trap sheet density and emission rate for individual e_{ref}

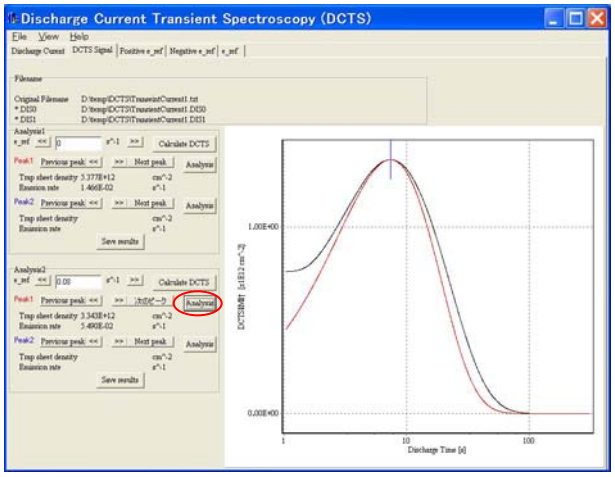
At the shorter time region shown in the above figure, the black line (experimental line) is greater then the red line, indicating that other traps with the higher emission time should be included in the film.

16. Input the value of e_{ref} on “Analysis2”, and click the “Calculate DCTS” button.

Here, $e_{ref} = 0.08\ s^{-1}$.



17. Click the “Analysis” button.

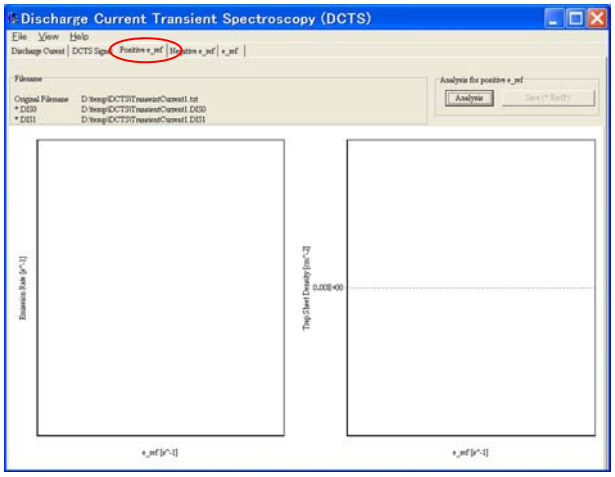


Since the emission rate is different from the trap determined previously, the trap determined using the different e_{ref} is different from the previous trap.

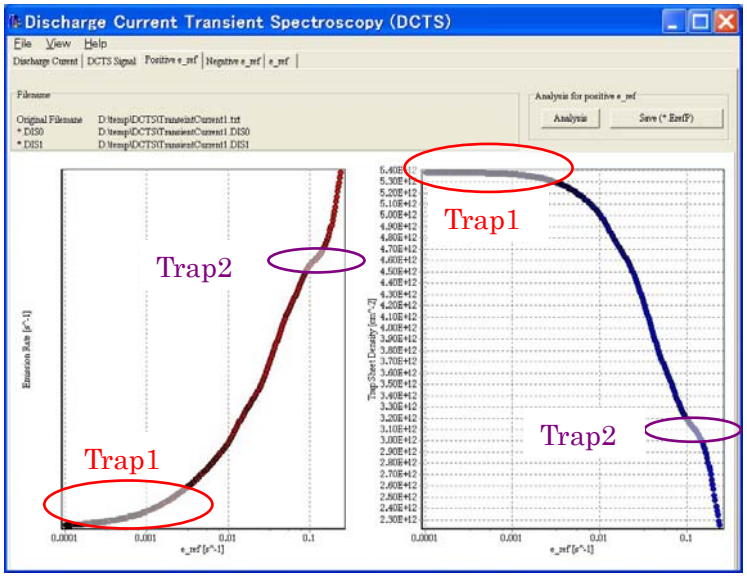
D. Search several types of trap species by changing e_{ref}

Case of positive e_{ref}

18. Click the “Positive e_ref” tub.



19. Click the “Analysis” button, and wait for a minute.



For a trap with a discrete energy level, the trap emission rate and sheet density are independent of e_{ref} .

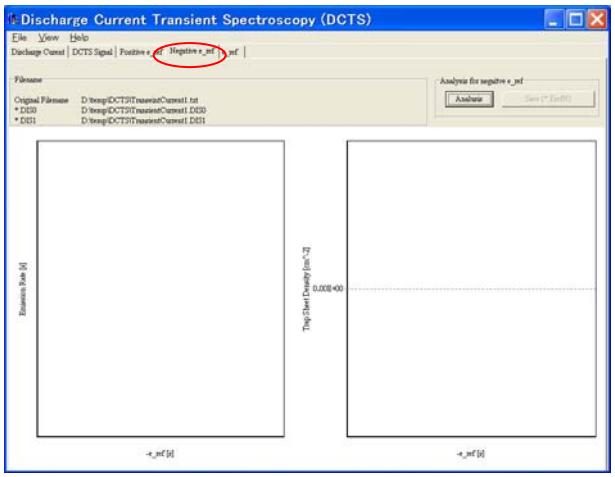
There are two plateaus in the figure, indicating that two types of trap species can be detected.

20. Click the “Save (*.ErefP)” button.

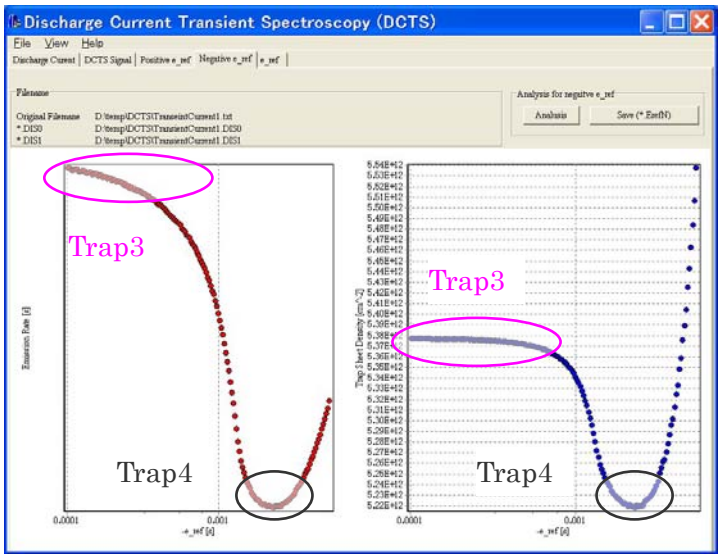
A “*.ErefP” file is created.

Case of negative e_{ref}

21. Click the “Negative e_ref” button.



22. Click the “Analysis” button, and wait for a minute.



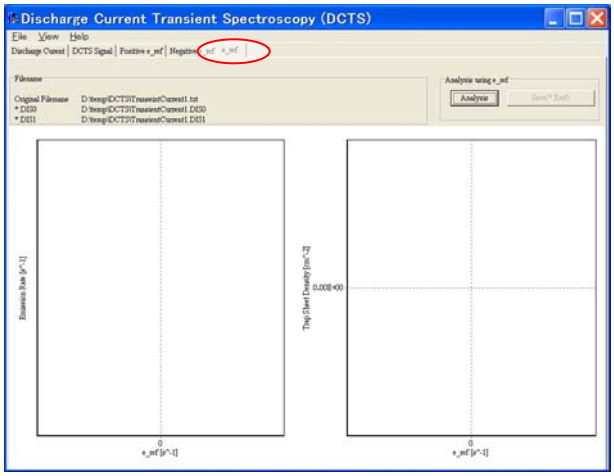
Another two types of trap species can be detected.

23. Click the “Save (*.ErefN)” button.

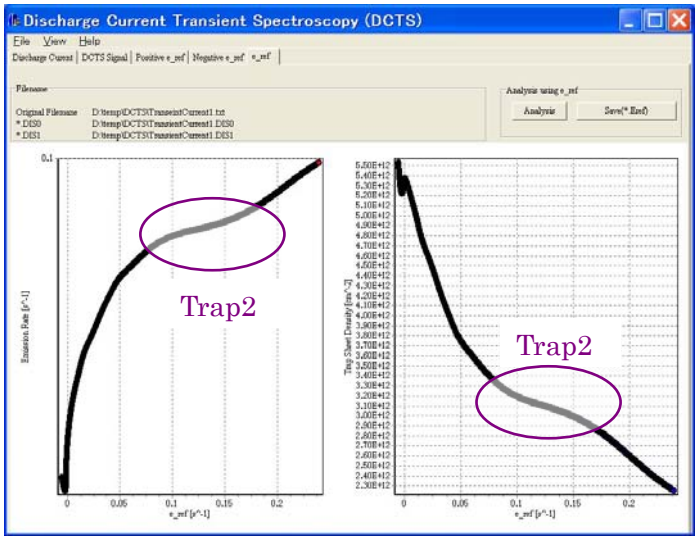
A “*.ErefN” file is created.

Case of e_{ref}

24. Click the “e_ref” tub.



25. Click the “Analysis” button, and wait for a while.



26. Click the “Save (*.Eref)” button.

    A “*.Eref” file is created.

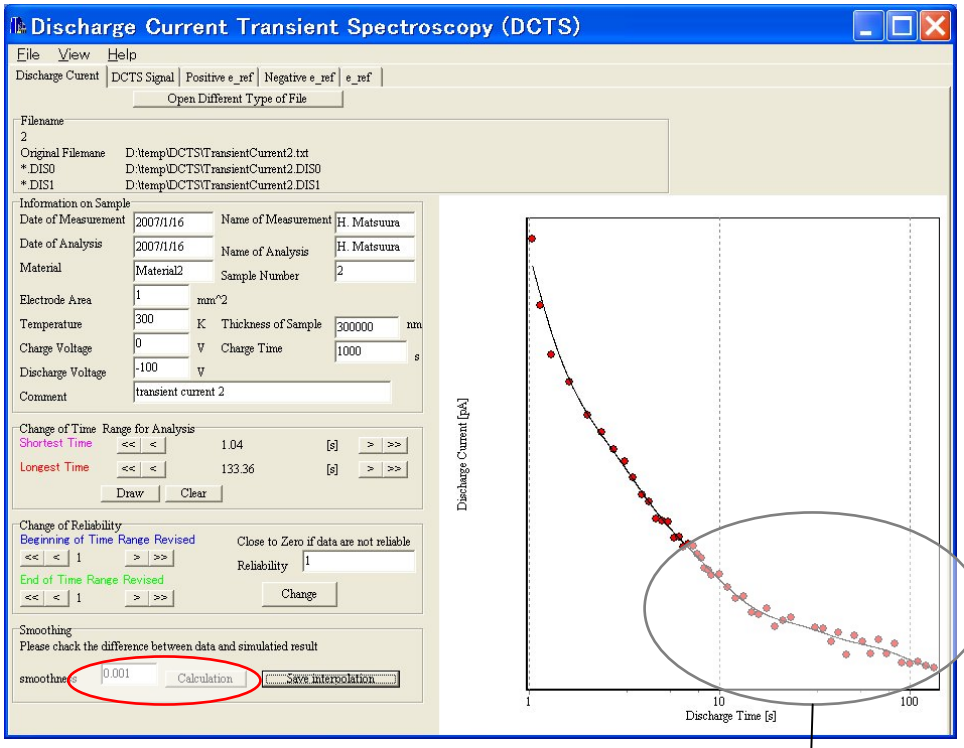
E. Results

Trap species	Sheet Density [cm^{-2}]	Emission Rate [s^{-1}]
Trap1	5.3x10^{12}	1.7x10^{-2}
Trap2	3.1x10^{12}	6.0x10^{-2}
Trap3	5.4x10^{12}	1.4x10^{-2}
Trap4	5.2x10^{12}	1.1x10^{-2}

II. Example B (TransientCurrent2.txt)

A. How to use the “Smoothing”.

1. Calculate the interpolated transient current with the “smoothness” value of 0.001.

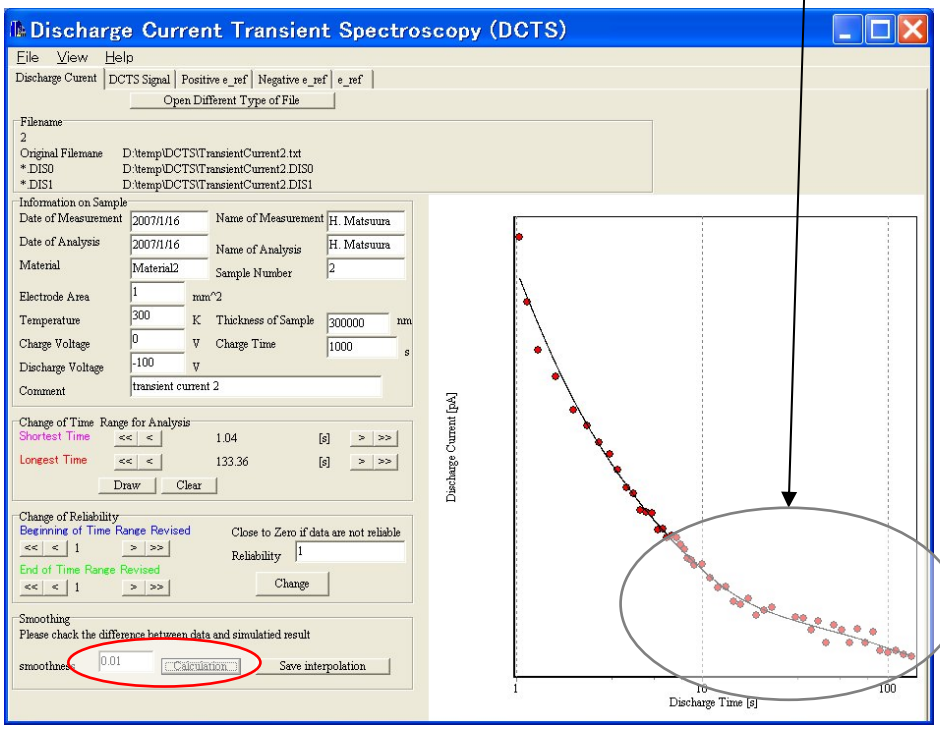


The interpolated curve denoted by the black line seems to be strongly influenced by the scatter of experimental data.

Therefore, the interpolated curve will be made smoother.

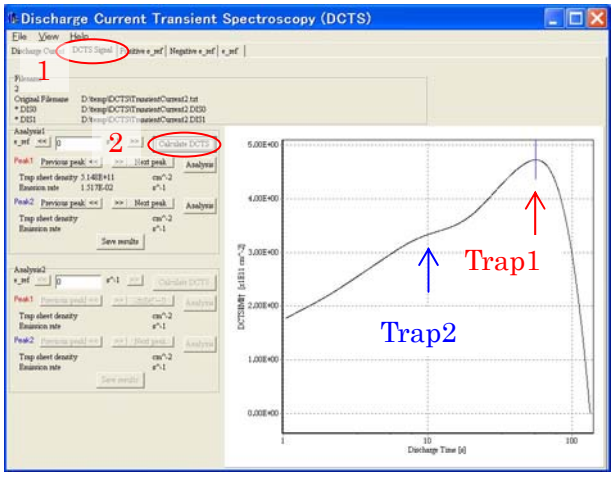
2. Change the value of “smoothness” from 0.001 to 0.01.

Click the “Calculation” button.



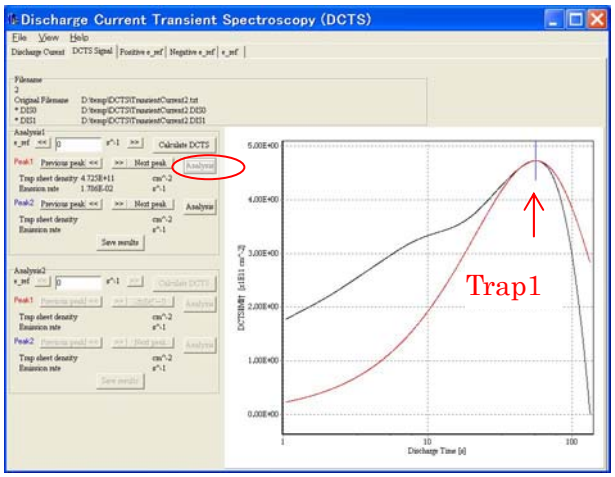
3. Click the “DCTS Signal” tub.

   Click the “Calculate DCTS” button with $e_{ref} = 0\ s^{-1}$.



   One peak and one shoulder appeared.

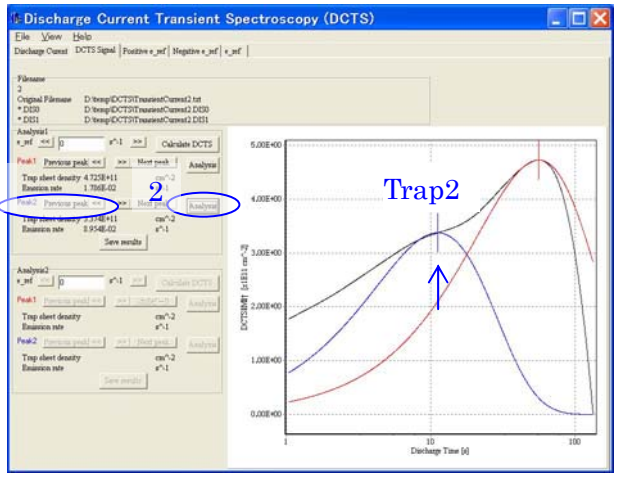
4. Click the “Analysis” button.



   The values of sheet density and emission rate of trap corresponding to the peak are determined.

   The component of the DCTS signal for Trap1 was denoted by the red line.

5. Click the “<<” button of “Previous peak” for “Peak2”, and then click the “Analysis” button.



   The values of sheet density and emission rate of trap corresponding to the shoulder (or apparent peak) are determined.

The component of the DCTS signal for Trap2 is denoted by the blue line.

Therefore, at least two types of trap species exist in this film.

6. Click the “Save results” button.

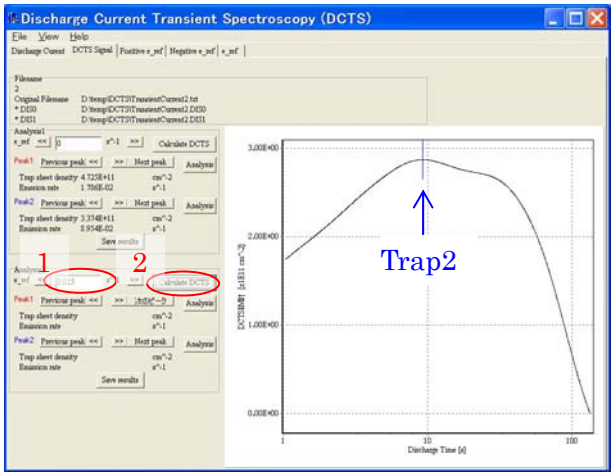
B. How to analyze the shoulder of DCTS signal.

(Relationship between the peak value and e_{ref})

When $e_{ref} = 0\ s^{-1}$, there were one peak and one shoulder in the DCTS signal.

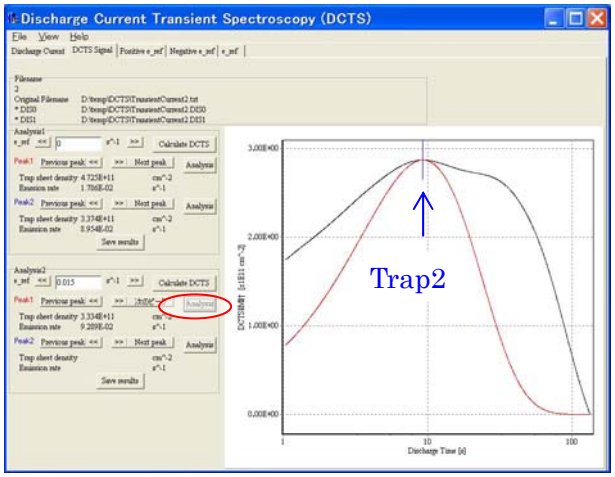
e_{ref} can change from the shoulder to a peak in the DCTS signal at around 10 s.

7. Change the value of e_{ref} on “Analysis2”, and then click the “Calculate DCTS” button.



When $e_{ref} \geq 0.015\ s^{-1}$, the shoulder at $e_{ref} = 0\ s^{-1}$ is changed to a peak, while the peak at $e_{ref} = 0\ s^{-1}$ is changed to a shoulder.

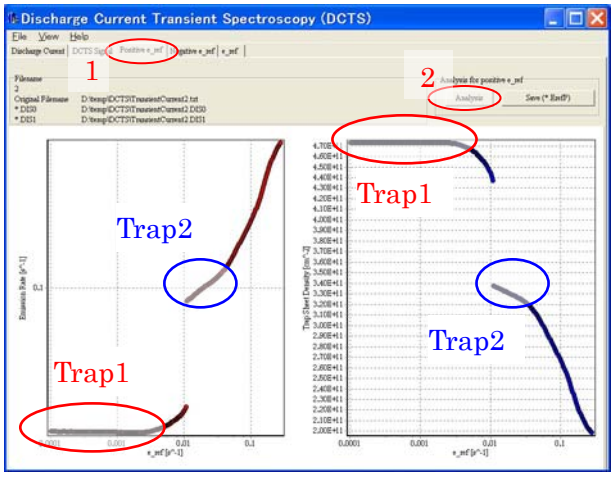
8. Click the “Analysis” button.



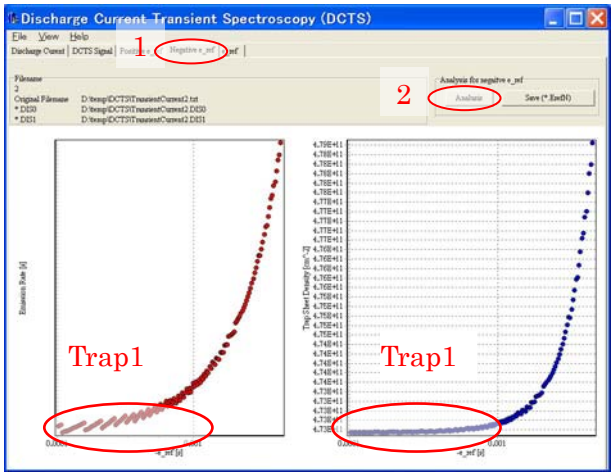
The values of sheet density and emission rate of trap corresponding to the peak are determined.

The component of the DCTS signal for Trap2 is denoted by the red line.

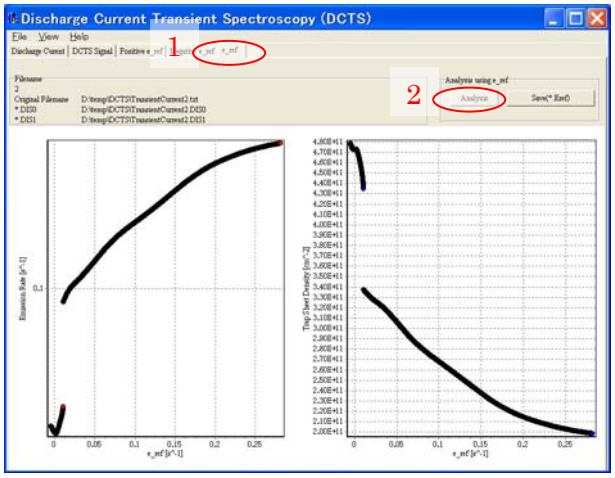
9. Click the “Positive e_ref” tub, and click the “Analysis” button.



10. Click the “Negative e_ref” tub, and click the “Analysis” button.



11. Click the “e_ref” tub, and Click the “Analysis” button.



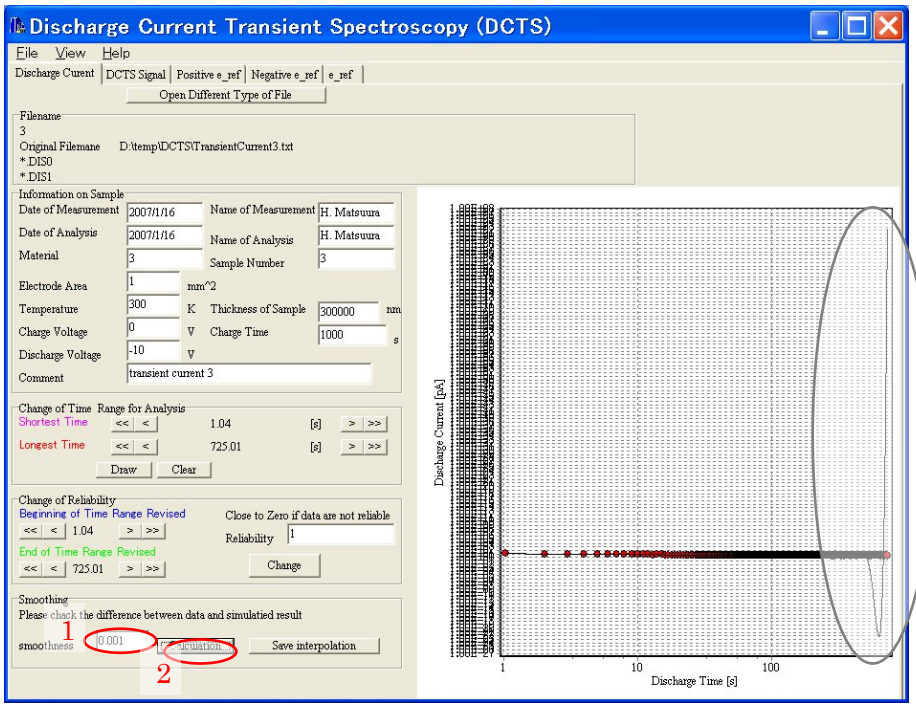
Results

Trap Species	Sheet Density [cm^{-2}]	Emission rate [s^{-1}]
Trap1	4.7×10^{11}	1.8×10^{-2}
Trap2	3.3×10^{11}	1.0×10^{-1}

III. Example C (TranseintCurrent3.txt)

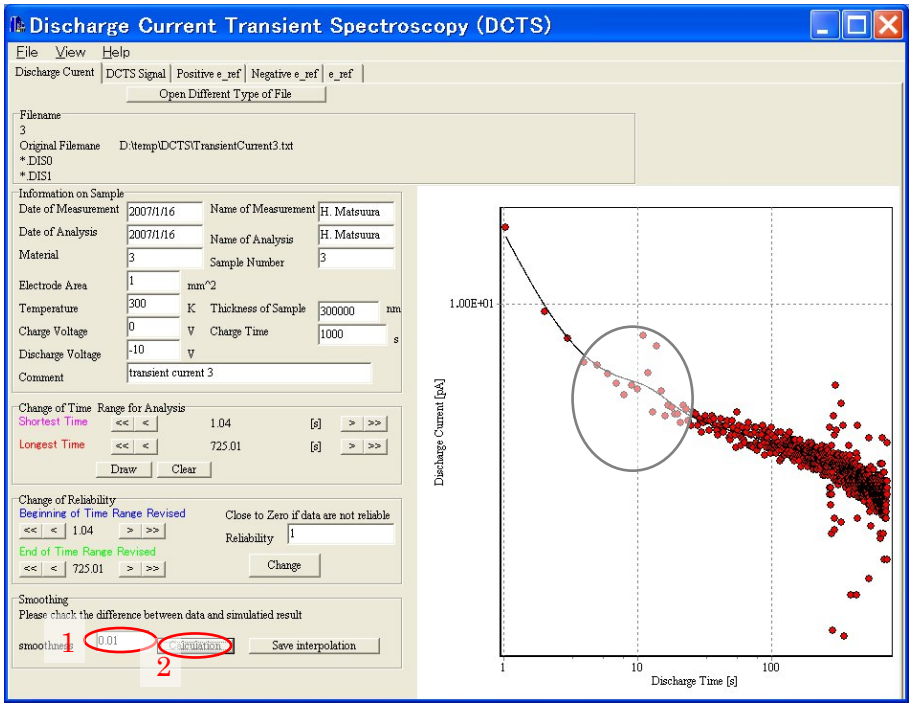
A. How to change reliabilities of individual data

1. Click the “Calculation” button with the “smoothness” value of 0.001.



Because of too small “smoothness” value, it is difficult to obtain the reasonable interpolated transient current.

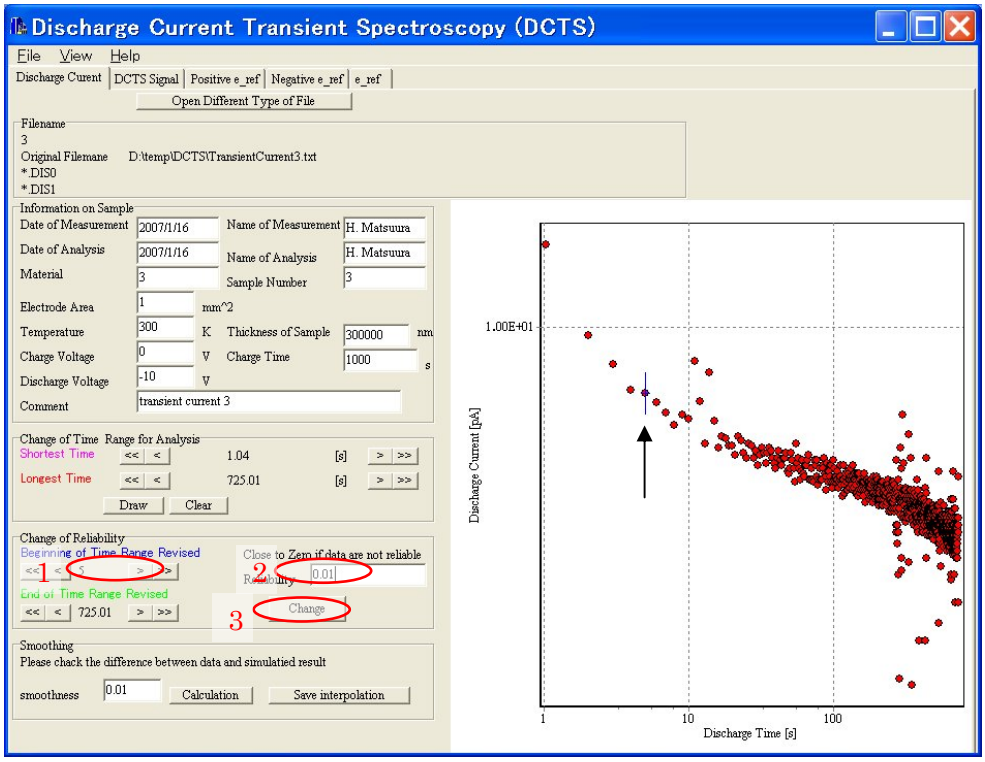
2. Change the “smoothness” value to 0.01, and then click the “Calculation” button.



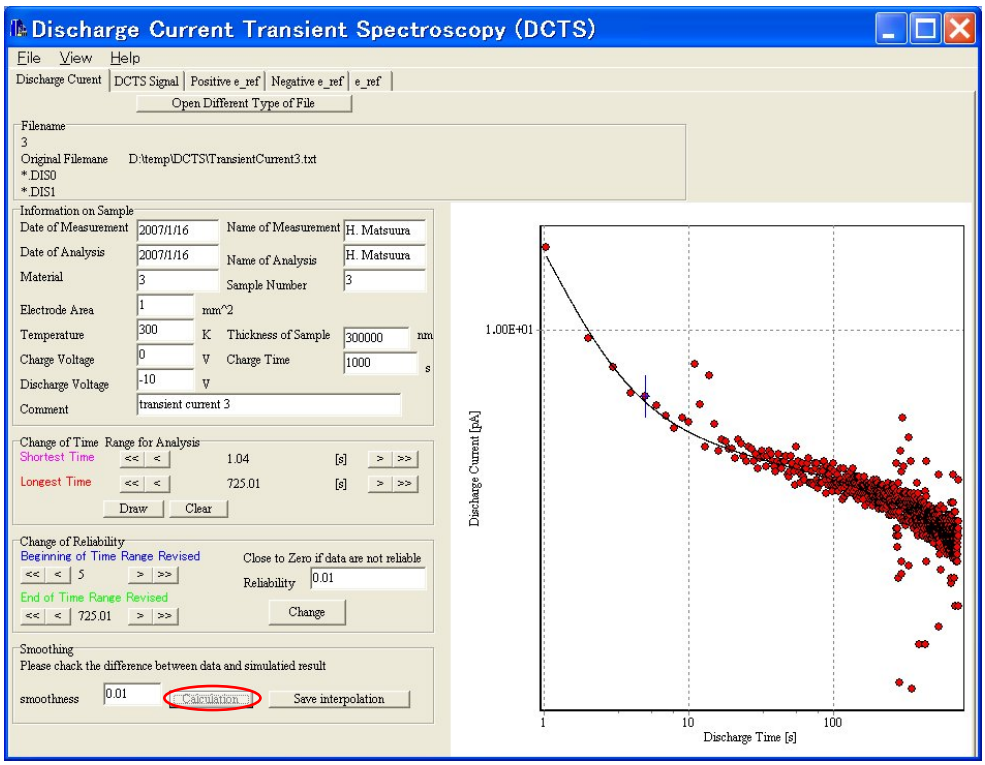
Since the experimental data longer than 10 s are not reliable, the interpolated line was strongly affected by the scatter of experimental data. For example, the line shows the shoulder at approximately 10 s.

The reliabilities of data longer than 5 s will be changed from 1 to 0.01.

3. Click the ">" button of "Beginning of Time Range Revised", and move "+" to the time at which you want. Here, 5 s was selected.
   Change the value of "Reliability" to 0.01, and then click the "Change" button.



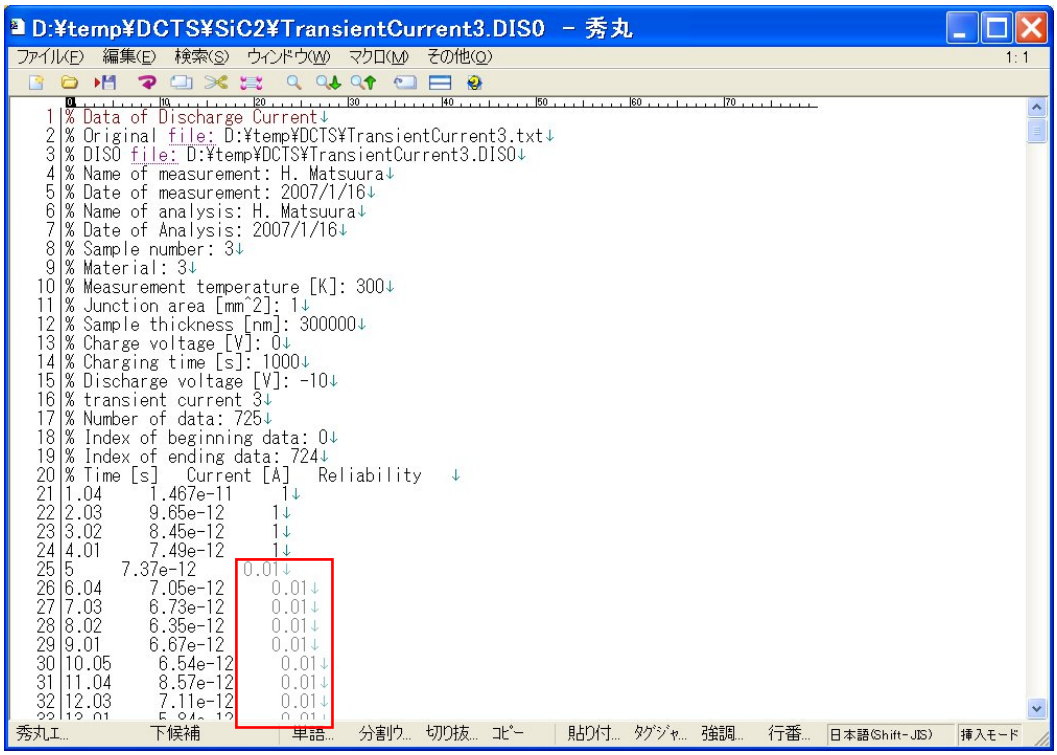
4. Click the "Calculation" button.



The reliable interpolated transient current can be obtained.

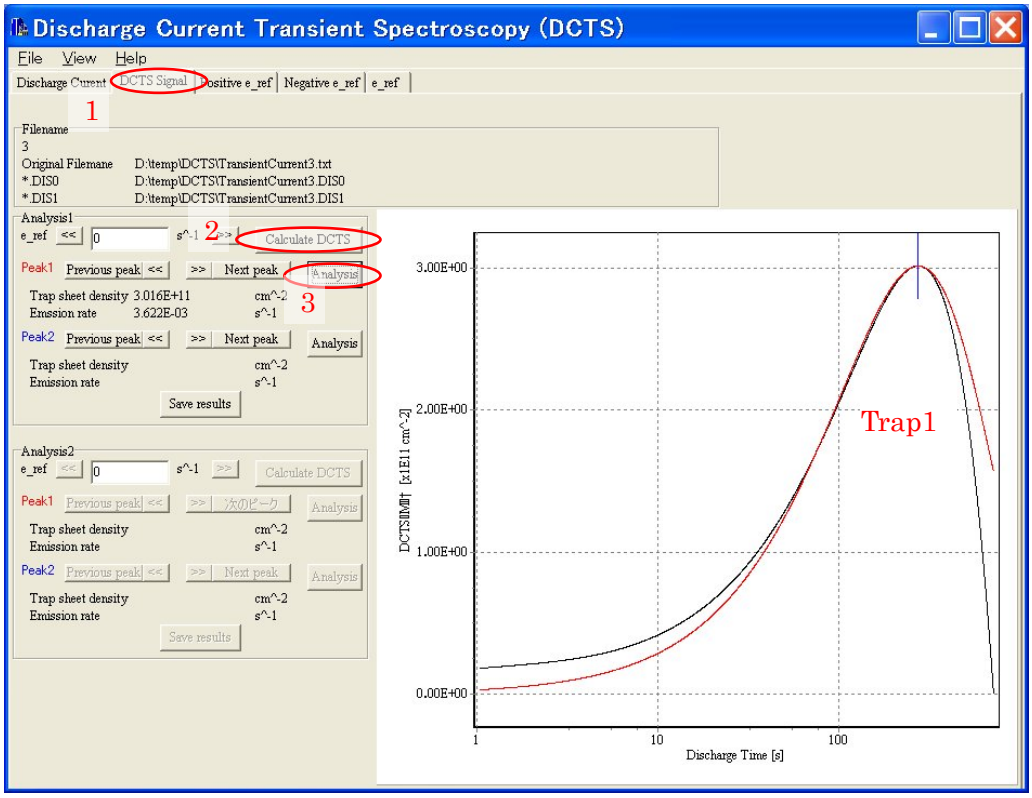
Note: You can also revise the reliabilities of data directly on the text of the "*.DIS0" file.

After revision, load this file using "File" -> "Load *.DIS0" menu.



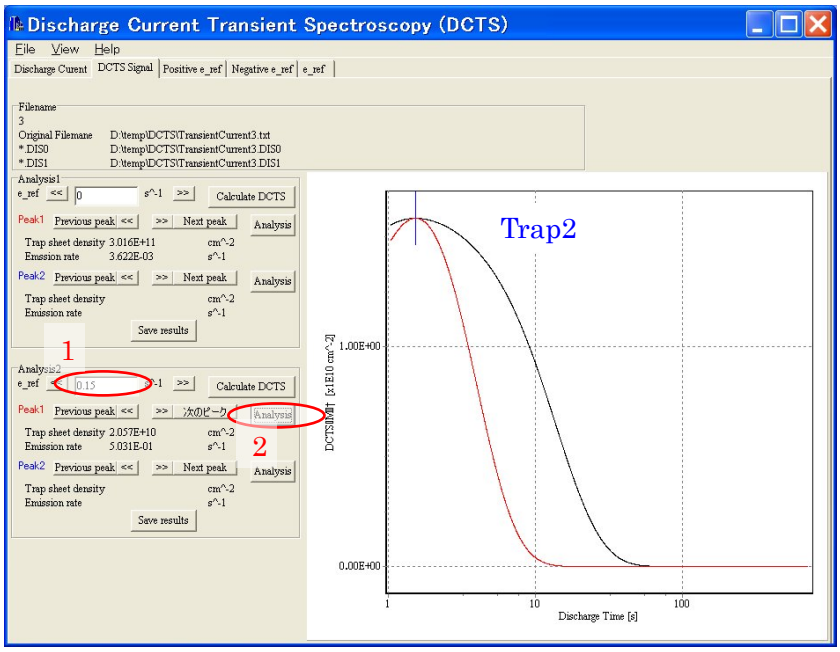
5. Click the "DCTS Signal" tub, and then click the "Calculate DCTS" button with $e_{ref} = 0\ s^{-1}$.

Click the "Analysis" button.



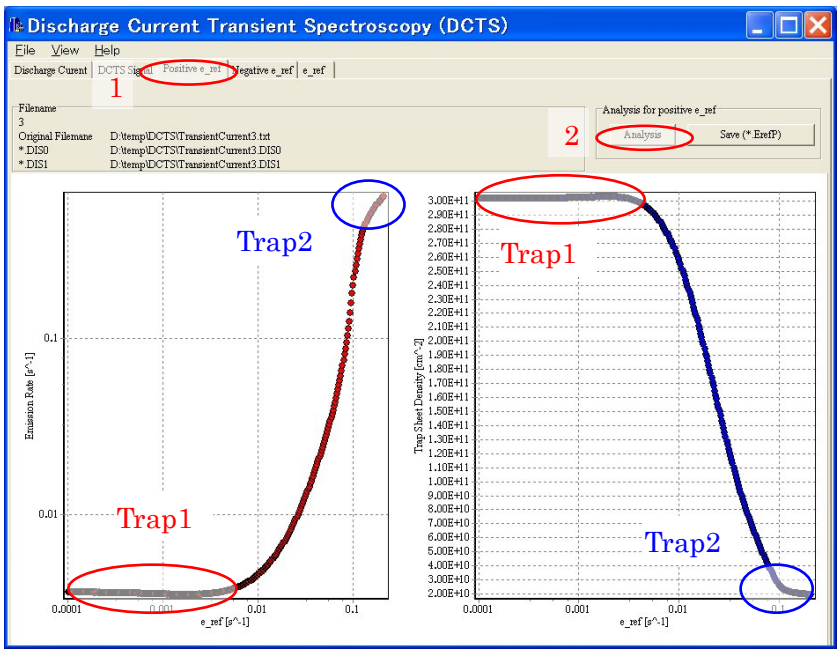
6. Click the "Save results" button.

7. Change the e_{ref} value to $0.15\ s^{-1}$, and then click the “Calculate DCTS” button.



The other trap can be detected.

8. Click the “Positive e_ref” tub, and then click the “Analysis” button.



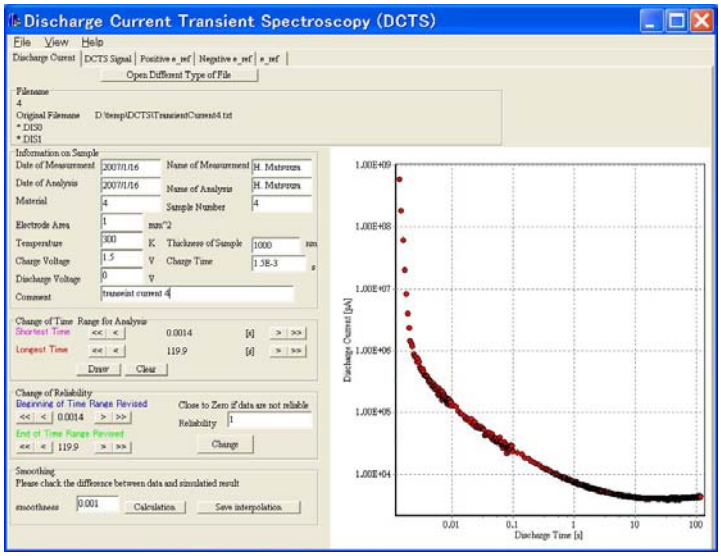
Results

Trap Species	Sheet Density [cm^{-2}]	Emission Rate [s^{-1}]
Trap1	3.0×10^{11}	3.6×10^{-3}
Trap2	2.0×10^{10}	6.2×10^{-1}

IV. Example D (TransientCurrent4.txt)

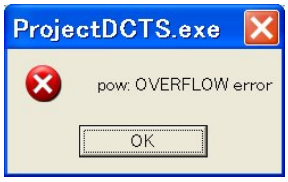
A. How to divide into analysis time regions

1. Load the data.



2. Click the “Calculation” button.

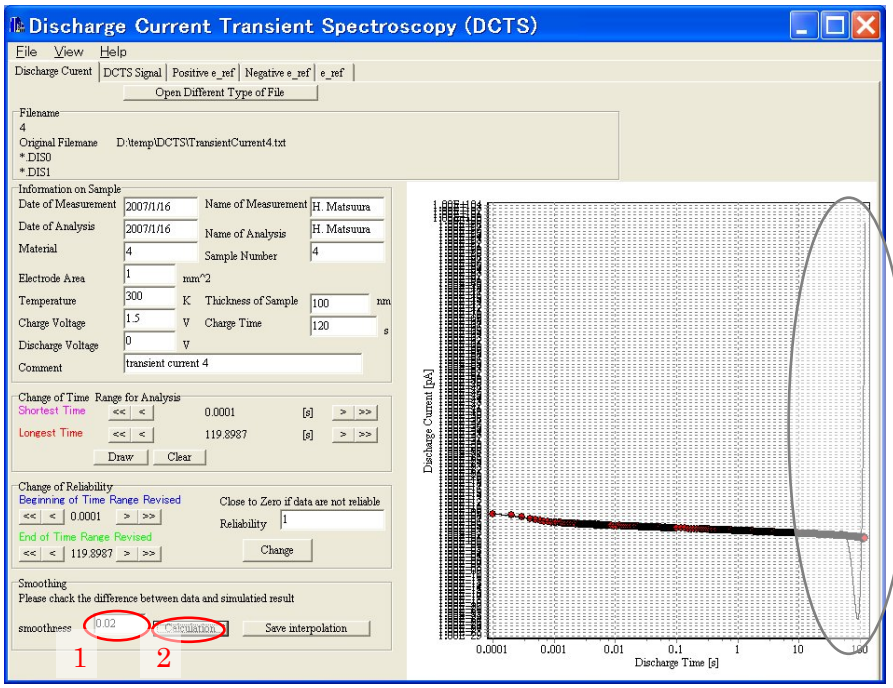
   The overflow under calculation occurred, and the alarm dialog appears.



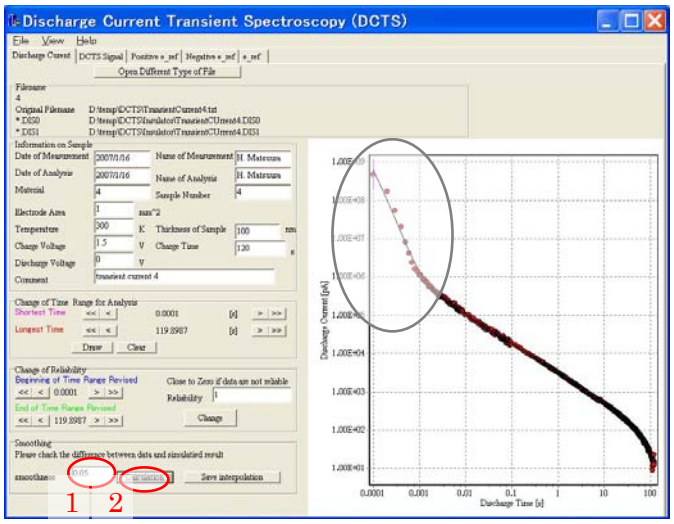
3. Open the “Windows Task Manager” (click “Alt”+”Ctrl”+”Delete” buttons simultaneously).

   Finish the DCTS program.

4. Change the “smoothness” value to 0.02, and then click the “Calculation” button.



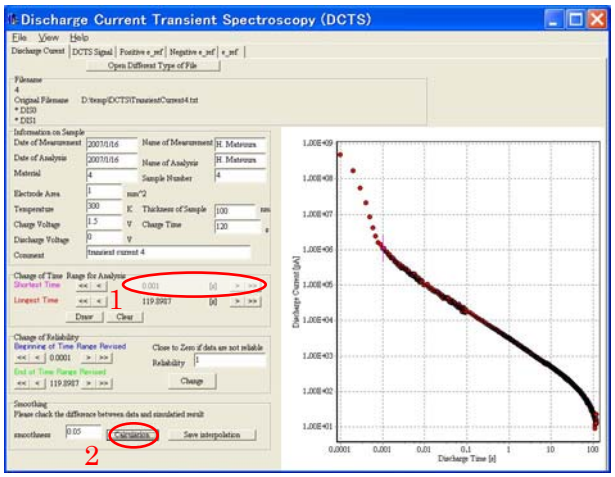
5. Change the “smoothness” value to 0.05, and then click the “Calculation” button.



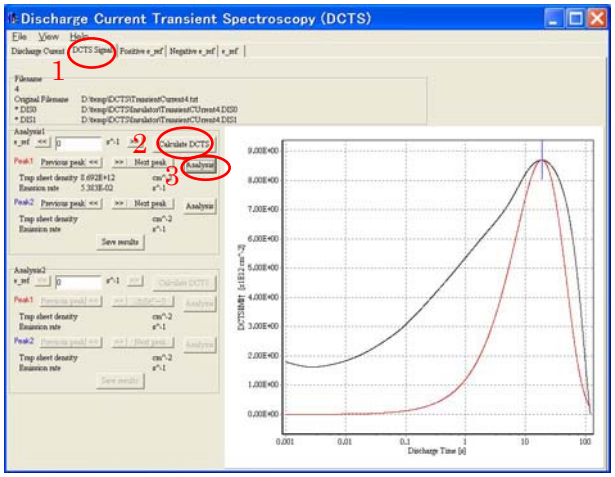
It is difficult to fit the interpolated curve to the experimental data at shorter than 0.001 s. Therefore, the analysis time region will be divided into two regions (0.0001 s < t <0.001 s and 0.001 s<t<100 s).

Longer time region

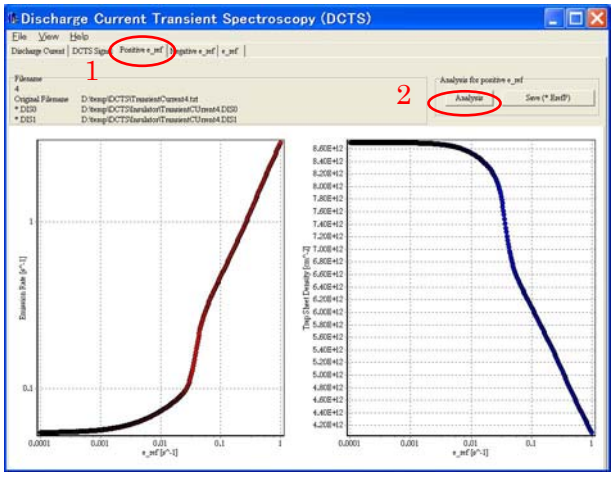
6. Click the “>” button for “Shorter Time” on “Change of Time Range for Analysis”, and then click the “Calculation” button.



7. Click the “DCTS Signal” tub, and then click the “Calculate DCTS” button.
Click the “Analysis” button.

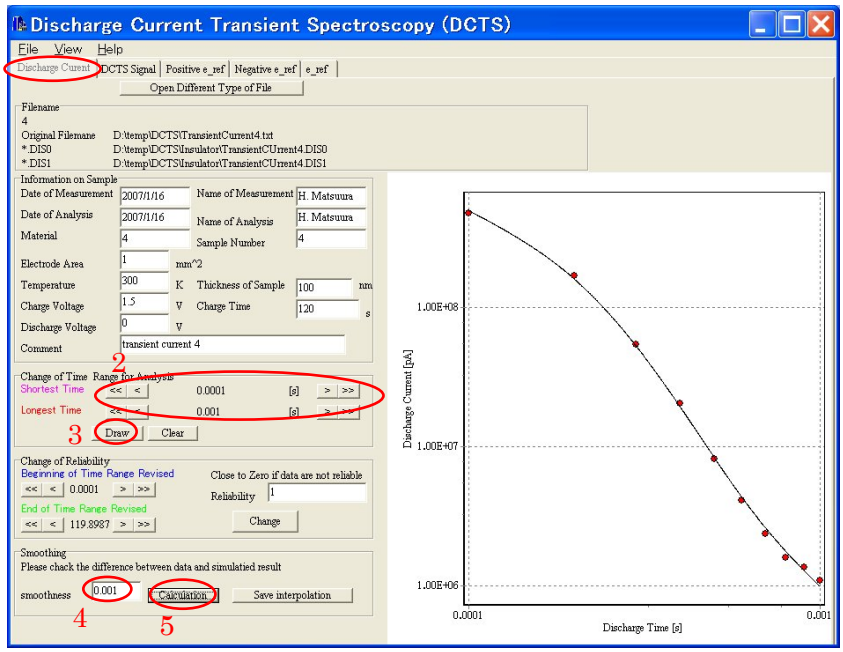


8. Click the “Positive e_ref” tub, and click the “Analysis” button.

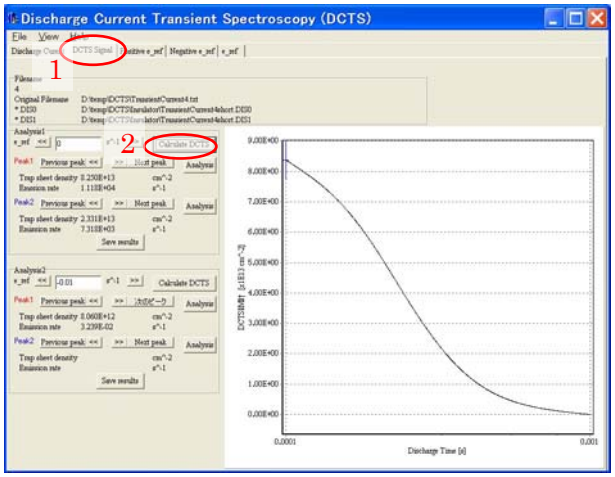


Shorter time region

9. Click the “Discharge Current” tub, and then change the analysis time region.
   Click the “Calculation” button.



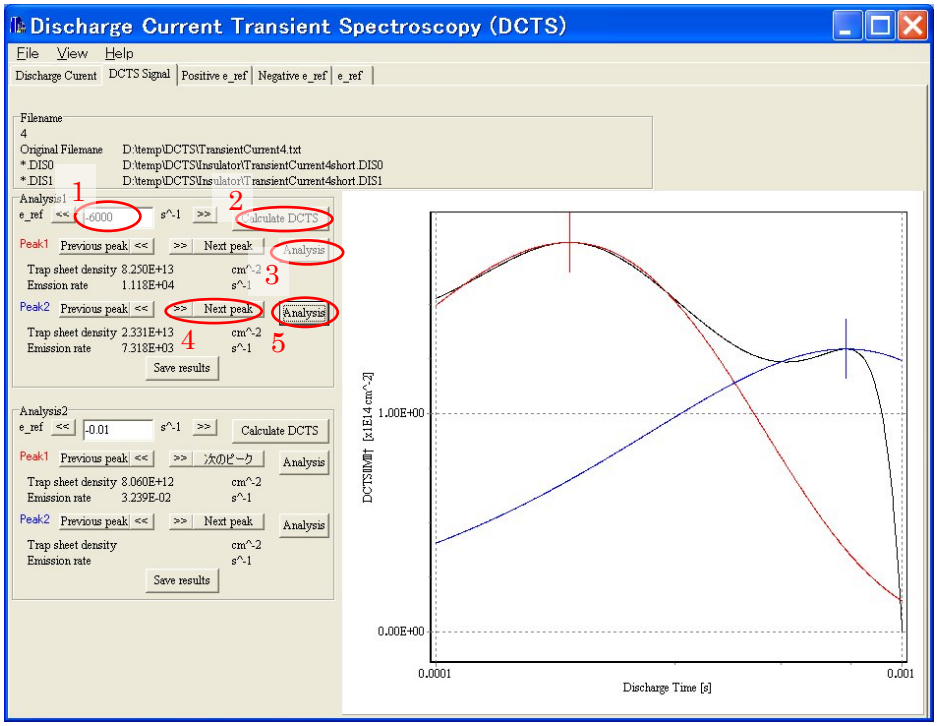
10. Click the “DCTS Signal” tub, and then click the “Calculate DCTS” button.



11. Input the e_{ref} value of $-6000\ \mathrm{s}^{-1}$, and then click the “Calculate DCTS” button.

Click the “Analysis” button.

Click the “>>” for “Peak2”, and click the “Analysis” button.



Two types of trap species can be detected in the shorter time region.