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Research Article

Improved Stability and Performance of Surface-Modified Constantan Wires, by Chemical Additions and Unconventional Geometrical Structures

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Abstract

At INFN-LNF, starting in 2011, we have investigated the behavior of the Constantan (Cst) alloy ($Cu_{55}Ni_{44}Mn_1$; ISOTAN44) with hydrogen and/or deuterium (H_2/D_2) absorption and the generation of anomalous excess heat (AHE) at high temperatures (i.e. $>$200°C). To further improve the intrinsic, excellent catalytic proprieties of Cst in $H_2 \rightarrow 2H$ dissociation, we subjected the surface to repeated cycling of "flash" oxidation (pulsed power up to 20 kVA/g), obtaining sub-micrometric particles of *mixed composition* (Cst–NiO_x–CuO_y–$Cu_xNi_yO_z$) and reducing deleterious self-sintering problems with nano-materials at high temperatures. Despite the fact that results with thin, long wires ($\Phi = 200$ μm, $l = 100$ cm) were generally positive and excess power (10–20%) was frequently recorded (5–10 W at 50 W input), reproducibility remained unsatisfactory. Later, we realized that iron impurities (up to 1% in the old, pre-1970 batch of Cst) enhanced AHE generation, especially at $T > 500$°C. Since 2014, we added $Fe(NO_3)_3$ solutions both to the Cst sub-micrometric surfaces (during flash oxidation process),and to borosilicate glass sheaths (SIGI-Fabier; micrometric fibers, previously wetted-dried with $Sr(NO_3)_2$ solution) where wires were inserted (as electrical (continue on p.10)
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insulation). Recently, we adopted the methodology of making several knots along wires (holes 150–200 μm), later coated multiple times with an iron solution. We introduced potassium into the solution (which is known as a promoter of iron catalytic performance) and, eventually, manganese to prevent or decrease potassium evaporation. H^+ electro-migration, due to large current (>2 A) flowing along the Cst wires as well as high magnetic fields at the center of the knots and on iron micro-particles (absorbing hydrogen at high temperatures) deposited inside micro-holes of Cst, is supposed to play a role in AHE. The cylindrical thick-glass wall reactor had a volume of 250 cm^3; operating pressures were 0.1–3 bar; the gases used were helium (for calibration), D_2, pure or mixed with xenon (which has ultra-low thermal conduction). In a difference from our previous experiments, we employed *only* D_2 and not H_2. The three wires we used were: platinum for calibration purposes and "indirect heating" of Cst wires, and Cst with 41 and 71 knots. Input power range was 10–90 W. Up to now we have observed that the AHE, measured at the external wall of the reactor, reached the largest values (over 85 W, by *comparison/extrapolation* with platinum under helium, isoperibolic procedure) when the highest input power (90 W) was applied to the 71-knots Cst in *D_2 mixed with xenon*. Further work is necessary to evaluate the effects of: I versus J, numbers of knots, gas mixtures, temperature (including electron emission from SrO: inspired by Iwamura's experiments**,** and the Richardson law).

1. Introduction

The main motivations for our new experimental work were as follows.

(1) Improving the reproducibility of results after realizing (in 2014) that some iron impurities in the main material (Constantan, an alloy with composition $Cu_{55}Ni_{44}Mn_1$, brand name ISOTAN44 from Isabellenhutte) and potassium (at low concentration, about 10% atomic in respect to Fe), are crucial to get positive results.
(2) Increasing the amount of the Anomalous Heat Effect (AHE) previously (2011) detected by our group using the Constantan (Cst) with its surface modified (sub-micrometric shape) and exploring the role of wire knots.
(3) Further studying the spontaneous anomalous voltage and current detected along wires once they absorbed hydrogen or deuterium.

Aside from other effects, AHE is mainly due to the interaction of hydrogen (H_2) or deuterium (D_2) gas absorbed and/or adsorbed by the Cst itself and/or on host sites, by enhancing the effect of nanostructures (pioneered by Y. Arata), under forced *non-equilibrium conditions*, even local, of any type. Up to now, the following phenomena leading to non-equilibrium conditions have been explored in the LENR field: electrical (everybody); thermal (everybody); hydrogen or deuterium electro-migration (F. Celani); deuterium flux (Y. Iwamura); magnetic; laser (Cravens and Letts; L. Holmlid and S. Olafsson; others); radiation stimulation (several); ultrasound (R. Stringham); fractures (A. Carpinteri [1]); nano-magnetism and energy localization (Brian Ahern); femto-chemistry (F. Celani); etc.

We note that in our experience, the AHE origin and process with Cst is similar to that with palladium. Nevertheless, Cst has the advantages of a significantly lower cost and higher robustness; in fact, AHE was still present after months of experiments and after repeatedly cycling the wires between several hundred degrees Celsius and room temperature. Unfortunately, we also observed that the catalytically active surface tends to become less effective upon exposure to high temperatures under vacuum or in the presence of an inert gas, probably due to sintering and loss of the key nanostructured surface produced by current pulses during wire preparation.

As described in our previous reports, we selected Cst because of its catalytic activity in hydrogen dissociation [2], providing around 3 eV for the dissociation of H_2 (or molecular deuterium, D_2) from molecular to atomic state ($H_2 \rightarrow 2H$). We typically used Cst in the shape of long (l =100 cm) and thin ($\Phi = 0.2$ mm) wires, with weight 278 mg. Their surface was made sub-micrometric (some particles have dimensions less than 200 nm, see SEM in Fig. 10) by means of high-peak power and electric-thermal treatments: the typical energy was as large as 600–1000 J/g of Cst and produced several hundred times by pulses with a width of 50 ms [3]. Because of such powerful, fast rise/fall times

(<1 μs) and short duration pulses, the wires incandesce in red (indicating a temperature of about 800–900°C), oxidize in some milliseconds of time and rapidly quench at the end of the pulse. In air, the oxidation conditions vanish at about 600°C. The energy density (J/g) is evaluated assuming no *skin effects*, but the effective density is larger. For some aspects the flash oxidation we developed is similar to the "explosive" preparation procedure adopted for production of nanomaterials, because of the formation of craters at the surfaces.

The procedure we developed resembles the highly sophisticated, melt-spinning and quenching procedure adopted and optimized by Prof. Yoshiaki Arata and other groups (Osaka and Tohoku University, Japan) since 1995, to produce nano-powders of Pd and Pd–Zr in the field of Solid State Fusion (the name given to LENR by Prof. Arata) [4]. We were inspired by this procedure and modified it for the use with wires.

In previous successful experiments, after prolonged cycling at high-low temperatures, under H_2 gas at high temperature, the SEM of the wires showed the presence of fracturing phenomena due to hydrogen embrittlement: the typical dimensionality of the particles was *smaller* with respect to an untreated sample used as reference, then, a useful effect.

2. Description of Experimental Set-up: Some Key Details

The experimental set-up is basically similar to that developed and published since 2011 [3]. In addition, we performed several modifications to the wire geometry with the introduction of knots and adopted a new procedure for the chemical impregnation of the borosilicate glass sheaths. In the following, we describe only the most recent set-up (started on 20/05/2016, and still in operation). We used only D_2, not H_2. D_2O was also employed in the preparation of the solution for impregnating the sheaths and coating the knots. It is possible that some residual hydrogen is coming both from HNO_3 used for preparing iron nitrate and from water adsorbed by the hygroscopic glass sheaths (when assembling the reactor). From the isotopic point of view, H_2, HD, D_2 will be present, at different concentrations. The amount of radioactive tritium, i.e. tritiated water (T_2O) in the heavy water (D_2O) that we used is quite low: measurements by Liquid Scintillation Counting (LSC) gave values $<$250 dpm/ml (disintegrations per minute/milliliter), i.e. $<$4 Bq/ml. The half-life of T, a β emitter, is 12.3 years and its specific activity (in the gas phase at *RT*) is 3.6×10^{14} Bq/g. Local internal excitation by β-radiation (end point at 18.59 keV) appears unlikely. For radiation stimulation we used a weak (10 kBq), γ-source (decay of natural Th^{232}, sintered with tungsten, i.e. usual TIG electrodes used for welding), well enclosed inside a thick SS cylinder, just positioned outside the wall of the glass reactor.

The overall system, which is quite complex and was developed using several unconventional procedures, is based on the following features and facts:

(1) Thick wall (3 mm) borosilicate glass tube (Schott-Duran, further processed by glass blowers Spaziani Rolando Srl), $l = 25$ cm, $\Phi =$ 32–40 mm. Gas pressures: vacuum, pressurized. The maximum pressure depends on glass temperature for safety limits: e.g. $<$3 bar ABS at 300°C of glass-tube wall temperature.
(2) Platinum wire (usually $l = 100$ cm; $\Phi = 100$ μm). In this specific experiment $l = 102.5$ cm. Platinum has multi-purpose uses: 1) power calibration of the system using inert gas (He); 2) indirect heating of the Cst wires; 3) evaluation of mean wire temperature (i.e. platinum used also as thermometer).
(3) Two Cst wires, $\Phi = 200$ μm. One with 41 knots, the other with 71 knots nominal. The initial length (without knots) were 113 and 127 cm. After tying the knots, the length was reduced to 102.5 and 108.5 cm. During assembly, the length of all wires was equalized to 102.5 cm: the number of knots in the 71-knot wire was reduced to 65. (Because of the previous convention in our log-book, we kept the identification "Cst71.")
(4) Usually, one wire is polarized and the other is left unconnected and used to measure the so-called "spontaneous voltage" (using a high-resolution Fluke 187 multimeter) or current (with a 2-Ω shunt resistance in the milliampere range). The current is limited only by the internal resistance of the wire (about 17–21 ?). The resistance decreases when D_2 is absorbed, similarly to previous (2011–2012) experiments with H_2.

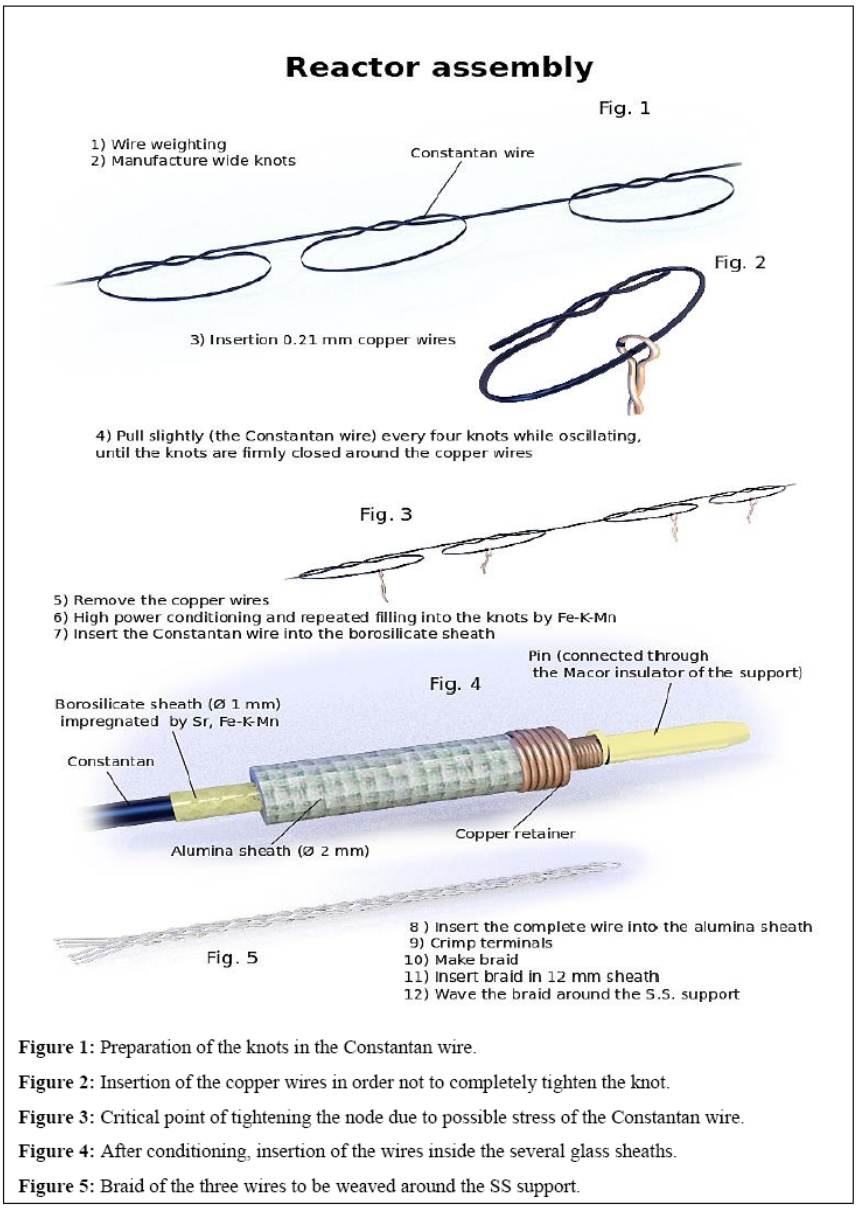

Figure 1: Preparation of the knots in the Constantan wire.

Figure 2: Insertion of the copper wires in order not to completely tighten the knot.

Figure 3: Critical point of tightening the node due to possible stress of the Constantan wire.

Figure 4: After conditioning, insertion of the wires inside the several glass sheaths.

Figure 5: Braid of the three wires to be weaved around the SS support.

(5) Each wire is inserted inside a borosilicate glass multi-filamentary flexible sheath (made by SIGI & Favier) with $\Phi = 1$ mm. Each porous filament has a diameter of 5 μm. The weight of the 1-mm diameter sheath, after burning the oil used to produce the texture of fibers by SIGI, is 1.9135 g/m. Each fiber is immersed in $Sr(NO_3)_2$ solution (made by us, starting from decomposition of $SrCO_3$ by 65% HNO_3 and diluted by D_2O).

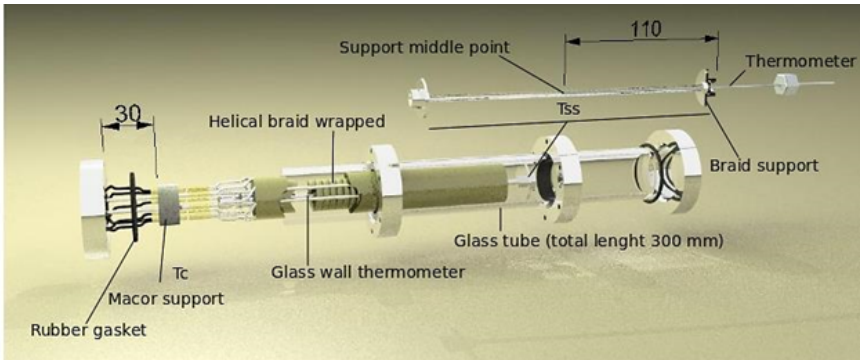

Figure 6. Overview of the reactor once assembled. Regarding temperatures, T_c is external, T_{ss} is internal to the reactor core.

After drying/heating (to 400°C) and the partial dissociation of $SrNO_3$ to SrO (a low work function material for electron emission, similar to CaO used by Yasuhiro Iwamura since 2000, [5] and references therein), the weight increases 44 mg per each meter of wire.

(6) Our conjecture is that SrO, at nanometric size, could have a work function (W) even lower than the value usually reported (about 2.1 eV), similarly to what happens when using cesium [6]. According to this hypothesis, large electron emissions may occur at significantly smaller temperatures (i.e., 500°C instead of the usual 800–900°C) than those enabling emissions from low work function metals (generally mixtures of Ba, Sr, Ca oxides used in vacuum tubes). The electron emission in vacuum follows the well-known law developed by Owen Willans Richardson:

$$J = A_C T^2 \exp\left(-\frac{W}{k_B T}\right),$$

where J is the current density (A/m^2), $A_C = \lambda_r A_0$ a constant with λ_r usually 0.5 and $A_0 = 4\pi m_e k_B^2 e/h^3 = 1.2017 \times 10^6$ A m^{-2} K^{-2}, T the absolute temperature (Kelvin); m_e the electron mass ($9 \times 10^9 \times 10^{-31}$ kg), e the electron charge (1.602×10^{-19} C), k_B the Boltzmann constant (1.38×10^{-23} J K^{-1}), and h is the Planck constant (6.626×10^{-34} J s).

(1) We had seen indications since 2013 that the glass sheaths can play a key-role in the whole reaction [7] and Reference 4 therein), also following the very detailed work of Irving Langmuir on hydrogen absorption on glass bulb surfaces ($H_2 \rightarrow$ 2H dissociation by tungsten filament at $T >$2000 K). Accordingly, the multi-filamentary borosilicate sheaths could absorb huge amounts of H/D just because of the extremely large values of surface (over 10^4 cm^2 for each sheath covering the wire) and its favorable geometry, being almost in contact with the Cst that dissociates the molecular H_2/D_2 to atomic H/D.

(2) *NEW PROCEDURE*. Three wires are inserted into sheaths, and then immersed in a solution of $Fe(NO_3)_3$+$KMnO_4$ in D_2O. The atomic ratio of Fe:K–Mn is 10:1. Potassium is used as a "promoter" of activation for the absorption or desorption reactions of H/D by Fe_xO_Y (mixed oxides, like FeO, Fe_2O_3, Fe_3O_4), similarly to the Cst dissociation properties. Hydrogen is adsorbed inside the iron lattice at high temperatures

Figure 7: Detail of a typical knot after preparation.

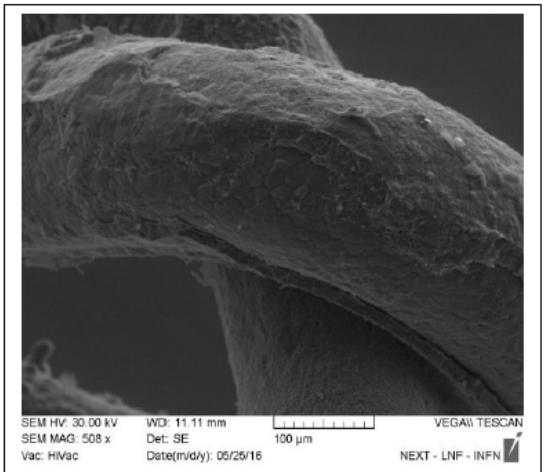

Figure 8: Detail of knot surface showing the irregular shape of material surface.

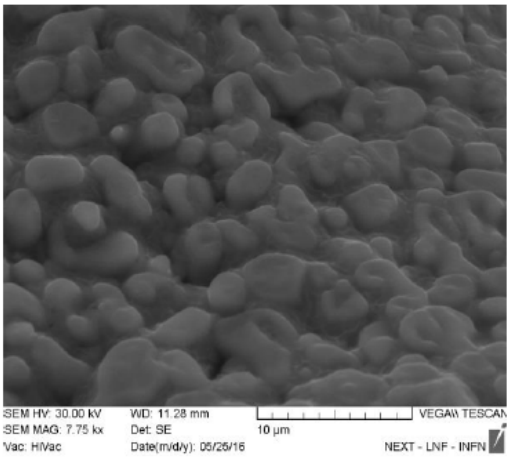

Figure 9: Knot surface view at 10 µm length scale.

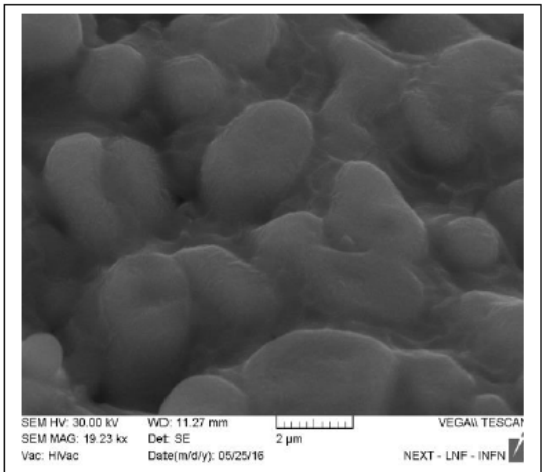

Figure 10: Knot surface view at 2 µm length scale.

Figures 7–10.

($> 500°$C). Manganese is mainly used to reduce potassium "evaporation", keeping the reactivity of Fe–K quite stable over time [8].

(3) In separate tests, we measured an increase of 10–20 mg/m of weight of sheaths due to $Fe_{10}K_1Mn_1O_x$ deposited on the fiber surface, after drying and the partial decomposition of nitrate and the (partial) oxidation at 500°C. The glass sheaths are mechanically stable up to about 60°C.

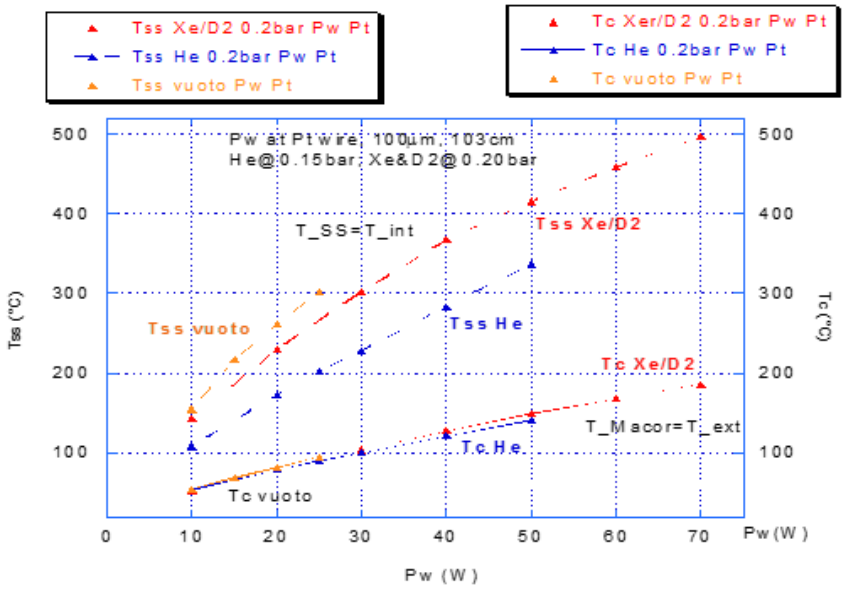

Figure 11.

(4) After drying/heating at 500°C, the glass sheath is inserted into another sheath ($\Phi = 2$ mm), consisting of Al_2O_3, able to withstand without self-damaging, up to 1200°C in continuous operations: avoiding dispersion of glass sheaths (at $T >$650°C) FeKMn, Cst mixed-composition surface, improved electrical insulation.
(5) The three sheaths were closely braided around each other (Fig. 5) and inserted inside another sheath of 12 mm diameter, which provides mechanical stability and further thermal homogeneity.
(6) At their ends, the sheaths are rolled up around the SS tube ($\Phi = 4$–2 mm) central support (covered by a glass sheath). To reduce the problem of sulfur content of AISI 304 (<0.015%), all the SS materials were conditioned at 700°C several times: cleaned with acid etching and ultrasound. Sulfur is usually deleterious to catalysts.
(7) A K-type thermocouple (made gas tight with a SS sheath) is inserted inside the SS tube to measure the inner temperature of the reactor ("T_{ss}" nomenclature in the following).
(8) The three wires are interconnected to external ambient using a MACOR® cylinder ($\Phi = 7$–24 mm) inside the reactor: it is heavy (10 g). Aside from the central hole (4 mm) there are other eight small holes ($\Phi = 1.6$ mm, like the cylinder of a revolver). The MACOR® cylinder is not in direct contact with the main glass-tube wall: there is a 5 mm gap. An overview of the reactor, with MACOR location and the key thermometers, is shown in Fig. 6.

3. Procedure for Wire Preparation: Some Details

The steps of wire preparation procedure, which is quite elaborate, is detailed in Figs. 1–5.

In Fig. 1, steps 1, 2, we show the initial procedure, i.e. accurate weighing of the wire and tying of knots.

In Fig. 2, step 3, we detail the insertion of the copper wire ($\Phi = 0.21$ mm, gold color), in reference to the "*main hole*" see also steps 5 and 6 in Fig. 3.

In Fig. 3, we describe steps 4 and 5 for "locking" the reference copper wire without causing too large stress in the

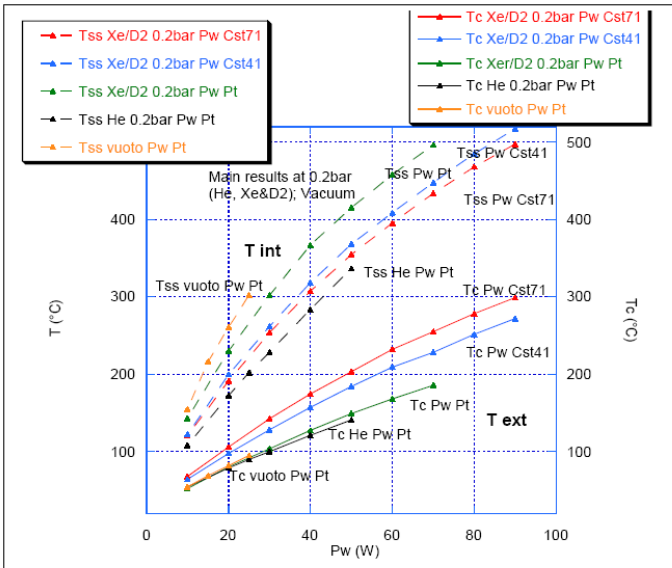

Figure 12: Overview of the *main experiments* performed in vacuum (Pw at Pt), He (Pw at Pt), Xe+D_2 mixture (Pw at Pt, Cst41, Cst71). A large increase of the external temperature Tc with compared to the test with Pt is apparent, when Pw is applied at Cst41 and Cst71 (the best result).

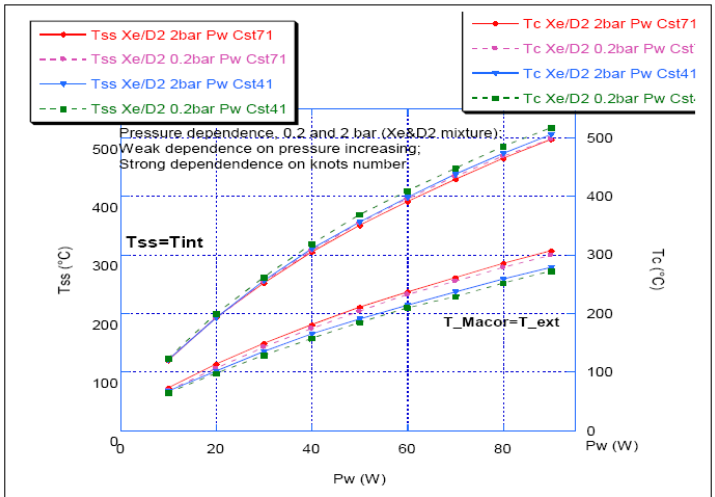

Figure 13: Dependence of internal and external temperatures on gas pressure of Xe+D_2 mixture: 0.2 and 2 bar. The effect is quite weak. At constant input power, temperature depends mainly on the number of knots.

wire. Such steps are the most critical and delicate part of the assembly.

In Fig. 4, steps 6 and 7, we report the *key* processes for "conditioning" the Cst in order to modify the surface from smooth to sub-micrometric (by "flash oxidation" electric pulses) with different chemical compositions (Cst, CuO_x, NiO_y, $Cu_xNi_yO_z$). The main hole and the micro-holes generated by explosive-like pulses on the wire surface are filled with liquid Fe–K–Mn solution several times. Such steps are the most tedious, time consuming (several hours) and risky part of the assembly: the wire can get destroyed because of the combined effects of aggressive chemicals (e.g. liquid nitrate, $KMnO_4$) and extreme thermal and mechanical stresses (e.g. pulsing to very high temperatures up to 900-1000°C and cooling in a few milliseconds). The Cst wires are inserted inside a borosilicate sheath (from SIGI-Favier; $\Phi = 1$ mm), previously wetted and dried, sequentially, with a solution of $Sr(NO_3)_2$ and Fe–K–Mn both in D_2O. At step 8 the borosilicate sheath is inserted into another sheath of Al_2O_3, $\Phi = 2$ mm able to withstand continuously up to 1200°C. At step 9, the ends of the wires are crimped with a gold plated mini-connector. At step 10, the three wires are braided around each other and put, at step 11, inside another borosilicate sheath ($\Phi = 12$ mm) for mechanical stability and thermal homogeneity. (This configuration is not shown.)

In Fig. 5, step 12 the ($\Phi = 12$ mm) sheath is rounded at the SS support, previously covered by a ($\Phi = 4$ mm) glass sheath. The rounded sheath is, at the end, covered with a ($\Phi = 25$ mm) final sheath with an internal diameter of 34 mm (not shown) for mechanical stability and overall thermal homogeneity toward the borosilicate thick-glass reactor.

4. SEM Images

Figures 7–10 show an overview of a typical Cst wire after thermal treatments (for oxidation and structuring of the micrometric surfaces) and Fe–KMn depositions. The actual diameter of the main hole is 160 μm, less than the "stated" 200 μm of the copper reference wire in Fig. 3.

After several cycles of hydrogen/deuterium loading and deloading at high temperatures, the diameter of the particles decreases in a remarkable way, supposing no sintering due to vacuum or inert gases happened. We guess that the "new" addition of Fe–KMn compound at the surface of the wires reduces the "weakness" of Cst toward sintering problems. We note that hydrogen is adsorbed at high temperatures (>500°C) inside iron lattice. Perhaps, the addition of potassium to iron can even reduce the starting temperature of absorption.

5. Main Results

After calibration under vacuum and helium gas with power applied *only* to platinum to avoid sintering of the nanoparticles at the Cst surface (due to high temperatures in vacuum or inert/noble gas atmosphere), the experiments were performed using D_2 at high (2 bar) and low (0.2 bar) pressures. The combined effect of pure D_2 (a cracking agent to reduce dimensionality of surface nanomaterials) and several LowHighLow temperature cycles further promotes deuterium absorption into the bulk of Cst, obtaining *useful aging effects*.

In order to increase the wire temperature, which enhances the AHE, while keeping the external power applied as low as possible, we added xenon gas to pure D_2 at 50% ratio. Among other useful and strange effects, to be fully explored and reconfirmed by us, this noble gas has an extremely low value of thermal conductivity. Most of the results we report are obtained with a Xe–D_2 mixture, mainly at a total pressure of 0.2 bar. Since 2010 [9], we added high-Z noble gas (e.g. argon) to reduce the thermal conductivity of the reactors. We observed that such addition even improved the AHE, but the results were too low in absolute values for us to completely sure they are real. For this reason we moved from argon to xenon (although the latter is quite expensive). Since then, we have speculated about the role of noble gases but we have not reached any firm conclusions.

The results are shown in Figs. 11–15.

Figure 14 shows the behavior of the so-called spontaneous voltage, which increases with the loading of the wire, the concentration of atomic deuterium and temperature.

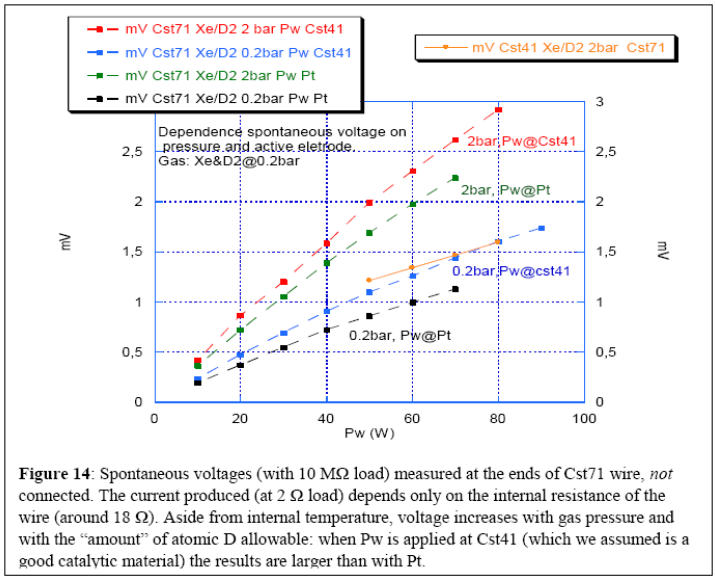

Figure 14: Spontaneous voltages (with 10 MΩ load) measured at the ends of Cst71 wire, *not* connected. The current produced (at 2 Ω load) depends only on the internal resistance of the wire (around 18 Ω). Aside from internal temperature, voltage increases with gas pressure and with the "amount" of atomic D allowable: when Pw is applied at Cst41 (which we assumed is a good catalytic material) the results are larger than with Pt.

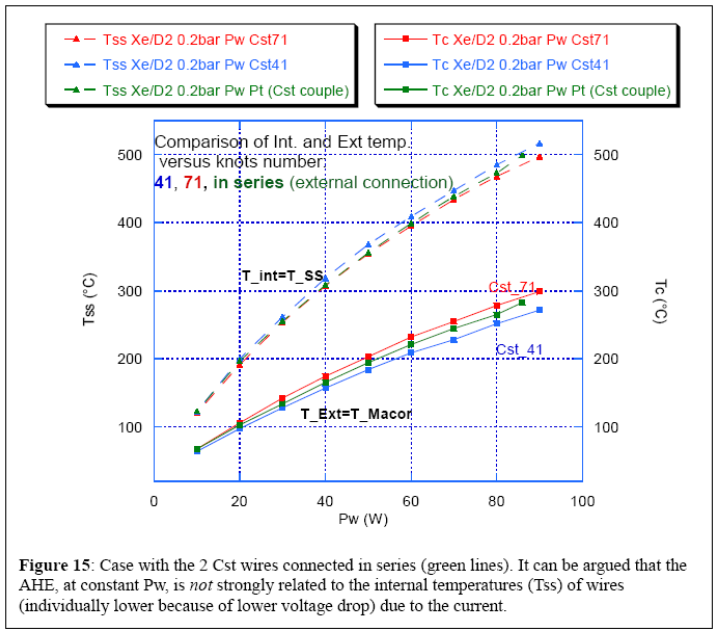

Figure 15: Case with the 2 Cst wires connected in series (green lines). It can be argued that the AHE, at constant Pw, is *not* strongly related to the internal temperatures (Tss) of wires (individually lower because of lower voltage drop) due to the current.

6. Highlights

The addition of Fe–Mn–K mixed oxides to our experimental set-up has caused a significant increase of the AHE compared to our previous similar experiments. The data point toward a complex of phenomena mediated by atomic

hydrogen/deuterium formation, transport and recombination despite pressure and temperature (unfavorable for atomic hydrogen). In fact the energy gain seems to strongly correlate with the process of dissociation and recombination of atomic hydrogen or deuterium.

We also have early indications that the migration of the active species is enhanced by current and voltage in the Constantan.

On the basis of our observations we propose a simplified model of the experiment where atomic hydrogen/deuterium is first formed by exothermic adsorptive dissociation on the surface of Constantan (Ni/Cu), then migrates toward the Fe–Mn–K impregnated fiberglass sheath and exothermically recombines (especially on MACOR ceramic) (**??**). The energy to sustain this process comes in the form of current on Constantan (via Joule heating and a possible electrochemical factor) and from a *yet unknown process, possibly at electron Compton wavelength scale, explaining perhaps the apparent excess heat.*

Future work will be dedicated to identifying and better understanding the active sites of energy generation. At the same time, special care will be given to exclude any "electrochemical" Peltier-like effect capable of mimicking some of the reported thermal anomalies In that respect we consider particularly valuable the work of Dr. Groszek that has been recently brought to our attention. In [10,11] he has recently described experiments where hydrogen absorbed on transition metal catalysts reacts with oxygen, releasing a heat pulse far beyond the enthalpy of combustion. Having said that, we suppose that in our experiments we are continuously regenerating the catalyst and the reagents of a Groszek-type experiment allowing a steady excess heat release. Future work will be dedicated to identify and better understand the active sites of energy generation and the role of the mixed oxides.

7. Final Remarks

Transport of atomic hydrogen may possibly occur from dissociation to recombination sites. These transport phenomena appear to be enhanced by current in Constantan, hence calling for a possible role of charged hydrogen/deuterium

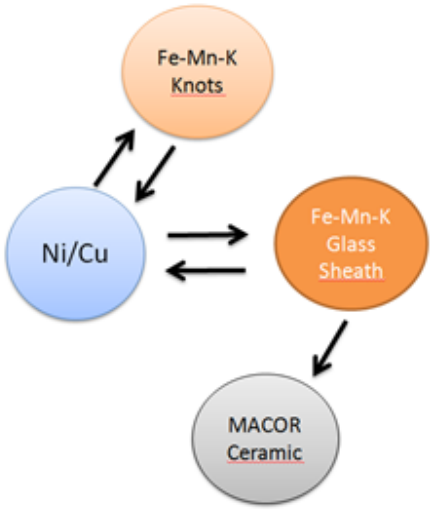

Figure 16. Possible exchange of atomic hydrogen in the current experiment.

species. Dissociation/transport/recombination make it difficult to identify sites where excess heat occurs. A minor risk for some sort of Peltier-like effect mimicking certain observations cannot be excluded yet.

8. Addendum

Recently, after of ICCF20, by chance it came to our attention that a researcher from Germany Horst Preusker, [12] claimed in a short patent that xenon acts as a catalyst for the nuclear reaction D_2+D_2^4He with emission of a large amount of energy, once D_2 gas is ionized. So far, we have not observed elements to judge whether the claims by Preusker are correct. In any case, we have experimental evidence of a performance increase *after* the introduction of xenon inside the reactor, even at low concentration, especially when power is applied to Cst.

Because of the possible effect of xenon, and others high-Z noble gases as co-catalytic agents of the AHE reactions (at least in our specific environment), we repeated previous tests (since 2013) to confirm the role of argon and xenon. Additionally, after taking into account a possible role of water which we may always consider present in traces in our experiment (mostly coming from the glass sheaths and the mixed oxides), we intentionally added D_2O again in the reactor chamber. Table 1 summarizes some thermal data collected at a fixed input power (Pw) of 50 W on Cst. We can argue that the additions of argon and, even better, of xenon gas to D_2*, really are effective in increasing AHE, beyond any doubt*. Water is also very effective and a synergistic effect with xenon can be observed. How all these compounds are interacting with the wire and mixed oxides is under investigation.

9. Conclusions

(1) One of the weakest points of LENR studies in general, i.e. the not at all satisfactory reproducibility, in our specific experimental situation seems to be overcome with the addition of some Fe–K–Mn to our Constantan wires and glass sheaths (saturated with SrO, whose role is the emission of electrons even at low temperatures, i.e. 600°C).
(2) The effect appears also related to the concentration (or hyper-concentration according to some authors such as Leif Holmlid and Svein Olafsson) of hydrogen or deuterium in specific sites including iron (absorbing hydrogen only at high temperatures, >500°C), once H_2 or D_2 are dissociated *in situ*.
(3) The role of glass sheaths, due to their specific composition and geometry and porosity, seems to be important, similar to that of alumina "support" in the field of automobile catalytic converters used to condition exhaust gases.
(4) The observation of "strange" nuclear effects, even including a reduction of ambient radioactivity and/or the emission of some low energy photons (<250 keV), has to be fully elucidated yet. Anyway, such phenomena arise only after the reactor is operated for a *long* time (several months) with large and stable "loading".
(5) The effect of the so-called "spontaneous or thermionic voltage", first observed accidentally by us on June 2014, has been confirmed and, since the first measures it has been increased by over one order of magnitude. This effect seems to arise from the Thermionic emission of Constantan wire in presence of hydrogen or deuterium, and could lead to interesting applications such as Thermionic Generators driven by AHE.
(6) Further *multidisciplinary* work is mandatory to exploit the full potentialities of our Cst configuration and LENR in general. Several phenomena are really unexpected and are *not* experimental errors:

Some of the new phenomena observed have the potential for practical applications.

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