



# Rare-earth Information Center INSIGHT

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## Liquid Nd Amplifier

To produce high peak power optical pulses, multipass and/or regenerative amplifiers are necessary for efficient energy extraction. But one of the problems is optically induced damage in the gain medium. This potentially can be overcome by using a liquid medium. Development of a suitable  $\text{Nd}^{3+}$  liquid has been plagued by the facts that either the liquids are corrosive, or that fluorescence quenching occurs in the non-corrosive liquid. Recent work by a Korean team of scientists headed by K. G. Han (KAIST, Taejeon, Korea) have shown that ethylene glycol can be used as a gain medium by using a new amplification scheme [*Appl. Phys. Lett.* **67**, 1501-1502 (1995)]. Ethylene glycol (EG) was chosen as the solvent since it readily dissolves  $\text{NdCl}_3$ . The  $\text{EG}:\text{Nd}^{3+}$  strongly absorbs the second harmonic ( $\lambda = 527 \text{ nm}$ ) of a  $\text{YLF}:\text{Nd}^{3+}$  laser, i.e. an absorption coefficient of  $1.3 \text{ cm}^{-1}$  for a 10%  $\text{Nd}^{3+}$  ion concentration. This amplification system pumps and amplifies within a Q-switching pulse duration. A maximum gain of about two was obtained in the amplification with their experimental set-up.

## Zirconia-Titania-Yttria Membrane for Hydrogen Production

The production of hydrogen by direct water splitting at high temperatures using a  $\text{ZrO}_2\text{-TiO}_2\text{-Y}_2\text{O}_3$  membrane was recently demonstrated by H. Naito and H. Arashi from Tohoku University, Sendai, Japan [*Solid State Ionics* **79**, 366-370 (1995)]. A membrane of the composition 80%  $\text{ZrO}_2$ , 10%  $\text{TiO}_2$ , 10%  $\text{Y}_2\text{O}_3$  was prepared by ball milling the appropriate amounts of the three oxides for 24 hours. The milled powders were compacted at a pressure of 200 MPa (29 ksi) and then sintered in air at 2023K (1750°C) for 5 hours. The resulting tube had an outside diameter of 13 mm with a wall thickness of 2 mm and a length of 40 mm.

At high temperatures ( $>1300 \text{ K}$  [ $>1000^\circ\text{C}$ ]), water begins to dissociate into  $\text{H}_2$ ,  $\text{O}_2$ ,  $\text{HO}$ ,  $\text{H}$  and  $\text{O}$ . The hydrogen and oxygen concentrations at 1873 K (1600°C) are 0.1% and 0.042%, respectively, and this increases to 0.17% and 0.059%, respectively, at 1956 K (1683°C). The concentrations of  $\text{HO}$ ,  $\text{H}$  and  $\text{O}$  are much lower. By placing the  $\text{ZrO}_2\text{-TiO}_2\text{-Y}_2\text{O}_3$  membrane between two chambers of gases with different oxygen partial pressures, the oxygen diffuses through the membrane as  $\text{O}^{2-}$  ions from the high oxygen ( $\text{O}_2$ ) partial pressure chamber to the one with the low  $\text{O}_2$  pressure. This separates the oxygen and hydrogen.

The flow of  $\text{O}^{2-}$  ions through the  $\text{ZrO}_2\text{-TiO}_2\text{-Y}_2\text{O}_3$  membrane is offset by the flow of electrons in the opposite direction to maintain electrical neutrality in the membrane. This is possible because the  $\text{ZrO}_2\text{-TiO}_2\text{-Y}_2\text{O}_3$  material exhibits: (1) both high ionic and electronic conductivities at high temperature at low oxygen partial pressures, and (2) is chemically stable to oxygen, hydrogen and  $\text{H}_2\text{O}$  gases.

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Hydrogen production using high-temperature steam electrolysis has been carried out previously. But the use of the mixed conduction membrane has the advantage over the electrolysis process because no electrodes or electric power are required, thus simplifying the hydrogen production process.

Although the authors have shown that hydrogen can be produced by a mixed conduction membrane, the amount of hydrogen produced is not yet practical. In order to improve the technique, better high electronic and high ionic conducting materials which operate at a lower oxygen partial pressure need to be developed.

### Etching CdTe

Cadmium telluride, CdTe, is a technologically important II-VI semiconductor. It is used in the fabrication of nuclear particle detectors and of x-ray and  $\gamma$ -ray spectrometers. In the production process etching of the surface is a common step. Unfortunately, the oxidizing agents generally used to etch CdTe have some undesirable features, such as a complex surface chemistry which leads to an enrichment of elemental tellurium (i.e. neutral, non-ionic  $\text{Te}^0$ ) on the surface. The  $\text{Te}^0$  layer can vary between a few nanometers (nm) to hundreds of nm, and this layer can have adverse affects on the optical and/or semiconducting properties of the bulk CdTe. French scientists from the Université de Versailles-Saint Quentin-en Yvelines, Versailles and the Laboratoire de Physique des Solides de Bellvue, CNRS, Meudon have shown that aqueous  $\text{Ce}^{4+}$  is an excellent chemical etchant for CdTe [F. I. Marin *et al.* *Jpn. J. Appl. Phys.* **34**, L1344-L1347 (1995)]. The concentration of  $\text{Ce}^{4+}$  varied from  $10^{-4}$  M to  $10^{-1}$  M in a 2M  $\text{H}_2\text{SO}_4$  solution. The etching rate was found to be proportional to  $\text{Ce}^{4+}$  concentration, and that it does not change with time. Etching rates up to 0.1  $\mu\text{m}/\text{min}$ . were obtained, and this rate can be increased by a factor of ten by using ultrasonic vibrations. This steady-state etching makes it possible to dissolve either small or large amounts of CdTe by varying either the concentration of  $\text{Ce}^{4+}$  or the time of etching. Surface analysis by using x-ray photoelectron spectroscopy reveals that the surface is free of CdO and  $\text{Cd}(\text{OH})_2$  (which are found on the surface when using other oxidizing agents), and that it has a small amount of  $\text{Te}^0$  on it. The  $\text{Te}^0$  layer thickness, however, is independent of the amount of CdTe removed during the etching process, or on the etching rate. Furthermore, the  $\text{Te}^0$  layer could be removed by dipping it into a KOH solution.

### Fluorescent Lamps

As of November 1, 1995 fluorescent lamps, which do not meet the Energy Policy Act (EPACT) standards, may not be manufactured in the USA or imported. The EPACT standards were signed into law in October 24, 1992, and prescribe the minimum standards for both efficiency (in lumens per watt = LPW) and color rendering index = CRI). The CRI is a measure of a lamp's ability to reproduce the color of objects correctly. The standards set for the color rendering index allows the use of the cheaper halophosphor colors (i.e. warm white and cool white) in only reduced wattage or energy saver types of lamps. The full voltage lamps, which are allowed by the EPACT standards, are rare earth containing lamps. These rare earth lamps are much more efficient (have large LPW values and superior color rendering qualities. The use of rare earths in fluorescent lamps is the largest market for high purity >99.99% rare earth material, and is a steadily growing market.

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