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Experiments on efficiency of electrolysis using pulsating direct current (using rectifiers)

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ABSTRACT

Electrolysis finds numerous industrial applications like synthesis, electroplating, electro refining. For all these purposes direct current source (generally a battery) capable of supplying 5-6A is used. Since the quantity of metal deposited is dependent on charge, so high current is preferred. But such high currents can also be obtained from a transformer and rectifier arrangement. The only difference is that a battery gives only D.C whereas a transformer gives pulsating D.C. The alternating components hinder the reaction and gives undesired products (even if filter is used). Battery on the other hand becomes expensive. For e.g. brine on electrolysis using battery gives pale blue $Cu(OH)_2$ (if copper wires are used as electrodes). But if the same is carried out by a transformer with rating 12V-3A using a half wave rectifier (using a single IN4007 diode) yellow colored insoluble particles are formed (which was not our destination at all).Use of a proper capacitor makes no significant improvement. In this paper the characteristics of electrolysis using different types of rectifiers at different voltages and currents have been outlined.

Keywords: Efficiency of electrolysis, Pulsating direct current.

INTRODUCTION

Electrolysis is used in metal refining like extraction of pure copper from impure copper. in the process anode used is thick block of impure copper, cathode used thin block of pure copper and electrolyte used is $CuSO_4$ solution (Sometimes a few drops of dilute H_2SO_4 is used to increase conductivity. In electroplating of silver, anode used is thick block of pure silver, cathode is article to be plated and electrolyte is sodium silver cyanide solution. In all these cases a high current source (generally above 4A) are preferred. Rechargeable batteries ranging from 6-12V are widely available. Each of them can supply at least 5A. The main disadvantages are -

a. They are very expensive.
b. Maximum longevity of about 1year.
c. Difficulties in charging.

A good alternative is the use of transformers (with rectifiers). But the choice of the type of rectifier and filter becomes with increase in current capacity of the transformer. With increase in current filtration becomes very difficult.

Adverse effects give undesired products which lead to-

a. Wastage of energy.
b. Wastage of electrolyte.
c. Loss of electrode.

d. Difficulty in separation.
e. Frequent burning out of the filter as will be discussed in the sections to come.

In this paper an attempt has been made to outline the difficulties and how to minimize them.

MATERIALS AND METHODS

Apparatus : Transformers rated 12V-3A, 12V-1A, 9V-1A and 6V-2A. Diodes IN4007. Capacitors rated 25V-4700µF, 25V-2200 µF. Electrodes -Cu wires. Electrolyte - Brine solution of various concentrations. Volume of each solution was kept fixed (100 ml) Rectifier types -Half wave (using a single diode), half wave (using 2 diodes in series), bridge (4 diodes).

Experimental: NaCl solution was electrolyzed using the set up as shown in fig1.

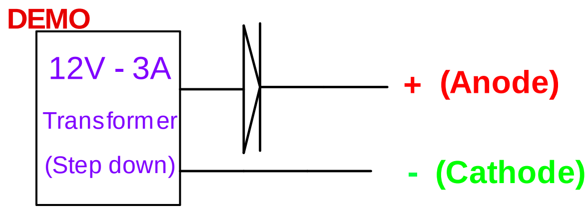


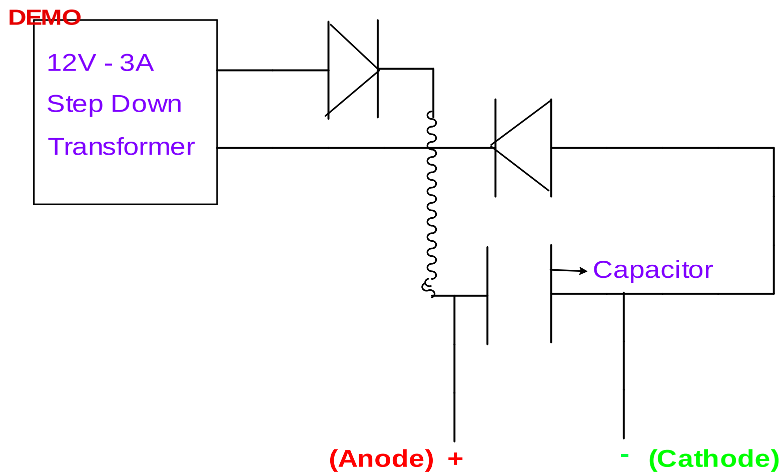
Figure 1.

A battery gives pale blue $Cu(OH)_2$ insoluble in water. On exposure to atmospheric CO_2 it changes to brilliant green crystals of $CuCO_3$. On heating it decomposes to give black CuO. This experiment is simple and cheap enough and can be used to produce $Cu(OH)_2$ in case we do not have alkali and a copper salt (sulfate, chloride etc.). The Reaction is

$Cu - 2e^-$ (ionization) + $2OH^-$ (from water) $\rightarrow Cu(OH)_2 + CO_2 \rightarrow CuCO_3$

12V-3A transformer when operated in the manner given above, the solution turns yellow. The color resembles that of $Fe(OH)_3$. It can hardly be distinguished.

No improvement was noticed. The capacitor exploded (both 4700 and 2200 µF both rated 25V). This might have been due to overloading of charge. The diodes do not offer much resistance in forward direction. Consequently they are not able to limit the large amount of current (and hence charge) from the 3A transformer. Bridge rectifier arrangement only stops the explosion of the capacitor. But the products can't be changed. The rectifiers get burnt out and destroyed after sometime. So they have to be replaced at regular intervals. In all these three cases quality of rectification is very poor. As a result efficiency is very low. Only materials and energy are wasted.



***A half wave rectifier having 2 diodes**

The same experiments are repeated using 12V-1A. No changes in the respective circuits were made. But this was also not effective enough. The main problems noticed were-rectification quality was not up to the mark, efficiency was very low and when the first arrangement was used (the one with the single diode), a lot of heat was produced in the diode itself. Approximately 20% energy was wasted as heat.
The 6V-2A when used in the respective circuits could not make any difference. A bridge rectifier only gets heated up to a great extent. Sometimes a diode having higher resistance than the remaining 3 (which may have been a manufacturing defect) gets burnt out and the arrangement has to be replaced. There remains the transformer rated 9V-1A. Half wave rectifier using single diode does not improve efficiency to a great extent even on adding capacitors. Bridge rectifier gets heated up. But unlike the other circuits it does not get burnt out. But bridge rectifier gives the desired products. For e.g. in case of NaCl solution as stated above, it gives very pure pale blue $Cu(OH)_2$. But due to presence of A.C. components heat is produced in the solution. In case of preparation of $Cu(OH)_2$ it does not make any difference but in case of temperature sensitive products it may cause decomposition. E.g. *a.* $KMnO_4$ it may cause its conversion to green K_2MnO_4. If methanol is electrolyzed it may ignite the solution. In case of oxidizing solutions, it may oxidize the electrodes (e.g. in manufacture process it may oxidize the graphite electrodes faster). Yet it (9V-1A, bridge rectifier circuit) is a lot better than the others.
A special experiment was performed using- 8 diodes (IN4007), 1capacitor rated 25V 2200 µF, a capacitor rated 25V-4700 µF, three 100 ml solutions (in 3 separate beakers) connected in series. A diagram of the arrangement is shown in fig2.

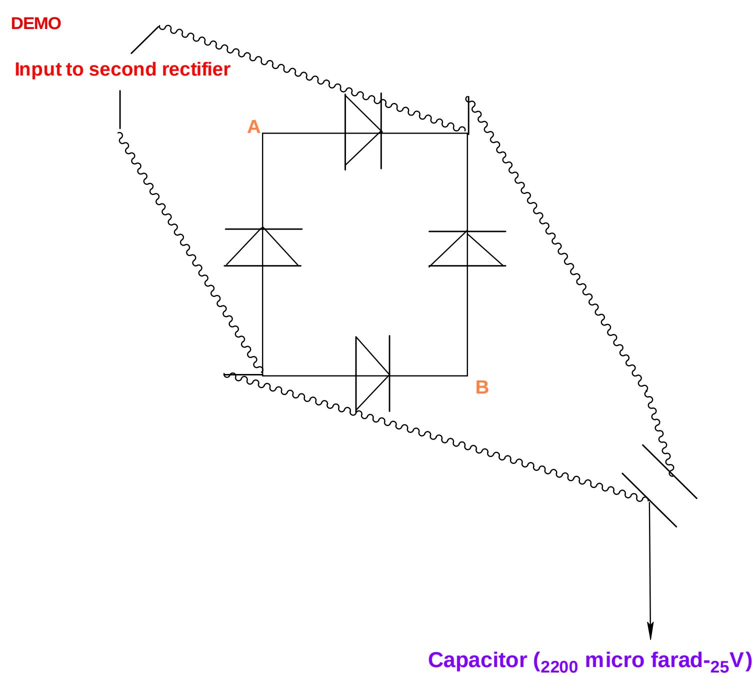


Figure2

*The output of the second rectifier was fed in to a capacitor rated 25V-4700µF. The circuit can be easily constructed from the previous circuit. Three beakers each containing 100m.l. of the same or different electrolytes were used in series.

The following changes were noticed - *A.* Heating became almost negligible. *B.* Speed of the reaction was very stable. *C.* Purity was almost 100%.

RESULTS AND DISCUSSION

The observations are summarized in the table 1. When the **9V-1A transformer** is used pale blue color is seen. This is pure $Cu(OH)_2$. It can be easily verified by addition of excess NH_4OH where it instantly forms **$[Cu(NH_3)_4](OH)_2$** which is deep blue in color and soluble. The brownish yellow solutions also may give deep blue color because it also contains Cu^{2+} evident from the corrosion of the anode. But it does not appear instantly. The rectifier-filter circuit is much more efficient than the previous circuits. The only disadvantage lies in the fact that here also heat is produced in the body of the diodes. The last circuit has almost all the advantages which are essential for electrolysis. They include- Appreciable reaction velocity ,No damage to the rectifiers, capacitors etc., Pure product, Steady direct current.

Table1.

Transformer rating	*Solution*	*Volume*	*Rectifier type*	*Expected color*	*Observed color*
12V-3A	NaCl	100m.l.	Half wave (1 diode)	P)ale blue	Brownish yellow
12V-3A	NaCl	100m.l.	Half wave (2 diodes)	Pale blue	Brownish yellow
12V-3A	NaCl	100m.l.	Bridge	Pale blue	Brownish yellow
12V-1A	NaCl	100m.l.	Both half wave and bridge	Pale blue	Yellow
6V-2A	NaCl	100m.l.	Both half wave and bridge	Pale blue	Mixture of yellow and brownish yellow

Electrolysis has indispensable applications. But it is often quite expensive due to energy source (batteries). The best alternative is in the use of a transformer. But it should be- Properly rated. Rectifier circuit should be designed to make rectification quality good. Filter should be properly designed so as to give maximum filtration. Resistances must be electrolytes and not ordinary rheostats so that work output increases. The working is simple and easy to understand. A bridge rectifier gives D.C output. A 25V-2200µF capacitor extracts the A.C components as it has a finite impedance to A.C given by $XC=1/2*3.14*f$ (f stands for frequency of the A.C supply which is normally 50Hz). The remaining D.C component is fed to the input of another identical bridge rectifier. The other does the same work. The output of this second rectifier is filtered with capacitor rated 25V-4700µF. So the output becomes almost pure D.C. The three solutions containing same or different electrolytes help to limit current and hence heating effect is minimized. Also as the resistances are electrolytes energy does not get wasted. We get useful work as the current passes through the electrolytes. Further filtration can be achieved by addition of capacitors but it is unnecessary.

APPLICATIONS

Studies are made on the behavior of various rectifier circuits and the developed circuit appears to be a real good alternative for a conventional battery and also cheap.

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CONCLUSIONS

Batteries supply electricity by chemical reactions. So they can give 100% D.C. But simultaneously they are becoming very expensive nowadays. But their use can't be stopped. So a better option is to perhaps obtain almost pure D.C from domestic or industrial supply. But the difficulty lies in conversion of A.C to D.C (i.e. rectification), filtration as presence of A.C components hinder electrolysis to a great extent. In this paper analysis has been made on the behavior of various rectifier circuits and the final circuit appears to be a real good alternative for a conventional battery. Not only the circuit is cheap but also it is easy to build. It can serve the purpose of electrolysis pretty well.

ACKNOWLEDGEMENTS

I, Parantap Nandi acknowledge that this paper cites original work based on experiments and keen observation.