IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper Vol.-6, Issue-8, Aug 2018 E-ISSN: 2347-2693

The Role of Magnetic Quantum Dot Cellular Automata In Replacing Traditional CMOS Technology

H. Umamahesvari

Department of Science and Humanities, Sreenivasa Institute of Technology and Management Studies (Autonomous), Chittoor, AP

**Corresponding Author:umamaheswarihema@gmail.com Tel.: 8331927822*

Available online at: www.ijcseonline.org

Accepted: 14/Aug/2018, Published: 31/Aug/2018

Abstract- The uprising innovation of nanotechnology is Quantum-dot cellular automata (QCA). Quantum Dot Cellular Automata is a new paradigm "Molecules can act as switches". QCA is fulfilling the gap left by the conventional memory systems in consuming power. There are various types of QCAs reported till now like Metal dot QCA, Molecular QCA and Magnetic QCA, metal Dot QCA has its own limitation that it can be operated only at low temperature. Though molecular QCA s are proved to be superior in operating condition compare to Metal- Dot QCA which can be operated at room temperature it also meets its own downside that its fabrication becomes complicated. In general most of the quantum dots include hundreds or thousands of atoms with variation in their energy and wave function. So creating quantum dots with digital reliability by eliminating the variations size, shape and arrangement remains indefinable. Since we need to go for a alternative device indeed to avoid the maximum power dissipation met with the high density ICs, let us think about the Magnetic QCA. Magnetic QCA relay on the property of alignment of spins in ferromagnetic material. The word" Quantum" implies quantum mechanical nature of short range exchange interaction which leads to alignment of spins. So Magnetic QCAs are having advantages over the previous two types that it is relatively uncomplicated. So in this paper we elaborately discuss about the QCAs, Types of QCAs and their functioning and the advantages of Magnetic QCA.

Keywords— QCA, Quantum, Magnetic QCA, Metal –Dot QCA, Molecular QCA

I. INTRODUCTION

To get the highest operating speed, the numbers of transistors are increased so rapidly and it consequently leads to the increases in power dissipation. This situation clearly describes that, increase in performance in future is inflexible. So the Information Technology and Electronic in future need a solution to get rid of this power dissipation and hence more efficiency in power reduction. The Quantum Cellular Automata (QCA) is presently being interrogated as a flipside to CMOS VLSI. So far many logical circuits and devices have been studied using QCA architecture. Though in theoretical point of view QCAs are considered to be superior compare to CMOS technology, in practice they are facing their limitations. In this paper we briefly discuss about QCA, types of QCAs and their advantages, disadvantages and the pre-eminence of Magnetic QCAs compare to Molecular QCAs.

II. PRINCIPLE BEHIND THE FUNCTIONING OF QCA

The computation in QCA lies on the principle of columbic interaction with neighbouring cells which influence polarization in the neighbouring cell. In QCA, four quantum dots are located to form a square by placing them in diagonals [1]. Quantum dots are small semi-conductor or metal islands with small diameter. Two movable electrons are loaded in the cell and they can occupy different quantum dots. The columbic repulsion experience between the electrons makes them to occupy the corners only. The different positions occupied by the electrons result in the polarization of the cells. The electron tunneling between the cells will be controlled by the potential barrier. The basic QCA cell is represented in Fig.1

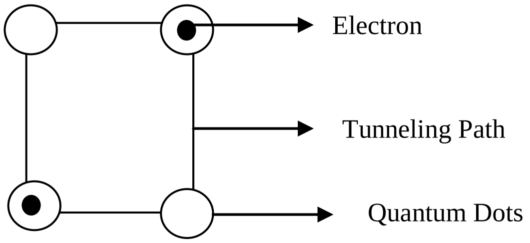


Fig.1. Basic QCA cell

In a particular QCA cell, the minimum potential energy arrangements of the two electrons in the quantum dots leads to different polarization as shown in below Fig. 2a & Fig .2b

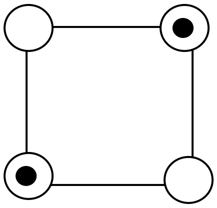


Fig.2a. P=+1 (Binary 1)

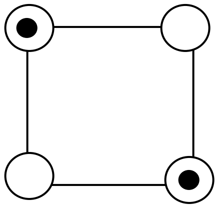


Fig.2b. P= -1 (Binary 0)

A. A Information Transformation in QCA

If we want to transfer the information from one QCA cell to another, the QCA cell from which the data must be transferred must close the tunneling junctions and in the neighbouring cell it must be opened to allow the electrons to change the positions in the quantum dots [2]. If the tunneling junctions are opened the electrons are pushed away from each other by columbic repulsion, after this process the tunnel junctions will be closed again, the transfer of the state is thus completed. The state of a particular cell can also be transferred to multiple neighbouring cells. This idea allow us to construct various digital circuits via QCA.

B. Types of QCA

The Metal-Island category consists of metal islands such as Aluminium Island of micrometer size, it is comparatively larger size and need very low temperature condition for electron switching [3]. Comparatively semiconductor QCA is having the possibility to implement them in practice that by means of lithographic techniques we could achieve (~20 nanometres [4]. The molecular QCA are noteworthy since single molecule can carry out the switching process which intern gives highly symmetric QCA cell structure, very high switching speeds, extremely high device density and can be operated at room temperature but it too have the constraint in choosing the molecule and clocking [5]. Interaction between the magnetic nanoparticles is the principle behind Magnetic QCA, the advantages of magnetic QCA compare to all other said types of QCA is that, it could be operated at room temperature [6].

III. MAGNETIC QUANTUM DOT CELLULAR AUTOMATA

Magnetic materials are classified by their response to an externally applied magnetic field. Accordingly they are classified in to five types via diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic materials and ferromagnetic. Ferromagnetic materials are playing significant role in storage device. Let us have a momentary look at ferromagnetic materials properties which make them in playing imperative role in storage devices. In ferromagnetic materials, the magnetic dipoles are coupled in groups. A magnetic domain which is also called as Weiss domain designate to a volume of ferromagnetic material in which all magnetic dipoles are in the same direction by the exchange forces. This concept of domains distinguishes ferromagnetism from Para magnetism]7,8]. A ferromagnetic material have various such domains as shown in the below Figure.3. As the size of the material reduces, the numbers of domains are reducing and when the size of a ferromagnetic material is reduced below a critical value, it becomes a single domain. For the logical storage devices we need single domain particle or grain [9].

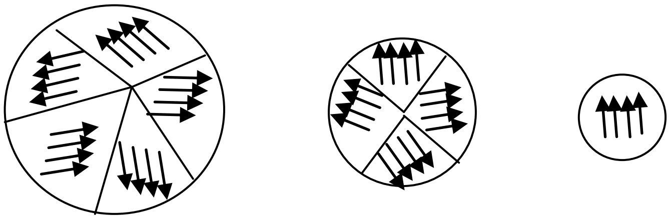


Figure.3. Multi domain to Single domain formation of Ferromagnetic materials

A. The magnetic domains in Ferromagnetic materials

Domains are the fundamental concept behind ferromagnetism. A ferromagnetic material is a magnetic material which exhibits spontaneous magnetization with a slight dependence on applied field. For a homogenous material in a constant temperature condition always shows uniform spontaneous magnetization, but the direction of spontaneous magnetisation is different in different regions. The size of the magnetic domain ranges from micrometer to some millimetre size [10-12]. The uniformity in the spontaneous magnetisation of different domains attain only by means of large applied magnetic field value or by reducing the particle size to achieve single domain. The domain walls are the interfaces between the domains with magnetization in various directions. When the grain size decreases, an optimal size called critical size will be reached where the grain unable to accommodate the domain wall.

Therefore below the critical size, the grain contains only a single domain (SD). A SD grain has its uniform magnetization and saturation Value.

B. The Single Domain Grains

The SD grains are very commanding compare to Multi domain grain (MD) , since in MD grains if we want to change the magnetization we need to transform the domain wall and it is found to be easy energetically and thus MD grains are considered to be soft and having less coercivities and remanence [13]. In the SD grain the only way to change the magnetization is to rotate the magnetic dipoles of course it is a difficult process which leads us to tell that the SD grains are magnetically hard and have high coercivities and remanence. When the size of the grain decreases below SD range, another critical threshold value reaches at which remanence and coercivity go to zero and make the material to attain a new magnetic property known as superparamagnetic property. In superparamagnetic materials, the coercivity becomes zero [14]. The super paramagnetism property is caused due to thermal effect. The thermal fluctuations cause the demagnetization and makes coercivity and Hysteresis .

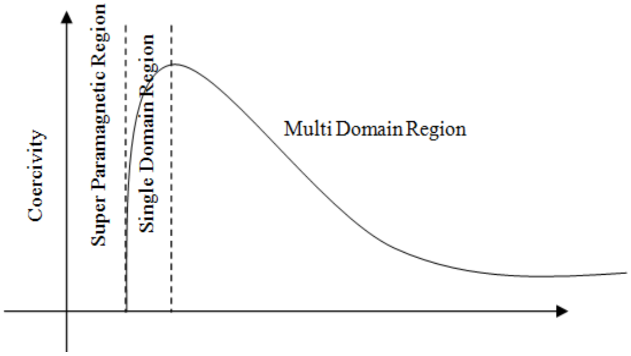


Fig.4.Grain Size of the Particle

C. Logical Implementation in Magnetic Quantum Dot Cellular Automata

The single domain concept of ferromagnetic materials makes us to identify another paradigm for binary storage device known as Magnetic Quantum dot Cellular Automata (MQCA). The principle behind the MQCA is logical storage based on magnetic dipole alignment. The saturation magnetization in two opposite direction depict the logic “0” and logic “1”

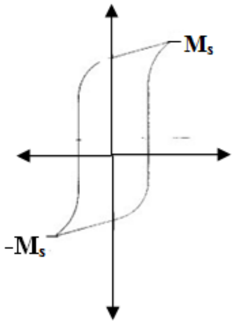


Fig.5.Remenance of Nanoferromagnets

The preferable size of the nanomagnets for this pupose to be stable against thermal fluctuations is 30 to 70 nm on edge, [6] and a few tens of nm thickness. Like the polarizations of the neighbouring cells in EQCA to get the logical circuits, in Magnetic QCA, as the nanomagnets are placed close to each other, there are two possibilities of coupling known as Ferromagnetic coupling and Antiferromagnetic coupling[15]. Ferromagnetic coupling gives parallel alignment of magnetic moments whereas Antiferromagnetic coupling leads to antiparallel alignment of magnetic moments as shown in Fig.6 (a) & (b)[16]

Fig.6. a) Ferromagnetic coupling b) Antiferromagnetic coupling

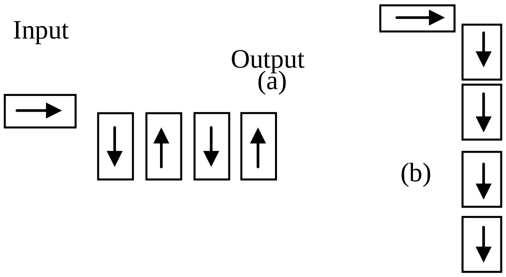
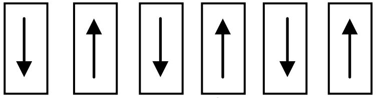


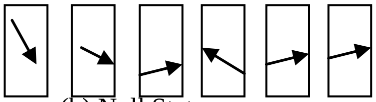
Fig.7. (a) Antiferromagnetically coupled MQCA device (b) Anti ferromagnetically coupled MQCA device

D. *Logical Implementation in Magnetic Quantum Dot Cellular Automata*

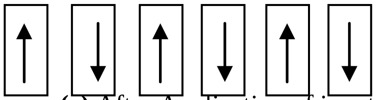
In EQCA, the clocking field influences the barriers which are trapping the electron. The applied clock fields raise the energy of the barriers between the quantum dots in the QCA cell. So to get a particular logical state we need to apply clock field. When the clock field is made as zero, no information will be stored in the EQCA cell. But in MQCA, the application of the clock field brings null state [17].



(a) Initial Configuration



(b) Null State



(c) After Application of input

Fig.8. Role of Clock in MQCA

IV ADVANTAGES OF MQCA OVER EQCA

The major advantages of MQCA are high integration density that is MQCA networks proffer a several thousand fold increase in integration density and a hundredfold reduction in power dissipation over contemporary microelectronic technology [17, 18]. MQCAs can act as non-volatile memory elements and no power supply is required to store information. MQCAs are defect tolerant and fabrication is simple. The superior advantage of MQCA is that it can be operated at room temperature unlike EQCA [19].

V CONCLUSION

MQCA has massive prospective to meet the future requirements of microelectronics for digital processing. The magnetic implementation of QCA favours the fabrication of circuits with tiny power dissipation and with intrinsic memory proficiency. The fabrication constraints in the single domain formation with thermal stability can be achieved by proper shape and scaling in the size of the grain. Though few results only been shown till now, by means of suitable fabrication techniques and simulation processes, MQCAs will play predominant role in data storage devices.

REFERENCES

[1] C. S. Lent, P. D. Tougaw, W. Porod and G. H. Bernstein, “Quantum Cellular Automata”,Nanotechnology,Vol. 4, Issue 1, pp.49-57,1993.

[2] C.S.Lent, , P.D.Tougaw, “A device architecture for computing with quantum dots" Proceedings of IEEE, Vol.85, Issue.4 1997, 85, 541-557

[3] A. O. Orlov, I. Amlani, G. H. Bernstein, C. S. Lent and G. L. Snider, “Realization of a Functional Cell for Quantum-Dot Cellular Automata” Science, Vol. 277, Issue .5328, pp. 928-930,1997.

[4] I.Amlani, A. Orlov, G. Toth, G. Bernstein, C.S. Lent, G.L.Snider, “Digital Logic Gate Using Quantum-Dot Cellular Automata” Science, Vol.284, Issue.5412, pp.289-291, 1999.

[5] C.S. Lent, Beth Isaksen,Marya Lieberman, “Molecular Quantum-Dot Cellular Automata”, *J. Am. Chem. Soc.*, Vol. 125, Issue.4, pp 1056–1063, 2003

[6] A. Orlov, A. Imre1 , G. Csaba, L. Ji , W. Porod, G. H. Bernstein, “Magnetic Quantum-Dot Cellular Automata: Recent Developments and Prospects”, J.Nanoelectron .Optoelectron, Vol.3, Issue.1, pp.1-14,2008

[7] Lianhua Qu,ZA.Peng ,XG. Peng, “Alternative routes toward high quality CdSe nanocrystals”, Nano Lett., Vol.1, Issue.6, pp.333–337,2001

[8] M.A. Hines , P.Guyot-Sionnest, “Synthesis and characterization of strongly luminescing ZnS-Capped CdSe nanocrystals”. J.Phys.Chem. Vol.100, Issue.2, pp.468–471,1996.

[9] Abolfazl Akbarzadeh, Mohammad Samiei, Soodabeh Davaran, “Magnetic nanoparticles: preparation, physical properties, and applications in biomedicine” , Nanoscale Res Lett., Vol.7,Issue.1, pp 1-14,2012.

[10] Yuri Mnyukh, “Magnetization of Ferromagnetic Materials”, American Journal of Condensed Matter Physics, Vol.4, issue.4,pp78-85, 2014.

[11] C.Kittel, Introduction to Solid State Physics, 4th Ed., Wiley @ Sons 1971.

[12] R. M. Bozorth, “Ferromagnetism (Chapter XII),” D. Van Nostrand Company, New York, 1951.

[13] E.P.Wohlfarth, “Magnetic properties of single domain ferromagnetic particles”, Journal of Magnetism and Magnetic Materials,Vol.39 Issue.1-2,pp 39-44, 1983.

[14] E W Lee,J E L Bishop" Magnetic behaviour of single-domain particle”s, Proceedings of the Physical Society, Vol. 89, Issue. 3,pp.661-676,1966.

[15] R. P. Cowburn ,M. E. Welland, “Room Temperature Magnetic Quantum Cellular Automata”, Science , Vol.287 , Issue.5457,pp. 1466-1468 ,2000.

[16] G. Csaba, A. Imre, G. H. Bernstein, W. Porod, and V. Metlushko, “Nanocomputing by field-coupled nanomagnets”, IEEE Trans. Nanotechnol, Vol.99, Issue.4, pp.209-213,2002.

[17] A.Imre A, G.Csaba , L.i ,A. Orlov, G.H.Bernstein,W. Porod, “Majority Logic Gate for Magnetic Quantum-Dot Cellular Automata”. Science, Vol.311, Issue. 5758 , pp.205–208, 2006.

[18] M.T. Niemier, X.S. Hu, M. Alam, G. Bernstein, W. Porod, M. Putney, J. DeAngelis, “Clocking structures and power analysis for nanomagnet-based logic devices” ISLPED’07, August 27–29, 2007, Portland, Oregon, USA, pp.26-31,2007.

[19] R. P. Cowburn, D. K. Koltsov, A. O. Adeyeye, M. E. Welland,D.M.Tricker, “Single-Domain Circular Nanomagnets” Phys.Rev.Lett., Vol.83,Issue.5,pp.1042-1045,1999.

Authors Profile

Dr.H.Umamahesvari received her Ph.D. Degree in Physics from the Mother Teresa Women’s University, Kodaikannal in 2009. From 1999 to 2002 she worked in Pondicherry University as guest Lecturer. From 2002 to till now in Sreenivasa institute of Technology and Management Studies, Autonomous, Chittoor, AP. She is presently involving in the research in quantum chemical methods under UGC. Her topics of research includes FT-IR and FT-Raman Spectroscopic Studies, HF and DFT quantum Chemical Methods, Quantum Computation. She has 20 international publications and 25 conference and Seminar Presentations under Universities and IITs