J. Condensed Matter Nucl. Sci. 36 (2022) 30–37

Research Article

A Possible Heuristic Explanation of Exotic Vacuum Objects (EVO's, Charge Clusters)

Graham K. Hubler*

The Medical School, University of Missouri, Columbia, MO USA

Abstract

In early 90's, Ken Shoulders was granted 5 patents on Exotic Vacuum Objects (EVO) claiming that they were **a new form of matter**. He produced many monographs about them and suggested they were the physics that explained cold fusion. In Ken Shoulders words, EVO's are, "Highly organized, **micron-sized clusters of electrons**, having soliton behavior, with electron populations density on the order of *Avogadro's number per cm*^{3} (A typical 2μm EVO has a population of 10^{11} to 10^{13} electrons). When interacted with solid material, these charge clusters perform a low-energy phase transformation type of atomic disruption that **liquefies the lattice** and propels the material to a **high velocity** without apparent signs of conventional heating. Using an ordinary thermal interpretation, a thermal gradient for bulk material greater than **26,000 degrees C** per micrometer would be required to achieve these effects". This paper presents lessons from thin film deposition methods like Vacuum Arc, Pulsed Electron beam, Pulsed Laser whose commonality with EVO generation is pulse energy impingement on a target. Rather than the hypothesis of a "new form of matter" as an explanation of EVO's, it is hypothesized that generation of a micro shaped-charge, in analogy with explosively formed shaped-charge munitions, can explain the characteristics of surfaces that were struck by EVO's. This hypothesis reproduces the effects that are underlined in the text above.

Keywords: Exotic vacuum objects, EVO, clusters of electrons, pulsed electron beams, vacuum arc

1. Introduction

In early 90's, Ken Shoulders was granted 5 patents on Exotic Vacuum Objects claiming that they were **a new form of matter**. He produced many monographs about them and suggested they were the physics that explained cold fusion [1].

In Ken Shoulders words, EVO's are, "Highly organized, **micron-sized clusters of electrons**, having soliton behavior, with electron population density on the order of *Avogadro's number per cm*^{3}. When interacted with solid material, these charge clusters perform a low-energy phase transformation type of atomic disruption that **liquefies the lattice** and propels the material to a **high velocity** without apparent signs of conventional heating." Ken Shoulders named at first these objects *Electron Validum* (EV) and later EVOs. Other researchers call the same phenomenon Condensed Plasmoids (CP) and make similar claims of their properties [2]–[5].

*Corresponding author: hublerg@umsystem.edu, 6635 Prestwick Drive, Highland, MD 20777

Figure 1. Pin hole high speed camera photo of an EVO in flight.

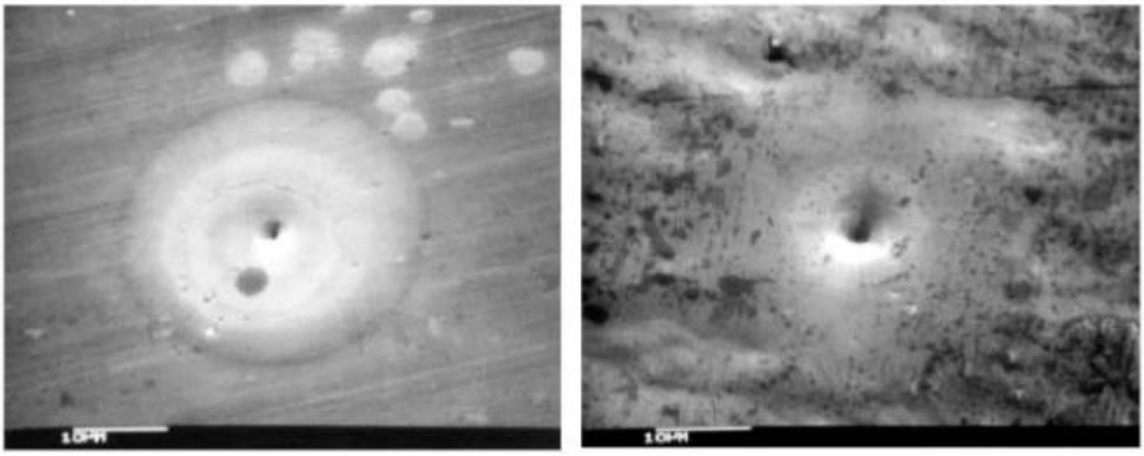


Figure 2. The entrance and exit sides of a 6 μm thick Al foil that was struck by an EVO leaving a $\sim$2 μm diameter hole [5].

Presented here are lessons from the thin film deposition methods Vacuum Arc, Pulsed Electron Beam, Pulsed Laser whose commonality with EVO generation is directed energy pulses impinging on a solid target. Rather than the hypothesis of a "new form of matter" as an explanation of EVO's, it is hypothesized that generation of a micro shaped-charge, in analogy with explosively formed shaped-charge munitions, can explain many of the characteristics of target surfaces and substrate surfaces that were struck by EVO's. This hypothesis reproduces the effects that are underlined in the text above.

2. Discussion

Figure 1 shows high speed photography of an EVO showing $\sim$2 μm diameter elongated features connected together like sausage links pointing in different directions [4], [5]. Figure 2 shows the entrance and exit sides of a 6 μm thick

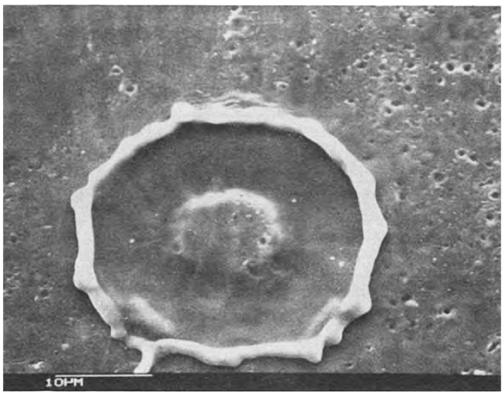


Figure 3. Circular feature left by charged cluster strike on a surface [1].

Al foil that was struck by an EVO leaving a $\sim$2 μm diameter hole [5]. An interpretation of Ken Shoulders is: "Using an ordinary thermal interpretation, a thermal gradient for bulk material greater than 26,000 degrees C per micrometer would be required to achieve these effects. This suggests that 26,000C would be the temperature required to melt a clean hole right through material with a melting point of 2,600 degrees C (i.e., SiC, not shown)".

Rather than postulate a new form of matter, let's first approach the problem using known physics from thin film deposition processes where pulsed lasers (PLD), pulsed electrons (PED) and vacuum arc (VAD) are employed to melt and/or vaporize a target and the subsequent vapor moves in a plume to coat a substrate. There is extensive literature on finite element and computational fluid dynamic simulations of these processes [6]–[12]. In PLD, typically 1 J/cm^2, 10-100 ns UV laser pulse atomizes a $\sim$50 μm diameter 0.2 μm deep slug of material [11], [12]. The ionized plasma expands into the space above the target by the high-pressure region expanding into the low-pressure region that reaches plume velocities of $\sim$1000 m/s in a highly directional expansion perpendicular to the target. PLD works well for opaque materials. In PED on an insulator [6, 7, 10], typically a 1 kA, 100 ns pulse of 15 keV electrons melts and vaporizes a $\sim$mm diameter, $\sim$2 μm deep slug of material that expands into space, greatly aided by Coulomb explosion due to the milli-Coulombs of charge deposited in the material, reaching plume velocities of up to $\sim$10,000 m/s [10]. In VAD [8], the process is similar to PED but with less control, and both PED and VAD work well on any material including insulators. In PED and VAD, the cathode is shaped to support a relatively large area impingement on the target in order to maximize the volume of material transferred to the target for overall efficiency of the deposition process. Figure 3 shows an unusual circular pattern left on a surface stuck by an EVO [4]. But Fig. 7 in Ref. [7] shows a similar feature on a Cu PED anode and Fig. 2 in Ref [9] also shows similar features for an insulating VAD anode. Other features of EVOs appear in numerous references regarding research and simulations of pulsed electron beam deposition [6], [7], [10].

Figure 4 is a schematic diagram of Ken Shoulders EVO generator [1]. A 10 to 20 KeV pulse of electrons is emitted by the sharp cathode at 12a and an EVO emerges and is caused to strike a secondary substrate at various angles or is photographed as in Fig. 1. This set-up to produce EVO's has several modifications making it distinct from the deposition processes. These are:

- The cathode is very sharp, making the electron beam small in diameter
- The cathode is placed very close to the target
- The target is a "high quality" insulator like quartz

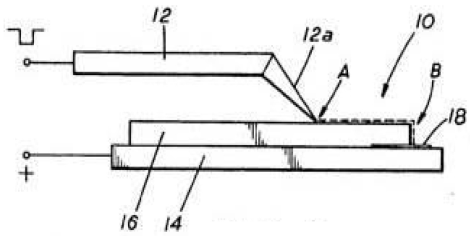


Figure 4. Schematic representation of EVO generator. A is a point cathode, 16 is thin insulating material, 14 is a conducting ground plane. A negative pulse is applied at A [1].

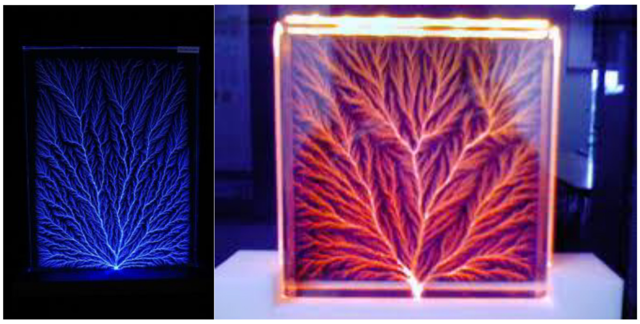


Figure 5. Lichtenberg Figure (Linac Tree, Wikipedia).

- The target is thin, and placed on a conducting ground plane
- The EVO's are observed in single pulse experiments versus high pulse rate for film deposition.

Figure 4 in Ref. [8] shows a series of snapshots of a VAD discharge on Cu from which plume velocity of 10,000 m/s can be estimated. From snapshots in Fig. 8 of Ref [10] for a PED discharge on an insulator, a plume velocity of 10,000 m/s can also be estimated.

To illustrate an effect of a mC of charge in a solid, Fig. 5 presents photos of a Linac Tree (Lichtenberg figure) [13]. The lightning-like pattern is produced by a milli-Coulomb dose of 60 MeV electrons incident across the entire face of a Lucite block. Putting your body near the block makes your hair stand on end. On the bottom of the block a grounded nail is struck with a hammer and the shock causes the trapped electrons to avalanche to the nail, damaging the Lucite block, leaving behind the beautiful Linac Tree. Question: What happens when the same milli-Coulomb of charge enters an insulator to a 10^{10} smaller volume of a ~ 2 μm diameter, 2 μm thick cylinder of material?

A final example to flush out the landscape of the effects of directed energy impingement on solids, I describe the shaped-explosive charge anti-armor munition as it may be directly related to EVO's. Fig. 6 shows a schematic representation of a shaped charge munition [14]. The high explosive (HE) melts the copper liner beginning at the Vee. As the detonation progresses the copper liner is expelled as an elongated slug of melted copper with a velocity of 10,000 m/s. Figure 7 is high speed photography of typical stages of a shaped charge. As a frame of reference – explosive front velocity of C4 high explosive is 1,680 m/s. The appearance of the slug is similar to an EVO in flight. The Cu slug penetrates thick steel armor by ***plastic flow***, not melting. Figure 8 shows how a shaped charge penetrated

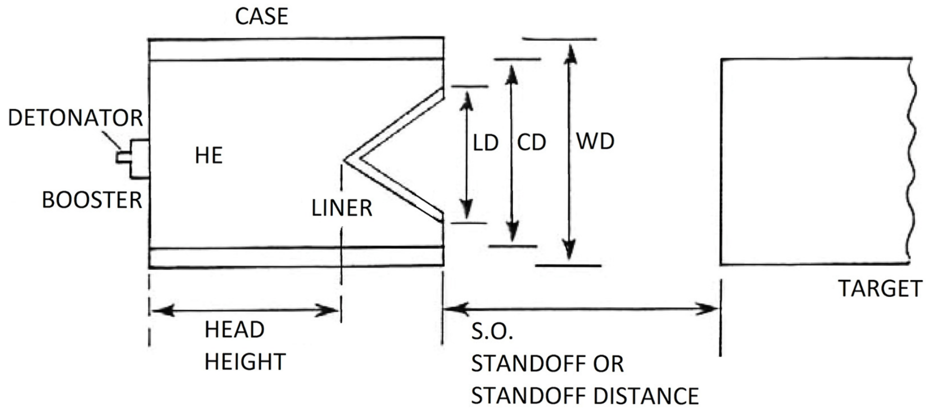


Figure 6. Schematic representation of a shaped-charge munition [13].

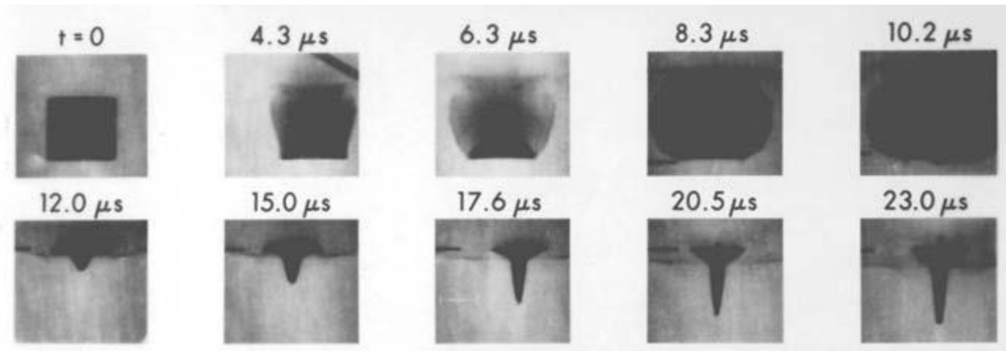
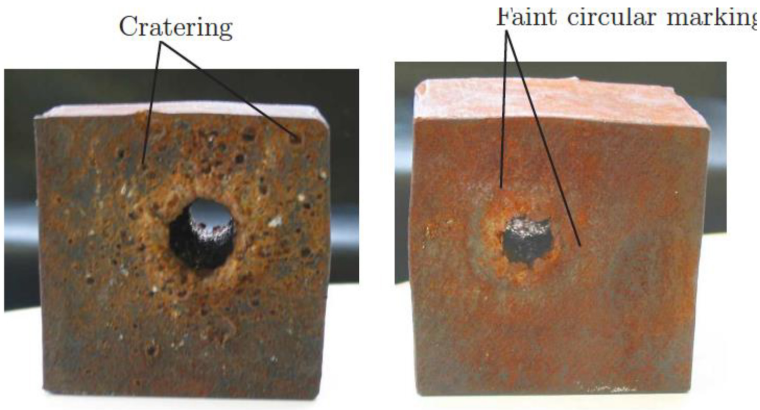


Figure 7. High speed photographs of detonation stages of a typical shaped charge [14].

a 10 cm thick armor steel plate. The pressure of the copper slug travelling at 10,000 m/s exceeds the Hugoniot elastic limit (HEL) where a solid flows like a liquid [15].

Now let's examine the EVO generator depicted in Fig. 4. The cathode is a sharp point placed close to the target so the area of impingement on the insulating target is small. Figure 9 shows a heuristic (common sense) version of what may occur when 15 kV, 100 ns, $\sim$mC pulse of electrons impinges on the target. In $\sim$100 ns, electrons stop in the insulator, depositing their several Joules of energy. In <1 μs, A slug of material melts that is $\sim$2 μm deep, $\sim$2 μm in diameter. The image charge induced in the nearby underlying ground plane aids in tight diameter control of the electrons as they penetrate over the pulse length time. This feature is not present in PED and VAD due to the thick insulating target used for deposition. The electrons spread laterally during the pulse to a greater extent than in the EVO target due to the repulsion of previously embedded charge. In $\sim$1 μs, the melted material is expelled from the surface by a combination of Coulomb explosion of trapped charge, and push from vaporized material.

Underneath the melted slug (due to energy loss of electrons, subsurface is hotter that the surface), and lateral pressure from the strain in unheated material surrounding the melt, the slug elongates, reaching a velocity of 10,000 m/s as it separates from the insulator, leaving a crater behind. As point of reference, a 5μm x 5μm x 5μm volume of



(a) The entry wound of the uppermost block of the penetrated target.

(b) The exit wound of the uppermost block of the penetrated target.

Figure 8. Photographs of hole in steel armor plate caused be strike of shaped charge munition [14].

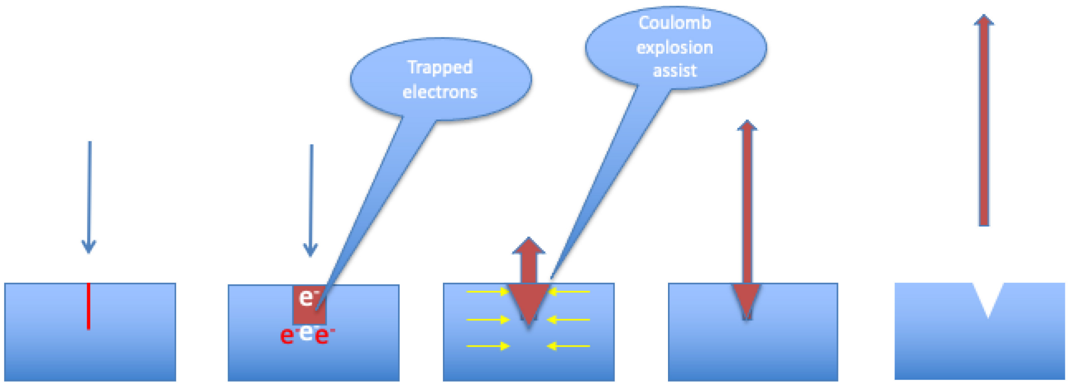


Figure 9. Schematic representation of strike of electron pulse on an insulator (see text).

insulator material corresponds to $\sim 10^{-10}$ grams. Figure 10 is a schematic of the 10,000 m/s liquid slug penetrating a target by hydrodynamic flow, leaving a clean hole behind. Again, the micro shaped-charge penetrates targets by plastic flow, not melting. The slugs will leave carved out tracks when launched parallel to surfaces, and the motion of the slugs are influenced by electric/magnetic fields due to small mass and the fact that they are charged. Another mechanism according to simulations can be that the electrons emerge perpendicular to the surface with a velocity of 100,000 m/s due to Coulomb explosion and the electrons drag the melted material behind them at velocities up to 30 km/s [10]. Figures 2 and 8 show the similarities in the ability of high velocity slugs to penetrate materials.

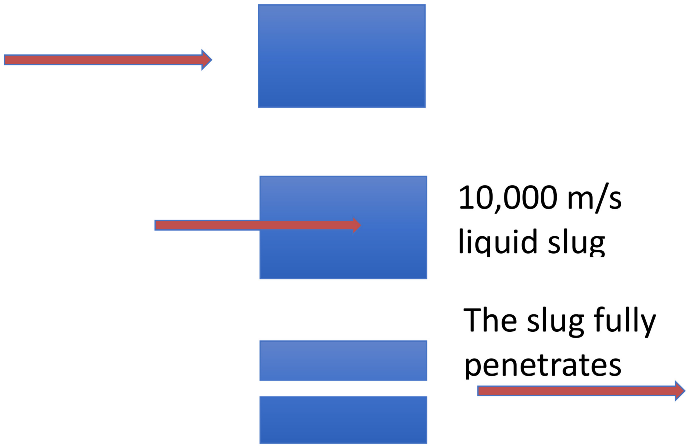


Figure 10. Schematic representation of strike of micro liquid slug of anode material on a solid (see text).

3. Summary

In conclusion, the characteristics of EVO's or charged clusters presented in the literature were compared to the characteristics of pulsed deposition systems and shaped-charge munitions. EVO's are generated with a single 10-20 kV, $\sim$100 ns electron pulse on a high quality, thin insulator on a ground plane. The sharp point cathode, thin insulator on a ground plane, and close proximity of the cathode and anode seem to be the unique features of the generator as compared to deposition pulses of electrons and photons. In the latter case the cathode spot is large by comparison to maximize the amount of material deposited with each pulse. It is suggested that EVO's are not a new form of matter (dense ball of electrons with diameter of microns containing 10^{23} electrons per cubic centimeter) but a manifestation of known thermomechanical and electromagnetic mechanisms acting on the thermal insulator, a small portion of which is rapidly heated that then generates a micro shaped charge. Many of the attributes of EVO's or charged clusters can be explained by this model.

Thermomechanical/electromagnetic modelling would be very useful to validate or invalidate the present hypothesis.

References

[1] See U.S. Patents by K.R. Shoulders. 5,018,180 (1991) - 5,054,046 (1991) - 5,054,047 (1991) - 5,123,039 (1992), - 5,148,461 (1992).

[2] Lutz Jaitner, "The Physics of Condensed Plasmoids and LENR", The Physics of Condensed Plasmoids (CPs) and Low-Energy Nuclear Reactions (LENR) 1-101, February 2020, lutz.jaitner t-online de, www.condensed-plasmoids.com.

[3] A history of EVO's and charged cluster research may be found at, https://condensed-plasmoids.com/history.html.

[4] Ken Shoulders produced numerous unrefereed monographs that may be accessed by searching Ken Shoulders EVO; What's an EVO? by Ken; or visit http://blog.hasslberger.com/2007/10/ken_shoulders_evos_exotic_vacu.html

[5] K.R. Shoulders, S. Shoulders, "observations on the role of charged clusters in nuclear reactions", J. New Energy, **1**(3) (1996) 111.

[6] Muddassir Ali, "Modeling of plasma dynamics during pulsed electron beam ablation", Ph.D. Thesis, Laurentian University, Sudbury, Ontario, Canada (2017).

[7] Ying Qin, Chuang Dong, Xiaogang Wang, Shengzhi Hao, Aimin Wu, Jianxin Zou, Yue Liu, “Temperature profile and crater formation induced in high-current pulsed electron beam processing”, J. Vac. Sci Tech. A **21**, (2003) 1934; https://doi.org/10.1116/1.1619417.

[8] Zhipeng Zhou, Andreas Kyritsakis, Zhenxing Wang, Yi Li, Yingsan Geng, Flyura Djurabekova, “Direct observation of vacuum arc evolution with nanosecond resolution”, Sci. Reports **9** (2019) 7814; https://doi.org/10.1038/s41598-019-44191-6 1.

[9] Peng Zhang, Tungwai Leo Ngai, Zhi Ding, Yuanyuan Li, “Erosion craters on Ti3SiC2 anode”, Phys. Letters **A 378** (2014) 2417–2422.

[10] M. Nistor1, N.B .Mandache, J. Perrière, “Pulsed electron beam deposition of oxide thin films”, J. Phys. D: Appl. Phys. **41** (2008) 165205; doi:10.1088/0022-3727/41/16/165205.

[11] S.S. Harilal, C.V. Bindhu, M.S. Tillack, F. Najmabadi, and A.C. Gaeris, “Internal structure and expansion dynamics of laser ablation plumes into ambient gases”, J. Appl. Phys. **93**, (2003) 2380.

[12] D.B. Chrisey, G.K. Hubler, *“Pulsed Laser Deposition of Thin Films”*, Book Editors, (Wiley Interscience, NY, 1994).

[13] An internet browser search will reveal many descriptive sites for Lichtenberg figures (Linac Tree).

[14] William Walters, “Introduction to Shaped Charges”, Army Research Laboratory Report ARL-SR-150, March 2007.

[15] Y. Ashuach, Z. Rosenberg, E. Dekel, “On the spall strengths and Hugoniot elastic limits of some strong ceramics”, AIP Conference Proceedings **955** (2007) 473. https://doi.org/10.1063/1.2833106