CSCanada
Energy Science and Technology
Vol. 5, No. 2, 2013, pp. 57-62
DOI:10.3968/j.est.1923847920130502.3187

ISSN 1923-8460[PRINT]
ISSN 1923-8479[ONLINE]
www.cscanada.net
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Analysis of Normal and Infected Bio-Cell Using Dual Nanoprobe

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Received 04 January 2013; accepted 17 March 2013

Abstract
The objective of this paper is to analyze the yeast cell, liver cell and blood cell under both infected and healthy conditions by applying electrical signal through dual nanoprobe from source to cell. Knowledge of nanoprobe based bio-cell analysis can be used to differentiate infected cells from healthy ones, since their electrical behaviour is different. The voltage can be applied either inside the cytoplasm penetrating the cell wall, or at the outer surface of cell membrane. In this paper, the simulation has been carried out by applying voltage inside the cytoplasm using ABAQUS 6.10 CAE, powerful finite element software and the results obtained from simulation shows current flow healthy yeast and dead yeast cells are 1·9nA and 34pA respectively whereas the value of the current measured for the leukaemia affected blood cell is 21·2nA, being 2% less than the White Blood Cell (WBC). Since the conductivity of the cytoplasm of the healthy cell is theoretically higher than that of dead or infected cell, which is verified by simulation. The results from simulation show that the measured cell current from liver tumour cell is 2-7 times larger than healthy liver cell including membrane as it is supposed to be since the conductivity of cell including cell membrane is theoretically greater for dead or infected cell than healthy cell.

Key words: Dual nanoprobe; Cell viability test; Yeast cell; WBC; Liver cell; Axon cell; ECD; ABAQUS 6.10 CAE; Electrical conductivity

Akter Hossain, Mohammad Shafkat Islam, Hedayet Ullah (2013). Analysis of Normal and Infected Bio-Cell Using Dual Nanoprobe. *Energy Science and Technology, 5*(2), 57-62. Available from: http://www.cscanada.net/index.php/est/article/view/j.est.1923847920130502.3187.
DOI: http://dx.doi.org/10.3968/j.est.1923847920130502.3187.

INTRODUCTION
Nanoprobe based bio-cell analysis method introduces the cell analysis in nanotechnology, a new field of science. In the analytical procedure, a single cell is analysed by measuring the current through the cell by the application of a dc voltage using dual nanoprobe. ABAQUS 6.10 CAE, powerful finite element software has been used to carry out the simulation. Figure 1 shows schematic diagram of penetration of dual nanoprobe into the cell. Figure 2 shows only contact of dual nanoprobe with cell membrane.

Among various electrical behaviours shown by bio-cell, two are taken into account for cell analysis. One is conductivity of cytoplasm and another is conductivity of the cell including cell membrane.

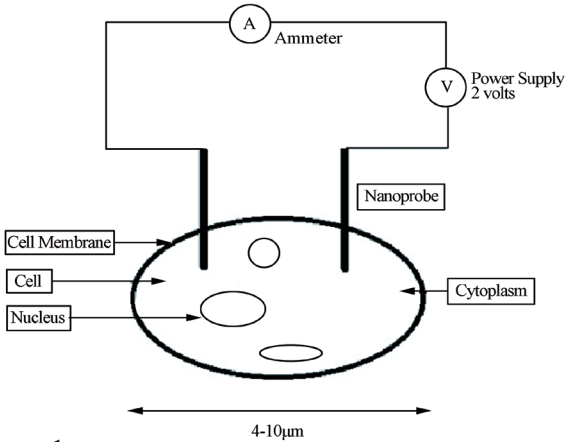

Figure 1
Schematic Diagram on Penetration of Dual Nanoprobe into a Cell [1]

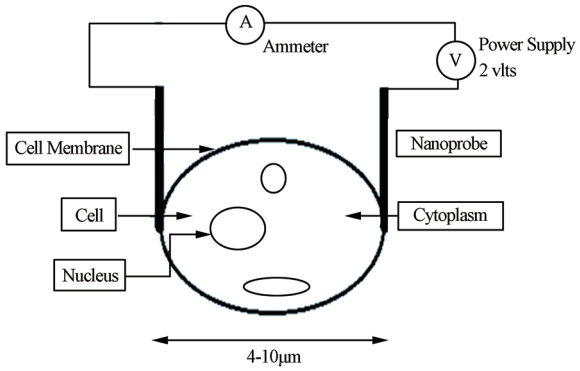

Figure 2
Schematic Diagram of Edge Contact of Dual Nanoprobe into a Cell (Ingebrandt et al. 2007)

The cytoplasm conductivity of cancerous or infected cell is lower than that of healthy cell. Because when the cell is dead or cancerous, the ions concentrations become lower than healthy cell (Ingebrandt 2007). On the other hand, the conductivity of cell including membrane shows higher conductivity in case of cancerous or infected cell than that of healthy one, because when the cell becomes cancerous the permeability of the cell increases causing more current to flow into the cell. (Steve Haltiwanger, Sahu, 2005; Tandon, 2012). The membrane composition in cancer cells gets altered and higher permeability results in movement of K, Mg and Ca out of the cell. The accumulation of Na and water results in flowing of more into the cell, hence current is higher.

The conventional method of cell viability and cancer detection is done by using chemical substances (Sulaiman, 2012). Colorimetric or florescent dyes are used for cell viability detection. The limitation of this method is the lack of capability to produce instantaneous and quantitative result but nanoprobe based cell analysis method is much better in terms of producing instantaneous and quantitative result (Sulaiman, 2012).

Bone marrow aspiration is a conventional type of biopsy used to diagnose leukemia. In open biopsy, the bone is taken out and stiches are given to the patient for which he may experience bleeding and has to stay at hospital. Nanoprobe testing provides better method for leukemia detection.

1. METHODOLOGY

For the purpose of analysis a dual nanoprobe is needed to apply electrical power to the bio-cell. From figure 1 the one end of nanoprobe has to be connected with 2V dc source and the other ends of nanoprobe have to be penetrated into the cell wall for both yeast and blood cell (figure 1) or have to be in close contact with the cell membrane for liver cell (figure 2). When power supply is switched on a current flow occurs through the cell. The power is supplied only for 0.1 second to protect the cell from damage.

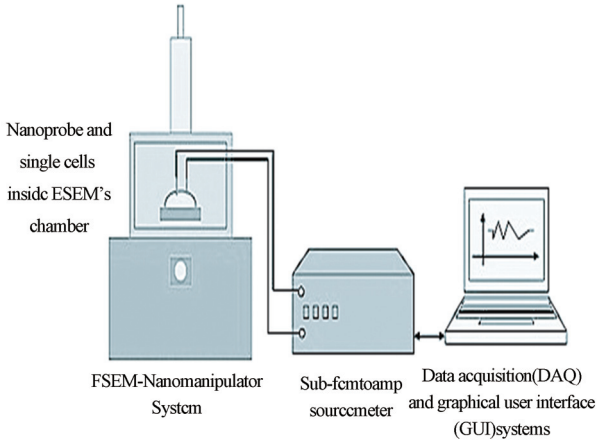

Figure 3
Experimental Setup (Sulaiman, 2012; Ahmad, 2009)

1.1 Experimental Method

The cell is analyzed with ESEM-Nano-manipulator System shown in figure 3. The output current is measured by Sub-femto ampere source meter and the analog current value is converted into digital by data acquisition (DAQ). This digital data is then represented by graphical user interface (GUI) system.

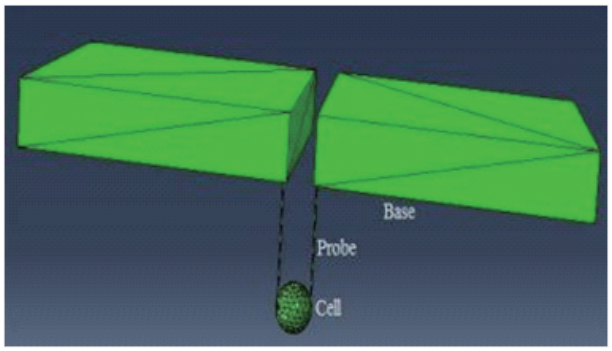

Figure 4
Simulation Setup

2. SIMULATION PROCEDURE

For the purpose of simulation ABAQUS 6.10 CAE (Computer Aided Engineering) software is used that provides strong platform to design and simulate any type. It has the ability for use in nano-scale level simulation.

The major part of the study is to characterize the nanoprobe based on the types of material, cross sectional area and length of probes. Resistance of the probe is one of the most important factors. Among different materials which can be used for the construction of the probe, the material with low resistance and no chemical reaction effect on the cell is the best choice. The size of nanoprobe used for simulation is 15μm long and 200nm x 200nm cross-sectional area and the probe is made of gold. Different mechanical and electrical properties are given to gain a model, which is seemed to be as close as real cell.

3. SIMULATION RESULTS

The current flow through the cells is represented by Electric Current Density (ECD) shown in figure 6. The output current is found by the product of average cross-sectional area of cell and average electrical current density (ECD) value.

$$I = ResultantECD \times A$$

Where, I = Current, A = Cross-sectional Area of cell.

Figure 5 represents the electric current density (ECD) for different cell model. The resultant ECD magnitudes are 268pA/μm^2, 4.8pA/μm^2, 162.6pA/μm^2, 443.4pA/μm^2, 3.037nA/μm^2 and 3.0nA/μm^2 for healthy, dead, normal liver, liver tumor, white blood and leukemia affected white blood cells respectively in figure 6.

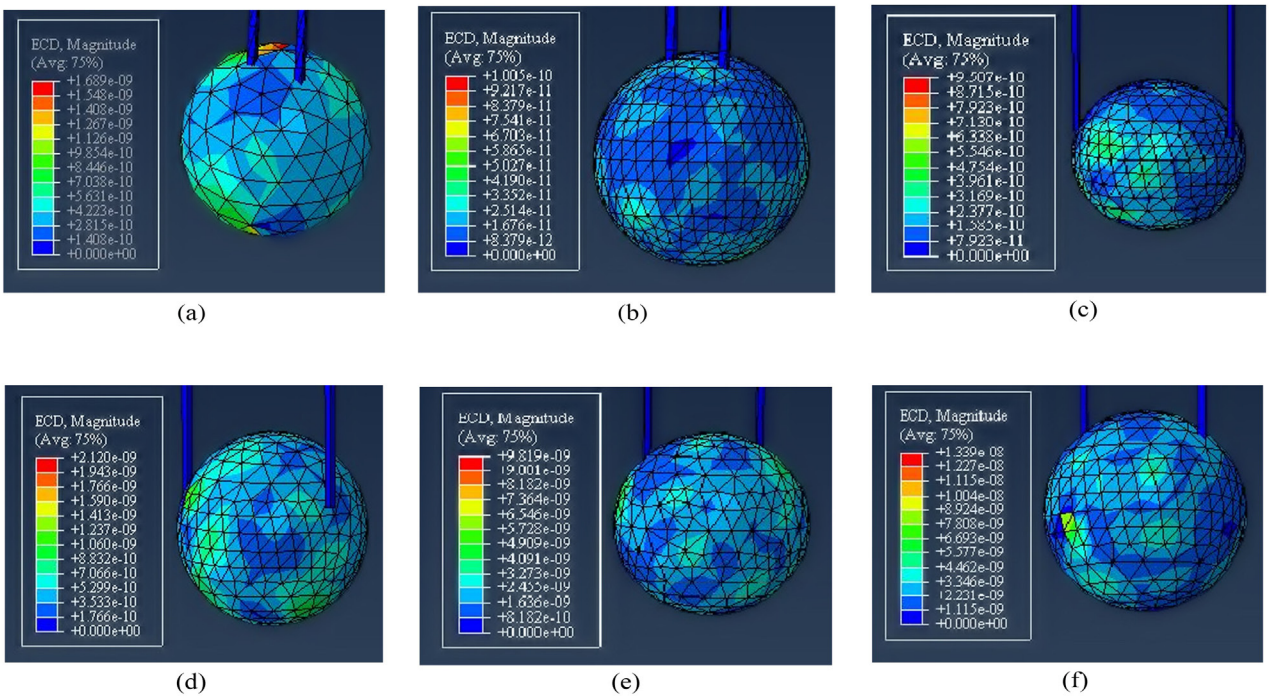

Figure 5
ECD Value for Different Cell Model. (a) Healthy Yeast Cell, (b) Dead Yeast Cell, (c) Liver Cell, (d) Liver Tumour Cell, (e) White Blood Cell, (f) Leukaemia Affected WBC Cell

By using resultant ECD magnitudes from figure 6 a current that flows through the cell can be drawn from (1).

From figure 7(a) the current values are 1.9nA and 34pA for healthy and dead cells, from figure 7(b), 1.1486nA and 3.1327nA for liver and liver tumor cells and from figure 7(c) 21.457nA and 21.2nA for WBC and leukemia affected WBC.

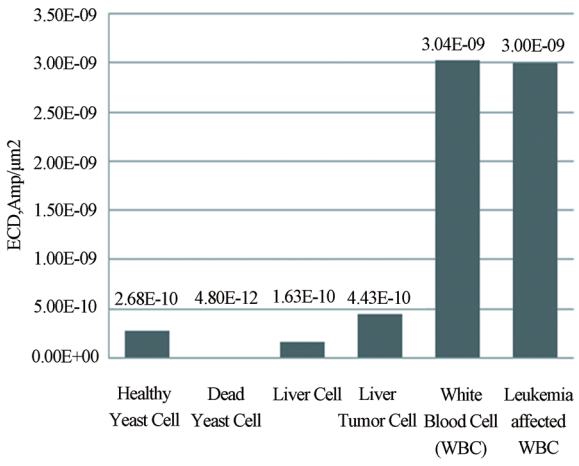

Figure 6
Average ECD Value from Different Cell Simulation

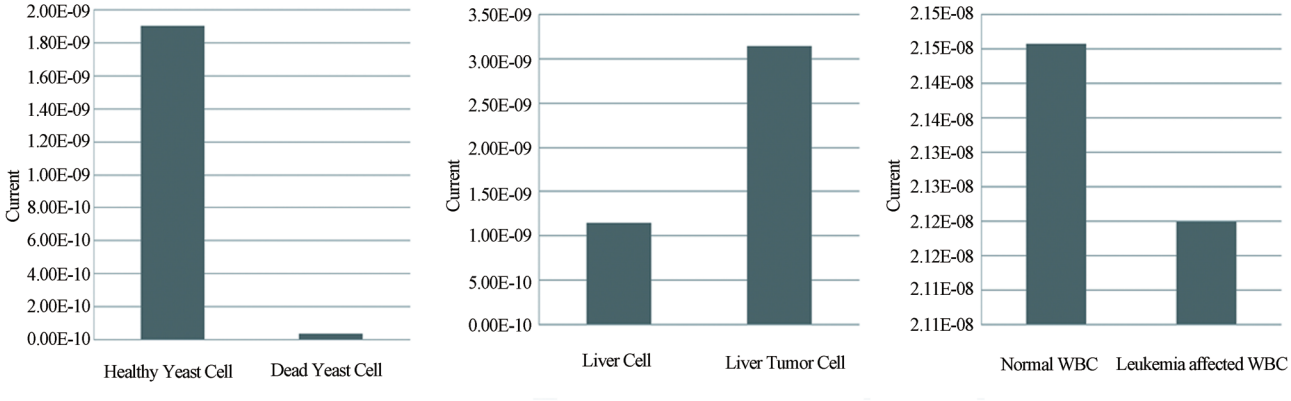

Figure 7
Values of Current (in S.I unit) for (a) Healthy Yeast Cell and Dead Yeast Cell, (b) Liver Cell and Liver Tumor Cell, (c) Normal WBC and Leukemia Affected WBC

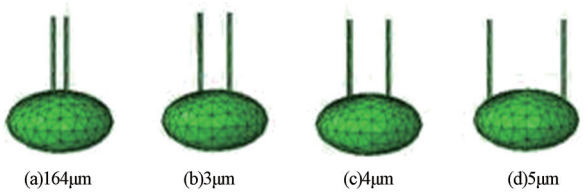

Figure 8
Different Probe Gap Distanc

3.1 Probe Gap

The simulation has been carried out for five different gap distances. Table 1 shows the results of the simulation for each gap distance and its corresponding current value for Normal WBC, Leukemia affected WBC, Healthy Yeast Cell, and dead Yeast cell. Fixed variables are the material for the probe and the penetration depth of probe into the cell. Figure 8 shows different probe gap.

Table 1
Chart of ECD and Current for Normal WBC, Leukemia Affected WBC, Healthy Yeast Cell and Dead Yeast Cell for Different Probe Gap

Distance (µm)	Normal WBC		Leukemia affected WBC		Healthy yeast cell		Dead yeast cell	
	ECD (A/µm^2)	Current (A)	ECD (A/µm^2)	Current (A)	ECD (A/µm^2)	Current (A)	ECD (A/µm^2)	Current (A)
1.64	4.99636E-10	1.366E-8	4.93928E-10	1.35E-8	2.00089E-10	5.49E-9	1.04125E-9	1.989E-10
3	3.21016E-9	7.849E-8	1.86454E-9	4.558E-8	5.00222E-10	1.22E-8	4.83929E-9	1.2E-9
4	3.20042E-9	6.9E-8	2.41974E-9	5.384E-8	1.20053E-9	2.59E-9	6.98492E-9	1E-9
4.5	4.9997E-10	9.737E-8	2.62527E-9	5.11E-8	2.16949E-9	4.2E-8	5.93147E-9	1.447E-9
5	3.63876E-9	6.21E-8	1.39704E-9	2.38E-8	1.26547E-9	9.3E-8	3.95127E-9	6.2E-10

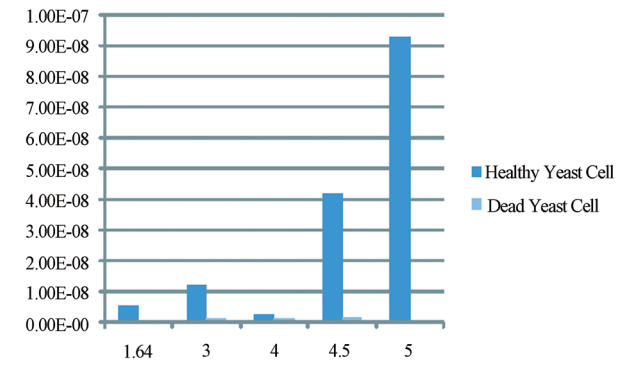

Figure 9
Current Values (in S.I Unit) Representation for Healthy and Dead Yeast Cell for different Probe Gap

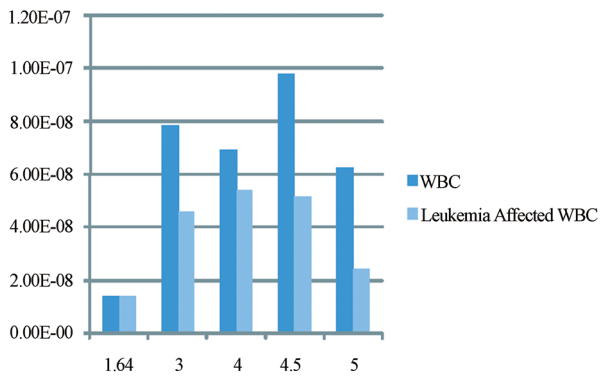

Figure 10
Current Values (in S.I Unit) Representation for WBC and Leukemia Affected WBC

Figures 9 and 10 both are representing the value of current for healthy and dead yeast cell and for WBC and leukemia affected WBC at different probe gap.

From the results obtained in simulation, the relationship between the probe gap and current is uncertain, because of various contact area between the cell and the probe. The cell has uneven surface which affect the contact area with the probe and the probe tip, being unable to provide a constant contact area with the cell. Hence, re-designing the probes to make them sharp to the point could provide better results, which is very difficult to fabricate.

CONCLUSION

Table 2 and table 3 show the comparison among experimental data, simulation result obtained from reference paper and present simulation done in this analysis. The probe gap was taken 1.46μm for penetration.

Table 2
Comparison of Experimental and Simulation Results

Types of Cell	Experimental Result with 2V Supply	Simulation Result Obtained from Reference Paper with 2V Supply	Present Simulation Result with 2V Supply
Healthy (yeast cell)	262pA current	54mA current	1.9nA current
Dead (yeast cell)	2pA current	0A current	34pA current

Table 3
Comparison of Experimental and Simulation Results for Nanoprobe Resistance and Sensitivity

Properties	Experimental Result	Simulation Result Obtained from Reference Paper	Present Simulation Result
Resistance, Ω	1k	37.46	107.2
Sensitivity,mA/V	1	27.6	9.3

Sensitivity is considered as linear function for this simulation. This simulation result is 9.3 times sensitive of experimental result and is more accurate than the results obtained from reference paper. The test may give perfect result if the cells are tested in same environment, keeping same probe gap and same depth of penetration because the conductivity between probes across the cell may vary with probe gap, depth of penetration and environmental condition surrounding the cell. More than one sample of blood cell having WBC should be tested for better confirmation of the presence of immature WBC as the conductivity difference between normal WBC and leukemia affected WBC is only 2%.

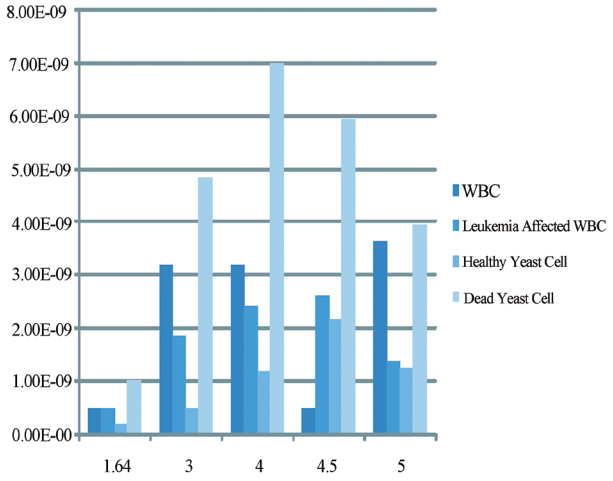

Figure 11
The ECD Value at Different Probe Gap for Different Types of Cells

This dual Nano probe based analytical process may have better opportunities, when it will be practically implemented. For detection of healthy, death and cancerous cells (leukemia), this process may give instantaneous and better results. This project is only a small portion of a big idea. Simulation is one of the universal approaches that researchers use in their research. This novel nanoprobe based detection process may introduce with versatile opportunities for researchers and a revolutionary change can occur in medical science especially in the section of detection, analysis and treatment of diseases.

ACKNOWLEDGMENTS

All eulogize to Allah the Almighty, the most genial, most gracious, and most munificent. We would like to acknowledge Dr. Muhammad Ahsan Ullah for his constant support and guidance. We would also like to express heartily gratitude toward our friend Habib Titas, for giving us guidance and providing the Finite Element Analysis software for our research.

REFERENCES

Ahmad, M.R., Nakajima, M., Fukuda, T., Kojima S., & Homma, M. (2009). *In Proceedings of the Single Cells Electrical Characterizations using Nanoprobe via ESEM-Nanomanipulator System*, *Genoa, 26-30 July 2009* (pp. 589-292). IEEE Xplore.

Cone C.D. (1970). Variation of the transmembrane potential level as a basic mechanism of mitosis control. *Oncology, 24*(6), 438-470.

Cure J.C. (1991). Cancer an electrical phenomenon. Resonant.

Ingebrandt, S., Wrobel, G., Eick, S., Schafer, S., & Offenhausser A. (2007) *Probing the Adhesion and Viability of Individual Cells with Field-Effect Transistors*. In Proceedings of the Solid-State Sensors, Actuators and Microsystems Conference, Lyon, 10-14 June 2007(pp. 803-806). IEEE Xplore.

Sahu, R.K., Zelig, U., Huleihel, M., Brosh, N., Talyshinsky, M., Ben-Harosh, M., Mordechai, S., & Kapelushnik, J.(2005). Continuous monitoring of WBC (biochemistry) in an adult leukemia patient using advanced FTIR-spectroscopy. *Leukemia Research, 30*(6), 687-693.

Steve Haltiwanger M.D., C.C.N,. *The Electrical Properties of Cancer Cell*. Retrieved from website: http://www.royalrife.com/haltiwanger1.pdf.

Sulaiman, A.H.M. (2012). Modeling and simulation of Novel Method of Cell Viability Detection via Electrical Measurement using Dual Nanoprobes. *In Proceedings of the Enabling Science and Nanotechnology (ESciNano), Johor Bahru, 5-7 Jan 2012* (pp. 1-2). IEEE Xplore.

Tandon, T. (2012). *Novel Detection of Hematological Cancer: A Proposed Conductivity Based Analysis for Early Leukemia Cell Identification*. California, USA.

