Scholars Journal of Engineering and Technology
Abbreviated Key Title: Sch J Eng Tech
ISSN 2347-9523 (Print) | ISSN 2321-435X (Online)
Journal homepage: https://saspublishers.com

OPEN ACCESS

Diode Made of Ice

Stanislav V. Yefimov[1*]

[1]Pharmetric Laboratory LLC, 11880 28th St N #210, 33716, St. Petersburg, FL, USA

DOI: https://doi.org/10.36347/sjet.2025.v13i01.001 | **Received:** 25.11.2024 | **Accepted:** 31.12.2024 | **Published:** 06.01.2025

***Corresponding author:** Stanislav V. Yefimov
Pharmetric Laboratory LLC, 11880 28th St N #210, 33716, St. Petersburg, FL, USA

Abstract **Original Research Article**

This paper describes the invention of a new semiconductor material “Ice”, and a semiconductor device based on it. The invention relates to the solid semiconductor composition comprising: a frozen aqueous solution of an acid and a frozen aqueous solution of a base. An inert electrode is frozen into each of the solutions. Both frozen solutions are tightly connected, forming a contact surface. The semiconductor device consists of two pieces of doped ice and electrical wires connected to electrodes frozen into the ice.

Keywords: Semiconductor, Ice, acid-doped ice, base-doped ice.

INTRODUCTION

The first semiconductor materials and devices were invented more than 100 years ago. 1874: “Semiconductor Point-Contact Rectifier Effect” was Discovered by Ferdinand Braun when he probed a galena crystal with the point of a thin metal wire, Braun noted that current flowed freely in one direction only. Around 1904, Henry Harrison Chase Dunwoody developed a cat’s-whisker detector using carborundum, and Greenleaf Whittier Pickard developed a cat’s-whisker detector using galena. The first silicon point-contact crystal detector was invented in 1906 by Greenleaf Whittier Pickard. In 1940, Russell Ohl learned about the photovoltaic effects in silicon and the p-n junction. Russell Ohl, who, in 1940 stumbled on the semiconductor “p-n” junction. Russell Ollier's invention is the closest to the invention presented here. Russell Ollier's patent # 2,402,662 for LIGHT-SENSITIVE ELECTRIC DEVICE may be considered to some extent as a prototype of this invention. The effect of one-way conductivity in contact between an aqueous solution of an acid and an aqueous solution of a base has been observed for a long time. In my student years, experimenting in the colloid chemistry laboratory, I discovered the effect of the predominantly one-way conductivity of a capillary connecting two solutions of different acidity. Later, while working in the membrane biophysics laboratory, I observed the effect of the one-way conductivity of an artificial membrane separating acid and base solutions. Similar effects were observed by many of my colleagues, but no one systematically studied this effect. It is time to return to consideration of the postponed but not forgotten problem. Now we have a theoretical basis allowing us to look at the impact of one-way conductivity of contact of acid and base solutions with a fresh look. We have derived the General Equation of State of electrolyte solutions “General equation of state of acid-base balance in solutions...” (Yefimov S. 2023)., we found the solution of this equation - a function and determined the special points of this function “Finding Singular Points of the Titration Curve…” (Yefimov S. 2023). Then, the same theoretical work was done for solid solutions, namely for crystalline semiconductors doped with donor and acceptor impurities “Derivation of the General Equation of State for a Doped Semiconductor…” (Yefimov S. 2024), and “Finding singular points of the concentration curve of doped semiconductors” (Yefimov S. 2024). It is shown that the equations and their solution coincide for liquid electrolytes and solid semiconductors. Thus, the identity of theoretical models of electrolyte solutions and doped crystalline semiconductors indicates their properties (semiconductors) should be identical. To test this, it is necessary to assemble a setup in which an acid solution and a base solution are electrically connected through a thin capillary or semipermeable membrane, place electrodes in these solutions, pass current in one direction and the other, and record the measurement results. However, the scheme has two disadvantages: firstly, due to the electrolysis the chemical composition of the cathodic and anodic solutions continuously changes; secondly, the contact resistance (capillary or membrane) is unstable. The first disadvantage can be eliminated by using a salt bridge (Yefimov S, *et al.*, 2000), but it will make the setup more cumbersome.

However, another main disadvantage of this scheme is that Arrhenius's Electrical Dissociation Hypothesis is traditionally used when interpreting the measurement results. We chose the following scheme: prepare electrolyte solutions, freeze them so that doped ice is formed, and then tightly connect the pieces of doped ice. In this way, a logical connection is established between the electrolyte solution and the solid crystal and between the two theoretical models of liquid and solid "Patent Pending" (Yefimov S. 2024).

MATERIALS AND METHODS

The work involved ultrasonicated HPLC grade water, copper electrodes, hydrochloric acid, and sodium hydroxide of analytical grade. The solutions were frozen in a freezer at -20°C. For electrical measurements, an EverStart digital multimeter was used in resistance measurement mode and in diode testing mode. Based on the measurement results, the average value and standard error of the average were calculated at a confidence level of 95%.

RESULTS AND DISCUSSION

A new semiconductor material is ice made from frozen aqueous solutions of acids and bases (Figure 1).

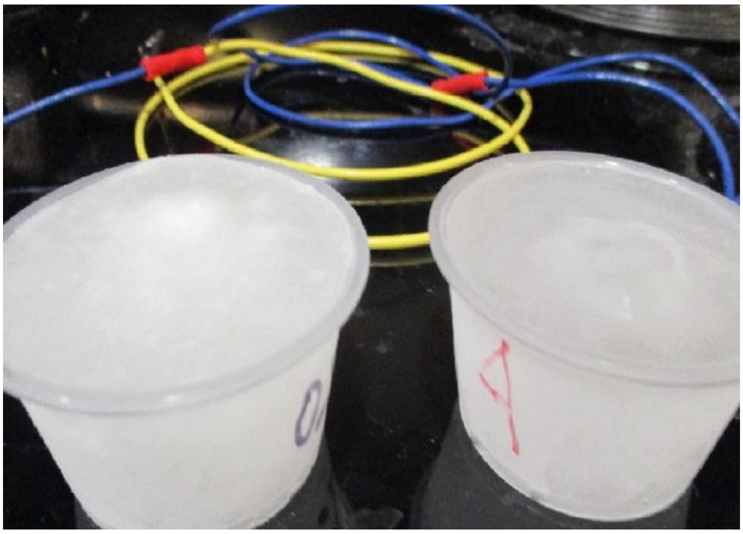

Figure 1: Plastic cups filled with aqueous acid and aqueous base solutions. The solutions are frozen in a freezer

Electric wires are frozen into each of the solutions (Figure 2).

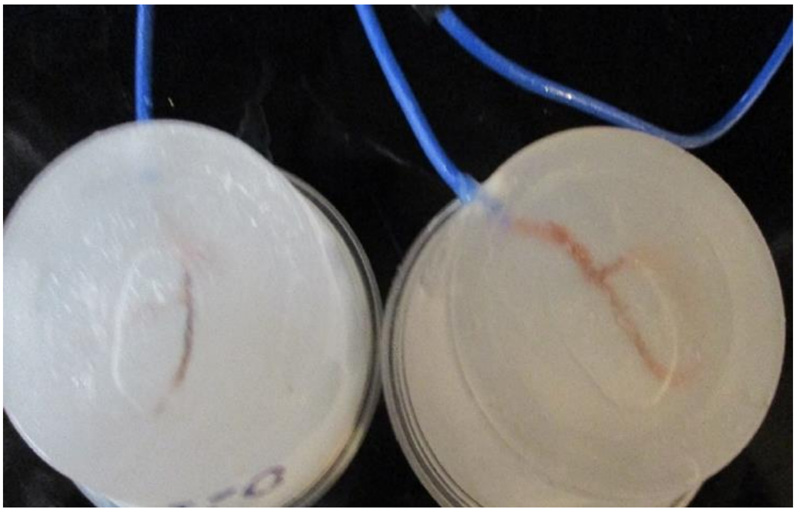

Figure 2: The bottoms of plastic cups show electrical wires (electrodes) frozen into the ice

The ice pieces are pressed tightly together using a screw clamp. Electrical wires are connected to the multimeter (Figure 3).

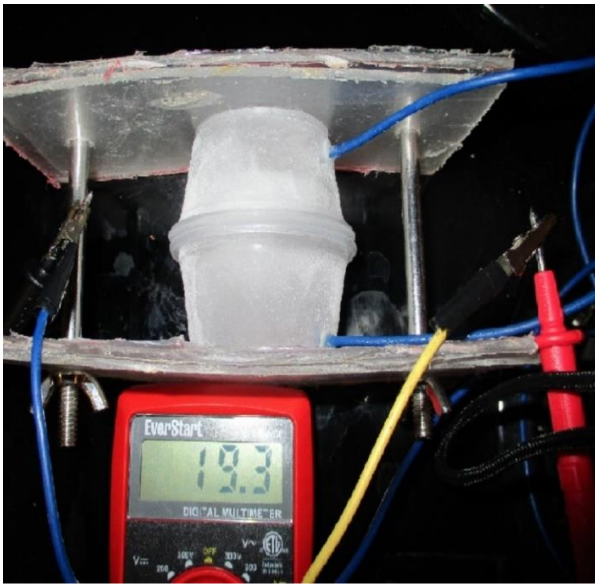

Figure 3: The installation is assembled. Two pieces of ice are tightly pressed together Electrical wires are connected to the multimeter.

The semiconductor device is the device that provides contact between a frozen aqueous solution of acid and a frozen aqueous solution of base and allows electric current to pass through this contact with low resistance in the forward direction and with high resistance in the reverse direction (Figure 4).

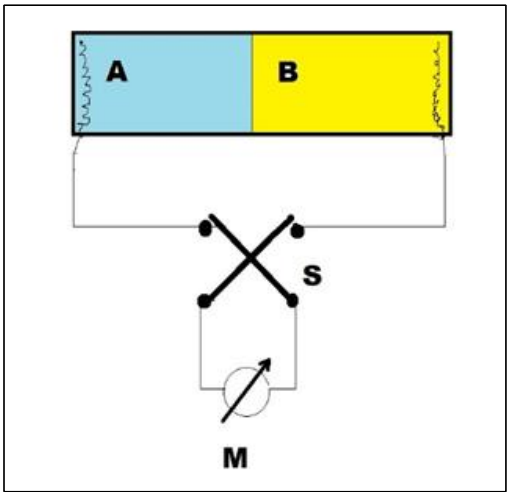

Figure 4: Scheme of the setup for recording the semiconductor properties of the contact of the acid-doped ice (A) and the base-doped ice (B). S - switch. M – multimeter

The measurements were taken in resistance measurement mode (Figure 5) and in diode test mode (Figure 6). In resistance measurement mode, the measurement accuracy is $\mp$(1.2%). The maximum open circuit voltage is 1 V. In diode test mode, the approximate forward voltage drop of the diode was measured. The open circuit voltage is about 2.2 V. The measurements were carried out in pairs changing the polarity from (+ / -) to (- / +). Each series had 3 pairs of measurements. The difference in the values in the pair (ΔΩ and Δmv), the average value of each polarity, and the average value of the difference were calculated. The standard error of the mean was calculated at a confidence level of 95%. In the first series of experiments, the resistance of tightly connected pieces of acid-doped ice and base-doped ice was measured in the direction perpendicular to the contact surface. The polarity of the electrodes was changed in pairs. Figure 5 presents the measurement results for two concentrations of the ligating agent (acid and base). The left column (Ω Acid (+)) shows the resistance of the device when a positive potential is applied to the electrode frozen into acid-doped ice, and the right column (Ω Acid (-)) of the opposite polarity. The predominantly one-sided conductivity is obvious. Figure 6 presents the measurement results for 0.1 M concentration of the ligating agent (acid and base) at 0°C. The predominantly one-sided conductivity is obvious.

Table 1

Electrical resistance (ohm) 0.1 M, 0°C				Electrical resistance (ohm) 0.001 M, 0°C			
#	Ω Acid (+)	Ω Acid (-)	ΔΩ	#	Ω Acid (+)	Ω Acid (-)	ΔΩ
1	1850.20	1.10	1849.10	1	1500.20	300.10	1200.10
2	2201.30	1.20	2200.10	2	1399.50	300.50	1099.00
3	1989.30	1.10	1988.20	3	1554.80	300.10	1254.70
average	**2013.60**	**1.13**	**2012.47**	average	**1484.83**	**300.23**	**1184.60**
standard error	408.32	0.13	408.20	standard error	181.94	0.53	182.44

Figure 5 **&** Table 1 in the resistance measurement mode, the doping concentration in the ice is 0.1 M and 0.001 M, and the temperature is 0°C.

Table 2

Diode Test (mV) 0.1 M, 0°C			
#	Acid (+)	Acid (-)	Δ mV
1	1198.00	625.00	573.00
2	1211.00	612.00	599.00
3	1200.30	601.10	599.20
average	**1203.10**	**612.70**	**590.40**
standard error	16.02	27.63	34.80

Figure 6 **&** Table 2 in the diode test mode, the doping concentration in the ice is 0.1 M, temperature 0°C. The voltage drop on the diode was measured.

These two tables clearly show that the conductivity from the base-doped ice to the acid-doped ice is significantly greater than in the opposite direction. Figure 7 shows the interpretation of the obtained data: Doping ice with acid creates the n-type conductivity of the semiconductor, and doping ice with a base creates the p-type conductivity of the semiconductor. The n-p junction is created in the contact.

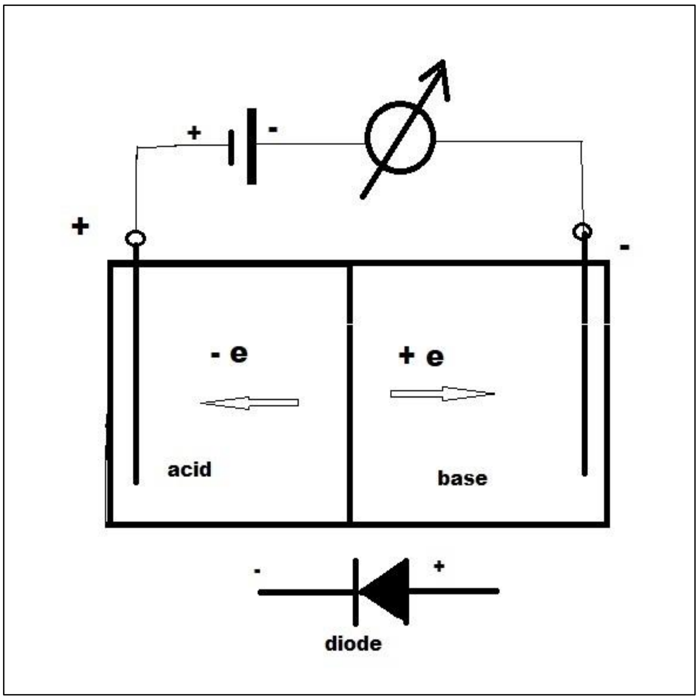

Figure 7: Figure explaining the operation of the ice diode. In the figure: -e are the main carriers of electric charge in acid-doped ice, +e are the main carriers of electric charge in base-doped ice. At a given polarity of the applied electric potential, the diode is "closed". The diode is "open" when the polarity is reversed, as in the diode symbol at the bottom of the figure

CONCLUSION

Ice is a new semiconductor material. Ice doping is accomplished by preparing aqueous solutions of acids and aqueous solutions of bases followed by freezing the solutions. A semiconductor device, namely a diode, is made by tightly joining or fusing a piece of acid-doped ice and a piece of base-doped ice. It is especially important to note that, according to the measurements taken, acid-doped ice is the n-type semiconductor, i.e. the main charge carriers in it are negative, while base-doped ice is the opposite.

REFERENCES

- Yefimov, S. (2023). General equation of state of acid-base balance in solutions. Resolution of the equation with respect to hydrogen ion concentrations and concerning the amount of added base or acid. Titration curves. *Sch Acad J Biosci*, *11*(3), 122-129. https://https://saspublishers.com/article/14111/
- Yefimov, S. (2023). Finding Singular Points of the Titration Curve by Solving the Equation of State of the Electrolyte Solution. *Sch Acad J Pharm*, *12*(3), 74-78. https://www.saspublisher.com/media/articles/SAJP_123_74-78_FT.pdf
- Yefimov, S. (2024). Derivation of the General Equation of State for a Doped Semiconductor. The Equation is Solved Concerning the Election Concentration in the Conduction Band for Different Concentrations and Properties of Doping Substances. *Sch J Eng Tech*, *12*(11), 324-331. https://saspublishers.com/article/20947/download/
- Yefimov, S. (2024). Finding singular points of the concentration curve of doped semiconductors. *Sch J Eng Tech*, *12*(12), 374-379. https://saspublishers.com/article/21194/download/
- Yefimov, S., Sjomeling, C., Yorgey, A. L., & Li, T. (2000). Recovery of Sodium Dodecyl Sulfate–Proteins from Gel Electrophoretic Bands in a Single Electroelution Step for Mass Spectrometric Analysis. *Analytical Biochemistry*, *284*(2), 288-95.
- Yefimov, S. (2024). Diode made of ice. Patent Pending. USPTO.