# United States Patent

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[54] **NEUTRON-GENERATING TARGETS**
**1 Claim, No Drawings**

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[51] **Int. Cl.** ........................................ **G21g 3/04**
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[56] **References Cited**

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**ABSTRACT:** Neutron-generating targets are made up of a layer of a hydride mixture of at least two metals of two different groups, one of which increases in volume during the chemical hydriding reaction and the other decreases in volume.

## NEUTRON-GENERATING TARGETS

The present invention relates to targets which are more especially employed for the production of fast neutrons by bombarding said targets, which contain one of the isotopes of hydrogen (deuterium or tritium), with a deuteron beam having an energy of the order of a few hundred kev., thereby initiating the known reactions D (d,n) $He^3$, T (d,n) $He^4$.

In targets of this type which are at present known, the isotopes of hydrogen are present in the target materials in the form of metallic hydrides which are deposited on passive substrates (for example of silver, copper, molybdenum and the like) by means of a conventional process. Said substrates serve to mount the targets in the deuteron path within an accelerator while at the same time permitting the dissipation of energy resulting from the impacts of said deuterons on the target material. It is apparent that, under these conditions, in order to ensure good operation of the targets and suitable reproducibility of the results, the adhesion of the hyride layers to the substrates must be particularly effective and the effects of the intense bombardment on the target must be reduced to a minumum so as to prevent the process known as "sputtering" by which atoms are stripped from the target surface. Finally, in order to obtain a maximum neutron flux, which decreases only slowly in time, it is essential to make use of a deuterium or tritium compound which is chemically very stable and contains the largest permissible quantity of the hydrogen isotope considered.

In order to meet the requirements outlined above, the targets of the type employed up to the present time are constituted by a thin layer (on the order of 1 mg./cm.$^2$) of a hydride of titanium, zirconium, yttrium or of the closely related rare earths. Although targets of this type do exhibit good thermal stability and can contain appreciable quantities of tritium or deuterium or both of these isotopes, it is not always possible to obtain perfect adhesion of the target material to the substrates. This presents problems of fabrication according to requirements and, in any case, limits the life of targets of this type. The faulty adhesion referred to is related, in particular, to a substantial increase in volume which accompanies the formation of metallic hydrides. By way of example, and as is apparent from the table given below in the case of metals such as zirconium, hafnium and titanium, the variation in density between the metal and the hydride corresponds to an increase in volume between 12.5 percent and 13.5 percent, depending on the metal considered.

| Nature | Zr | $ZrH_2$ | Hf | $HfH_2$ | Ti | $TiH_2$ |
|---|---|---|---|---|---|---|
| Density | 6.4 | 5.625 | 13.3 | 11.48 | 4.5 | 3.75 |
| Increase in volume, percent | 12.5 | | 13.5 | | 13.3 | |

The present invention is directed to novel neutron-generating targets which overcome these disadvantages. Accordingly, these targets are made up of a layer of a hydride mixture of at least two metals of two different groups, one of which increases in volume during the chemical hydriding reaction and the other or which decreases in volume. The respective quantities of the two metals are chosen so that the mixture exhibits only a slight variation in density irrespective of the proportion of hydrogen isotope which it contains.

Under these conditions, the invention consists in constructing targets using two metals which are subjected to a reaction involving attack by a hydrogenated medium containing the hydrogen isotope which it is desired to introduce into the target. Hydrides are produced which are of lower density for one metal and of higher density for the other metal respectively by said metals as a result of expansion and shrinkage which counterbalance each other.



The metals of the first group can be selected from zirconium, hafnium, titanium, yttrium or some of the rare-earth metals while the metals of the second group are selected from calcium, strontium, ytterbium or europium. By way of example, the shrinkage observed in on the order of 13.5 volume percent in the case of ytterbium hydride and 19 volume percent in the case of europium hydride.

The procedure involved in fabrication of targets of this type is conventional and can be summarized as follows:

1. Fabrication of targets of substantial thickness:
   the metallic hydrides chosen are prepared from a mixture of powder of the metals of each of the two groups considered in proportions which are chosen so as to obtain a substantially zero variation in density during the hydriding reaction. It is thus possible to chose a mixture composed of 50 percent hafnium and 50 percent ytterbium or alternatively 55 percent neodymium and 45 percent ytterbium. The mixture of metal powder which is thus formed is then subjected to a hydriding reaction in a hydrogen medium containing the isotope to be introduced into the target. The hydride mixture which is obtained is then sintered at high temperature and in the presence of the same hydrogen isotope in such a manner as to obtain a compact pellet having a thickness of a few tenths of a millimeter and a diameter which is slightly larger than the deuteron beam. Said pellet is then set in a substrate which has good thermal conductivity.

The targets thus produced not only possess high mechanical stability but contain a substantial proportion of hydrogen isotope which provides a useful life of very long duration. Finally, the thickness of such targets makes it possible to utilize deuterons of high energy and therefore of high penetrating power.

2. Fabrication of thin target:
   as in the previous example, a powder consisting of metals of the two groups considered above is mixed so as to form a compound which does not undergo any dimensional variation at the time of changes in the proportions of hydrogen isotope. There is also prepared a substrate which has good rigidity, excellent capacity for adhesion to the hydride and good thermal conductivity. After polishing and ultrasonic cleaning in a bath of pure alcohol, said substrate is degassed under a high vacuum and at high temperature ($10^{16}$ mm. of mercury, 500° C.). Conventional techniques are then employed for the deposition of the two selected metals under a high vacuum and at a controlled rate. The metallic film thus obtained is then heated in a deuterium and tritium atmosphere until it has absorbed the desired quantity of the isotope. The targets thus obtained have considerably improved adhesion and better resistance to the "sputtering" phenomenon.

What we claim is:

1. Neutron-generating targets, comprising a layer of a hydrogen isotope containing hydride mixture of at least two metals of two different groups, one metal of which mixture increases in volume during the chemical hydriding reaction and the other metal of which mixture decreases in volume during the chemical hydriding reaction said metals of the first group being selected from the group consisting of zirconium, hafnium, titanium, yttrium and neodyminum, and said metals of the second group being selected from the group consisting of calcium, strontium, ytterbium and europium.