The Great Father of Phase Change Memory
Stanford R. Ovshinsky

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ABSTRACT

Stanford Ovshinsky was born on November 25, 1922 in Akron Ohio and is gone on October 17, 2012. He proposed the new amorphous science and created so many inventions such as new battery, thin film amorphous solar cells and phase change memories. His vision on science and technology will be forever alive. We the colleagues of phase change science researchers respect him as "the great father of phase change memory" and here his great history is shown with deep mourning.

1. Enter Ovshinsky of the GENIUS[(1)]

I first visited Ovshinsky's estate in Bloomfield Hills, Michigan in 1985 with some colleagues. It showed well trim vast lawn garden and the front is the lake beach, in the wood of this garden, dear were living. He arranged the watering place for dear. There was an apple tree, where Stan & Iris had speculating time on science and world. They had an indoor pool in the house. It showed American dream.

More than 60 years before from that time, in 1920s, Stan was a still boy and working every day for their livelihood in the cold early spring season at the wide wheat farm in Ohio, stepping on the buds of the wheat for strengthen and well growing them. In every night, he studied from a lot of books borrowing from the public library. This time was his relaxation for hard work in daytime. The books were for wide range subjects for example science, technology, medical, novels, history, society and arts. His X'mas cards always showed his poem and the beautiful photo by his wife Iris, with humanity minds and visions. His active right side brain showed valuable visions and intuition. This is the start of the great genius self taught Stanford R. Ovshinsky. The self taught education gave him Freedom of thought.

In 1940s, his first job was the lathe operator of tool maker in machine shops. He had deep interest in the metal material, since many kinds of materials showed different characteristics such as hardness, strength, stickiness and the dependency of characteristics of the metal with the additional elements and the conditions of operation. Then he invented new high speed lathe method with his self taught knowledge and idea. In the factory, he studied next three important steps, the first was analyzing the problem, well understanding, the second was creation of idea for resolution and the last was the demonstration of the idea, he knows words were not enough. These experiences formed his base of research and development and his deep insight for materials and atomic arrangement, bonding and their relation of the material functions. At the same time, he

awared the labor's working environment, keeping labor's right and Freedom grow up their motivation. And he introduced this management to his company when he started ECD (Energy Conversion Devices Inc.). with his wife Iris in 1960, Michigan, Troy.

In the early 1950s, he wrote a paper on a quite new computer system of artificial brain with "neurosynaptic cell" devices. In those days, however, the first commercial product computer machine IBM701 had just appeared. His concept must have been too early; professors of the days did not precisely review his paper. In 1954, Bell Lab. announced the single crystal Si solar cells and the non-fuel energy source became the important subject. Stan & Iris in ECD were developing hydrogen absorption materials for a fuel engine and amorphous Si thin film for a solar cell. They started a venture company, ECD, aiming at innovative developments for "energy conversion devices". In 2001, they developed the amorphous Si solar cell mass production plant of 40MW/ year, now it becomes 80MW plant.

2. Discovery of amorphous semiconductor[2]

2.1 Amorphous semiconductor switching

In 1968, Stan first discovered the switching function of amorphous chalcogenide thin film materials; it was a revolution on material science. Semiconductor transistor was announced in 1947; after that semiconductor science had been restricted in the crystalline materials possessing ordered periodic structure and the adequate band gap. The discovery of Stan, "amorphous semiconductor," widely expanded the concept of semiconductor including the disordered amorphous materials that had not been paid any attentions at all by old scientists and old academy. Stan made "liberation of research materials" from the restraint of ordered crystalline materials. In 1969, M.H. Cohen, H. Fritzsche and S. R. Ovshinsky proposed the CFO model of mobility gap in amorphous materials, which shows a kind of band gap[3]. In 1977, his long years friends of N.F. Mott and P.W. Anderson were Nobel Prized by "Electron theory in disordered system"; thus, the amorphous semiconductor was recognized in the field of material science[4].

2.2 Proposal of Phase Change Memories[2]

Stan found two types of switching function on chalcogenide amorphous materials; one is OTS(Ovonic Threshold Switching) and the other is OMS(Ovonic Memory Switching) and OMS is based on the order-disorder(crystalline-amorphous) reversible phase change process. In 1971, Stan et.al announced the laser-induced optical phase change rewritable memory[5]. Then, the research and development on the amorphous phase change memory became so active in Japan and also world widely. Unfortunately, soon the R/D activity stormed into the long term death-valley period due to the lack in the rewrite cycle reliability. Just at that time, there was a strong competing technology of MO(Magneto-Optical Disc) which had been already in the market and approved by ISO. During in 1990s, there were exciting R & D race of MO vs. PC as if "Rabbit(MO)

vs. Turtle(PC)". It should be noted here and we can be proud that this PCOS (Phase Change Oriented Symposium) has largely contributed for advancing phase-change technologies with ODS(Optical Data Storage, US), ISOM(International Symposium on Optical Memory, Japan) and EPCOS(European Phase Change Ovonic Symposium).

In 1986, ECD-Panasonic phase change material co-development started. In 1989, Ohta et. al. announced "Million Overwrite performance of phase change optical disc"[(6)], then the phase change optical disc R & D activity has been accelerated world widely. The world-first product was shipped as IBM7110 in 1990 from Panasonic. PC was approved by ISO, then DVD was promoted and MO gradually fade out.

Stan joined many times to EPCOS and PCOS; he always appreciated the symposium and gave us the direction by his impressive talks there.

Today, the market of Flash-memory is growing. And PCRAM(Phase Change Random Access Memory) is recognized as one of the most possible candidates for replacing it due to the fast response and the high overwrite performance with simple device structure such as a cross-point. In particular, the CVD thin chalcogenide film process[(7),(8)] can promote high density and large capacity PCRAM and has the capability for replacing Flash and DRAM by OUM(Ovonic unified memory) in near future.

3. Ovshinsky's vision

PCRAM has functions of both switching and memory. Utlizing the two functions, Stan proposed a new function of state memory, cognitive device.[(9)] This device function is in a sence like the neuron-synapse of human brain. As already written in this paper, he proposed neurophysiology concept in the early days of 1950s. Applying this cognitive device (state memory memrister[(10)]) into the conventional logic circuit, the logic operation will obtain the ability of self-learning as the artificial brain computer in future.

Why could Stan establish amorphous disorder material science? It existed in his conviction for the importance of Freedom. For young researchers, to find signs and figures in amorphous materials and to combine with your intuition, will promote new valuable function devices for Information, Energy, Environment and Human life which will contribute to Ovshinsky's vision.

REFERENCES

(1) STANFORD R. OVSHINSKY : THE SCIENCE AND TECHNOLOGY OF AN AMERICAN GENIUS ; H. Fritzche, B. Schwartz, World Science Publishing Co., (2007).

(2) S. R. Ovshinsky, "Reversible Electrical switching phenomena in disordered structures", Phys. Rev. Lett., 21(1968)p.1450.

(3) M. H. Cohen, H. Fritzsche, S. R. Ovshinsky, "Simple Band Model for Amorphous Semiconducting Alloys", Physical Rev. Lett. Vol. 22, No.20 May 19, (1969)p. 1065.M. H. Cohen, H. Fritzsche, S. R. Ovshinsky: Phys. Rev. Lett. 22(1969)p.1065.

(4) N. F. Mott: ノーベル賞講演, 日本物理学会誌, 米沢富美子訳 34 (1979)p. 136.

(5) J. Feinleib, J. de Neufville, S. C. Moss, S. R. Ovshinsky: "Rapid reversible light-induced crystallization of amorphous semiconductors", Appl. Phys. Lett., 18(1971)p. 254.

(6) T. Ohta, M. Uchida, K. Yoshioka, K. Inoue, T. Akiyama, S. Furukawa, : K. Kotera, S. Nakamura, "Million cycle overwritable phse change optical disk media", Proc. SPIE, Vol. 1078(1989)p. 27.

(7) D.H. Im, et. al, Samsung, "A Unified 7.5nm Dash-Type Confined Cell for High Performance PRAM" IEDM (2008) paper 9.2

(8) J. F. Zheng, P. Chen, W. Hunks, M. Stender, C. Xu, W. Li, J. Roeder, S. Kamepalli, C. Schell, J. Ricker, R. Sandaval, J. Fournier, W. Czubatyl, G. Wicker, C. Dennison, S. Hudgens, T. Lowrey, "Conformal MOCVD deposition of GeSbTe in High Aspect Ratio Via Structure for Phase Change Memory Application".:MRS, Spring(2007) Meeting.

(9) S.R.Ovshinsky, B. Pashmakov, "Innovation Providing New Multiple Functions in Phase-Change Materials To Achieve Cognitive Computing", Mat. Res. Symp. Proc. Vol. 803, (2004), p.HH1.1.

(10) J. Borghetti, G.S. Snider, P.J. Kuekes,J.J. Yang, D.R. Stewart, R.S. Williams, "Memrisive' switches enable 'stateful' logic operations via material implication", Nature 464 (2010) p.873.

Happiness can be everywhere
Where two people share love

Life is so much easier on a porch
On a beautiful summer day

It is a pity that a beautiful summer day
Is not reflected in a peaceful beautiful world

Maybe an answer for earth and its strife
Is a global porch and people sharing their love

Stan & Iris
Poem by Stan and Photo by Ohta (June, 2003)
Bloomfield Hills