METHODS REQUIRED FOR THE PRODUCTION OF EXCESS ENERGY USING THE ELECTROLYSIS OF PALLADIUM IN D_2O BASED ELECTROLYTE

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INTRODUCTION

As first proposed by Drs. Pons and Fleischmann [1], excess energy can be created by electrolyzing palladium as the cathode in D_2O using an electrolyte containing 0.1-1.0 M LiOD. Reproducibility of this amazing result can now be greatly improved by following procedures described in this paper. A variety of other environments and materials have been found to produce the effect but these will not be discussed here.

Nuclear reactions can be initiated in a special condition of matter (SCM) that is formed from β-PdD having a sufficiently high deuterium content combined with several other factors. These factors include the presence of still unknown impurities in the palladium and the application of various forms of energy. Apparently, an activation energy exists for the formation of the SCM and this energy is lowered by a suitable deuterium and impurity concentration. This barrier is overcome by the application of some externally generated energy. The closer the chemical conditions are to the ideal condition, the less external energy is required to initiate SCM formation. Once the SCM forms, it is more stable than is ß-PdD thereby suggesting the existence of an activation energy for decomposition as well.

Heat production is not consistently associated with γ-ray, X-ray, neutron or radioactive isotope production. However, all of these products of nuclear reactions have been seen many times both with and without significant heat production while using the electrolytic technique. While these easily detected products do not prove that the excess energy is being produced by a nuclear process, they do demonstrate that various unexpected nuclear reactions can be made to occur in this environment. The most likely source of significant heat production appears to be the formation of ^4He [2,3,4].

CRITICAL DEUTERIUM CONTENT

The first requirement is to achieve the necessary deuterium content at the surface of the palladium. An average content greater than $PdD_{0.84}$ is required to support the larger value at the surface. The average concentration is created by competition between gain at the surface produced from electrolysis and loss of deuterium as gas from microcracks within the palladium. Gain of deuterium is improved by using a sufficiently high electrolytic current density and thin layers of certain impurities on the surface. The loss rate is reduced by using crack-free, high-strength palladium. Such palladium is rare and difficult to obtain with consistent properties.

1. Uptake Rate

The rate of deuterium uptake is determined by the current density and chemical conditions at the surface. A minimum current density of 150 mA/cm^2 appears to be required [5,6,7,8,9,10]. However, much higher current densities are occasionally found necessary to initiate heat production. This current should be uniformly distributed over the entire surface of the sample. Once excess heat production starts, the higher the applied current density above the onset value, the greater the excess power with a nearly linear

relationship between the two quantities. A D/Pd ratio above ≈ 0.84 for the average deuterium content is frequently observed when excess power production first starts [7,6,11,12]. Values above $PdD_{1.0}$ are occasionally achieved. The actual deuterium content of the SCM is still unknown.

In addition to a sufficiently high current density, the presence of certain impurities on the palladium surface is important to improve deuterium retention. These impurities can come from the anode, the electrolyte, or the container. Several of these beneficial impurities include aluminum and silicon [6], which result if Pyrex glass is used as the container. Aluminum (2-20 ppm) added after the palladium has achieved its maximum deuterium content is sometimes found useful in initiating excess heat production [6,10]. Thiourea has also been used with success [13]. Absence of certain surface impurities such as copper, lead, or silver (from solder) is also important. However, thin films of gold (≈ 7000 Å) on the palladium surface have been found to increase the limiting D/Pd ratio [14]. The benefit of lithium and platinum, two impurities normally observed on and within the surface region, is still unknown. Because of electrodeposition from the electrolyte and electromigration within the palladium, the chemical composition of the surface is a complex function of time, integrated current, temperature, and purity of the palladium. Therefore, the chemical composition of the SCM is unknown and is probably significantly different from the bulk material.

Heavy-water sometimes contains impurities that will inhibit the effect. Therefore, the D_2O should be distilled or purified before use. In addition, heavy-water easily picks up normal water from the atmosphere. Excess heat production is significantly reduced when the normal water content is only slightly increased.

2. Necessary Characteristic of Palladium

The nature of the palladium is the second part of the requirement. Most palladium forms microcracks and dislocations when it is converted to the hydride [15,16]. Only very unusual palladium is found to be relatively crack-free after hydriding. A quantitative measurement of the volume resulting from crack formation can be used to evaluate particular batches of palladium prior to heat measurements [17]. Crack volume in excess of 2% of the total volume after forming ß-PdD frequently makes the material inactive [18] while a smaller excess volume can result in a higher success rate. In addition, successful palladium can be seen to absorb almost 100% of the deuterium delivered to the surface until the composition reaches about $PdD_{0.6}$. During this stage, very few bubbles are formed on the surface. Further electrolysis of a potentially active cathode results in a stable average composition above $PdD_{0.85}$. If excess energy is to be produced by the sample, it will appear after several hundred additional hours of electrolysis at currents above the onset current density. During this time, uniform bubble formation should be observed across the entire surface. A successful cathode also shows higher overvoltage than does bad material [19,20]. Crack formation can be reduced if the initial loading rate and temperature are kept low. Initial current densities below 20 mA/cm^2 are suggested. Once a composition above $PdD_{0.7}$ is achieved, the current density and temperature may be increased.

Improved success has been claimed when the palladium has been polished [21] or when it has been cold-worked to achieve an unusually large hardness [22, 23]. Annealing in vacuum seems to have no significant effect while success may be improved after oxidizing in air between 500° and 800°C. Thin films (5-20 µm) of palladium formed on a silver substrate by electrodeposition or an alloy of 0.9 Pd and 0.1 Ag have also been found to give higher success rates.

Successful palladium has been found to produce excess energy even after it has been deloaded and reloaded, after it has been kept in liquid nitrogen before being reelectrolyzed, and when heated as hot as 100°C [24,25,21] during electrolysis. Bad palladium may occasionally work for brief periods at low

power production levels, but it can not be relied on to produce significant results regardless of treatment.

INITIATING CONDITIONS

Application of nonequilibrium conditions can initiate the "excess heat" effect. Very successful results have been reported after using pulsed (1 μsec) high voltages with a resulting high current (up to 100 A) [22], current switched between two extreme values [18,21,26], and MHz frequencies of particular values at the mW level [27,19].

Excess heat production also increases as the temperature is increased [10]. Indeed, significant heat has been produced at 100°C after electrolysis stopped when the electrolyte boiled off [24]. Therefore, increasing the temperature after excess heat has been produced can increase the magnitude of the effect. Even in the absence of externally applied energy, bubble formation creates micro regions of current and voltage variations that may produce the required frequencies and local heating. This energy source alone appears to initiate the effect once other necessary conditions have been achieved within the palladium. However, because the best conditions are seldom achieved over the entire surface, the application of additional energy is beneficial.

CONCLUSION

Three major factors are important to achieving excess power using palladium plus deuterium. These are: an average D/Pd ratio above 0.84, the presence of certain unknown impurities in the surface region of the palladium cathode, and the application of externally generated energy. When a proper mixture of these independent factors is achieved, a transformation takes place in the palladium deuteride. Various nuclear reactions can be initiated in the resulting SCM depending on several unknown variables. This SCM is more stable at high temperatures than is normal ß-PdD. It is unlikely that the SCM is simply another phase in the Pd-D system.

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