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Research Article

Observation of Macroscopic Current and Thermal Anomalies, at High Temperature, by Hetero-structures in Thin and Long Constantan Wires Under H_2 Gas

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Abstract

Since 2011, we introduced into LENR field, the use of a Constantan (Cnst) alloy to absorb/adsorb proper amounts of H_2 or D_2 and to generate thermal anomalies even at low temperatures (>200°C). We developed a reactor with a core of sub-micrometric layered Cnst wires that produced measurable excess power (almost reproducible). Subsequently, we used fiberglass sheaths as electrical insulation and found out that this material actually improves reactor performance. In the most recent configuration, we studied the effects of adding Fe nanolayers to the Cnst wires and of including several small knots along their extension, actions that resulted in a larger excess power that grew with increasing wire temperature. We detected a new electric effect: the generation of spontaneous voltage between the ends of a floating wire in the reactor. We performed tests to study results in agreement with Inverse Rydberg Matter model by L. Holmlid.
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1. Constantan alloys as H_2-Dissociation Catalyzers

Our investigations concerning the ability of metals such as palladium (Pd) and nickel (Ni) to absorb D_2 and H_2, and to generate anomalous heat at high temperatures, gained new momentum following the introduction of Constantan alloys to LENR research in 2011.

Our original idea was to create a low-cost material able to replace the very expensive (and mechanically weak) palladium in LENR experiments.

We focused our interest on the family of copper-nickel Constantan alloys as materials that fit our purposes because of their ability to dissociate molecular hydrogen [1]. In particular, we selected a low-cost commercial material called ISOTAN44, with atomic composition $Cu_{55}Ni_{44}Mn_1$ (Isabellenhütte Heusler, Germany). Together with a high H_2-diffusion coefficient at high temperature, this material offers good mechanical resistance against the aging effects of the thermal cycles and H_2 absorption/desorption. Moreover, it has very large values of (calculated) catalytic power with respect to hydrogen dissociation, as shown in Table 1.

We demonstrated experimentally that Constantan at nano-/micrometric size and at low temperatures ($T > 120°C$, in comparison with about $2000°C$ for tungsten) is able to catalyze the dissociation reaction $H_2 \rightarrow 2H$ and absorb/adsorb atomic hydrogen even inside the bulk of the lattice, as well as at the surface. The demonstration was reported in Ref. [1], chapter IV, points 18 and 19, as follows: 18) To get deloading we put the cell under a dynamic vacuum and increased the temperatures. 19) After several hours, we got the original starting value of $R/R_0 = 1$, meaning that the test was fully successful. The fact that H_2 decreases the resistivity of Constantan was first reported in Ref. [2].

Table 1. Catalytic power of different metals and alloys with respect to the reaction $H_2 \rightarrow 2H$, computed in Density Functional Theory [20].

	ΔE (eV)
Ni0.3750 – Cu0.6250	+3.16
Ni0.6250 – Cu0.3750	+2.86
Ni0.8125 – Cu0.1875	+2.10
Ni	+1.74
Ni0.1825 – Cu0.8175	+1.57
Ag0.8125 – Pd0.1875	+0.57
Ag0.625 – Pd0.375	+0.51
Ag0.1875 – Pd0.8125	+0.51
Pd	+0.42
Cu	–1.11
Ag	–1.42

In our experiment we employed Constantan wires of length 100 cm and diameter 0.1– 0.2 mm (Fig. 1). To increase their effective surface available for catalytic processes, wires were subjected to specific thermal/electric treatments that created sub-micrometric and multilayered structures at the surface and deeper in the bulk (Fig. 2). The sub-micrometric structures were simply created by oxidation, with a threshold temperature of 600°C in free air. Such structures are somewhat similar to hetero-structures.

The treatment includes electric high peak power pulses (20 kVA/g of material) with a rise time $T_r < 1\,\mu s$, corresponding to a current density $J > 50$ kA/cm^2, even neglecting skin effects. Such pulses induce extremely fast thermal treatments (warming→cooling) and shock waves. A rough evaluation by fast photo-camera of the color of light emitted from the wire revealed a surface temperature even larger than 1000°C in some tests. At the end of the process we observed glassy materials formed on the wire surface.

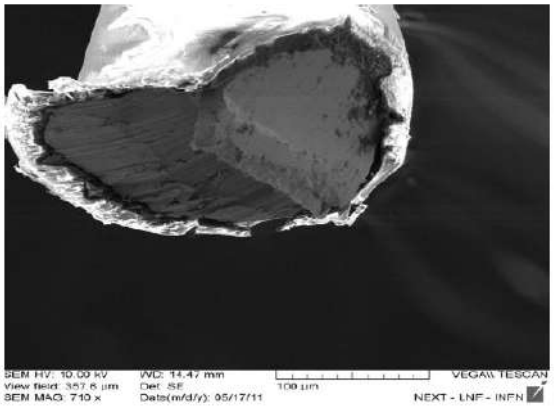

Figure 1. SEM image of the cross section of the Constantan wire as provided by Isabellenhütte Heusler. The plastic cover of the wire is visible as the light area rounding the wire.

This treatment produces sub-micrometric geometries, a sort of chaotic mixture of Ni, NiO, Cu, CuO, $Ni_xCu_yO_z$, reducing/avoiding, at the same time, the usual deleterious self-sintering processes due to high temperatures. SEM observations revealed that the wires so treated had a large number (up to 700 in some samples) of multilayered structures with thickness of 20–100 nm.

The number of layers was roughly characterized by preliminary experiments using 10, 20, 50 and 100 pulses, by SEM and "oblique" cross section of the wire. Among other parameters, we observed that the distance between layers decreases with an increase in the number of pulses. Sadly, the original documents (papers and CD) of this preliminary testing, located in another laboratory, were destroyed by a "third party" in February 2015, together with other materials and documents.

Our treatment was inspired by the Melt Spinning and Quenching metallurgical process, extensively used by Prof. Yoshiaki Arata and his collaborators (Osaka and Tohoku Universities, Japan) to produce nanomaterials (palladium, or Pd_xNi_y, both dispersed into a matrix of ZrO_2 at 65(%) concentration) for his Solid State Fusion devices under

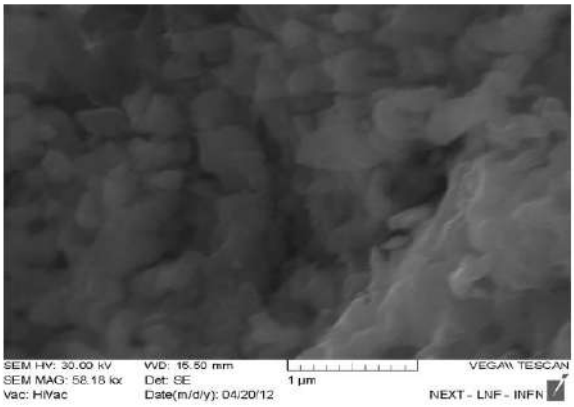

Figure 2. SEM image of the Constantan wire surface at micrometric scale after repeated high-power pulse treatments.

interaction with D_2/H_2 at 150–300°C, pressurized up to 60 atm [3]. In the quenching process their cooling rate was over 100,000 K/s. The important feature of Arata's technique was this "ultra-fast quenching" which yields glassy-like materials. Arata used fast rotating Cu disk where the mixture of palladium (35%) and zirconium (65%) was dropped in a melted state (about 1600°C). Instead of using this kind of disk, we employed ultra-fast powerful electric pulses with fall time <1μs. We needed only cooling from about 900°C down to 650°C. With very long and thin wires it is easy to perform this in a short time, just by natural cooling, because of the dependence of emitted power as T^4 (in Kelvin), i.e. the Stefan–Boltzmann law.

2. First Generation Experiments: the Introduction of Constantan wires

The dissipation reactor we designed to test the new generation Constantan wires consisted of mica sheets (of the type used in electrical heating elements) supported on a central stainless steel (SS) tube ensuring electrical insulation, on which two wires, one active (the surface-modified constantan wire) and the other inert (Ni–Cr control wire), arranged in parallel and helicoidally wound. Because the Ni–Cr wire is intrinsically stable against oxidation or other stresses, it was used to heat the reactor itself (via "indirect" resistive heating, i.e. by radiation and conduction by gas). The core of the reactor was contained inside a borosilicate Schott Duran glass tube with a wall thickness of 3 mm. Temperatures at the external glass wall and inside the reactor were detected by means of several Type K, SS-screened, MgO insulated, thermocouples (diameter 1.5 mm) [1].

Calibrations were made in noble gases (helium, argon) with different power levels applied to the inert wire. The first test was conducted in an atmosphere of H_2/Ar mixture in the ratio 75/25 at 7 bar of total pressure. The power input was 48 W. Figure 3 shows the behavior of the measured quantities over time. The green color line represents the temperature of the external borosilicate wall, while red shows the temperature close to the mica inside the reactor. The key monitor parameter is the ratio R/R_0 between the resistance of the wire at a given temperature T and at room

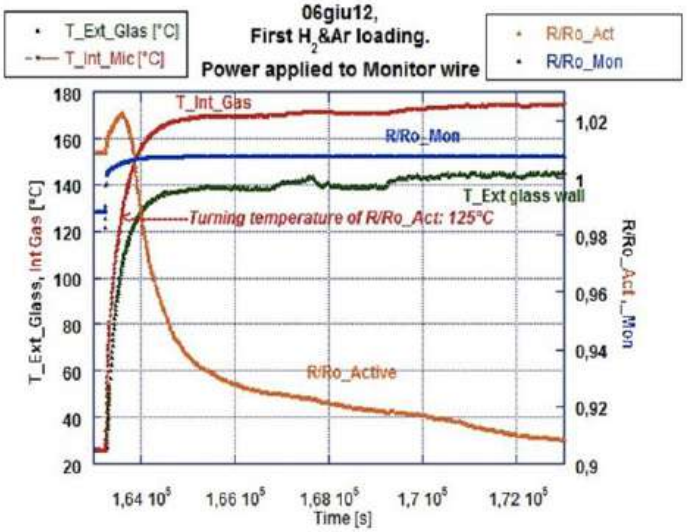

Figure 3. Time behavior of the measured quantities during the first loading by H_2/Ar mixture: temperature of the external glass (*green*), temperature of the internal mica support (*red*), R/R_0 of the inert wire (*blue*), R/R_0 of the active wire (*orange*). Ar inert gas introduced also to reduce H+H probability of uncontrolled recombination to H_2 in the reactor atmosphere.

temperature T_0. For Constantan, this ratio, because of hydrogen interaction, decreases with increasing temperature and time. In the blue line we indicate R/R_0 for the inert (Ni–Cr) wire and in the orange line R/R_0 for the active (Constantan) wire. Recall that one of the key characteristics of Constantan is its normally excellent resistivity stability ($\pm 1\%$) from –75 up to 500°C.

We observed that when the temperature inside the reactor reached 120°C, the R/R_0 of the active wire fell to 0.92 in about 2500 s and to 0.88 in 100,000 s. Correlated with this decrease in resistance, we also observed an increase in excess output power of the reactor. Coinciding with this, all temperatures in the reactor increased. The external glass temperature increased from about 140°C to 150°C; the SS tube temperature from 168°C to 190°C, and the gas temperature (close to the mica) from 170°C to 195°C (Fig. 4). These variations are unrelated to changes in room temperature. Instead, room temperature instabilities somehow helped the anomalous heat generation, perhaps by introducing non-equilibrium conditions. In fact, after a long time, room temperature went back to its initial value, while heat production continued to increase.

During several tests performed in Frascati with mainly Agilent instrumentation (in addition to many ancillary home-made instruments), the excess power ranged between 2 and 12 W (reaching 12 W a few times) at the reference input power value of 48 W. When excess heat was produced, it was typically in the range of 5–10 W. We found no difference in operating the reactor at constant current and constant voltage. Most of the time it was in the constant current regime.

After the National Instruments Annual Meeting (NI-Week, August 2012, Austin, TX, USA), the reactor at Frascati Laboratories, Italy, was disassembled, shipped and reassembled in the USA where it was operated in a public demo for three days. During this event, we observed the highest values of maximum excess power for this experimental set-up: about 21 W with indirect heating (power applied on the inert wire) and about 25 W with direct heating of the active wire with input power of 48 W. Just after NI Week, the reactor was again shipped to South Korea for our participation at the ICCF17 conference at Daejeon. Even there, after overcoming difficulties with the new strict safety rules and conditions of air travel from USA (no gas apart from air inside and no vacuum or pressure conditions allowed), the reactor functioned normally with reasonably reproducible results: 5–15 W of anomalous excess heat with 50 W of electric input power. The values seen were lower than in the test performed during NI-Week. Moreover, for safety reasons, the reactor was operated for most of the time in Constant Voltage regime, both at NI-Week and ICCF17.

After returning to Frascati and performing several cross checks, we realized that the new NI system (the hardware and software set-up since August 2012) in our hands had underestimated the value of electric input power in the regime of Constant Voltage by 11.11% in the range of input power of 40–60 W, i.e. that used in the experiments. Considering this unexpected problem, the real values of AHE power would change to: 8–20 W at Ni-Week, 0–10 W at the ICCF17 Conference (assuming similar hardware arrangements).

We note that all the data were and are fully correct in the constant current regime. The reported lower values are however closer both to our starting values in Frascati and to the results of the subsequent experiments performed by the Martin Fleischmann Memorial Project group which used a batch of Constantan wire with a different starting composition from the old pre-1970s batch we used in the first series of experiments. See Section 3 for further details.

Regarding the overall better performance during NI-Week, in the absence of any systematic study, we can only suspect a positive effect from an accident that happened during the preparation of the set-up: some vapor of silicon oil from the rotary pump went inside the reactor chamber. We did try to remove the possible residual deposits by heating the wires. Anyway, we feel that such an accident was a further strong indication of the catalytic origin of the AHE effect, at least with our materials and operating parameters.

3. Second Generation Experiments: the Addition of Glass

The successive series of experiments exhibited unsatisfactory overall reproducibility. Using SEM/EDS/ICPMS analyses, we found out that the first batches of raw material we used in our experiments, which were produced before 1970, had a composition different from those we used later. Analyses revealed iron contamination in the order of 1000–5000 ppm, and locally up to 10,000 ppm.

Because of a severe budget cut in late 2013, we were forced to redesign and reschedule our experiments with the purpose to study again more deeply some of the most interesting effects obtained in the past and, if possible, to increase the AHE.

In the new experimental set-up we modified the geometrical arrangement of the wires inside the reactor [4]. We used three wires instead of two: a 500-layer Constantan wire, a 2-layer Constantan wire and a platinum wire for control and monitoring purposes. They were inserted inside fiberglass sheaths ($L = 100$ cm, $\Phi_{\text{ext}} = 1$ mm, produced by SIGI–Favier, Italy–France Company). Each fiber was porous, of 5 μm mean diameter, and closely braided together. The braid was then twisted around the central SS support that was likewise covered with a fiberglass sleeve with internal diameter of 12 mm. As before, the core was inserted into the thick-wall borosilicate glass tube previously used.

Since February 2013, all the sheaths were embedded in a $Sr(NO_3)_2$ diluted solution and further decomposed in SrO by thermal treatment. Strontium is a material with a low work function for electron emission ($W = 2.59$ eV), similar to the calcium oxide used by Yasuhiro Iwamura at Mitsubishi Heavy Industries Laboratories (Yokohama, Japan) since 1999. Electron emitter materials are empirically recognized to have "beneficial effects" on LENR reaction. We have studied the effects of calcium, barium, strontium and magnesium in electrolytic environment, since about 1995. Iwamura, independently, adopted CaO in his famous transmutation device (2002, JJAP) by flowing deuterium gas. Moreover, he showed that MgO is not effective, similarly to our electrolytic experiments (barium worked best, but it is toxic).

We calculated the emitted power using Stefan–Boltzmann law (emission proportional to T^4, in Kelvin) for the

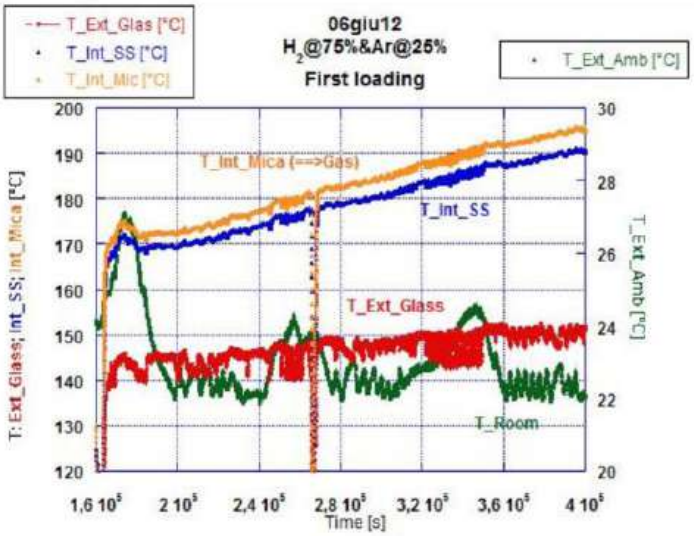

Figure 4. Temperature of the external glass wall (*red*), the internal SS tube (*blue*), the internal mica support (*orange*) and the ambient (*green*) as a function of time.