Hydrogen Storage in Diamond Powder utilizing NaF Surface Treatment for Fuel Cell Applications

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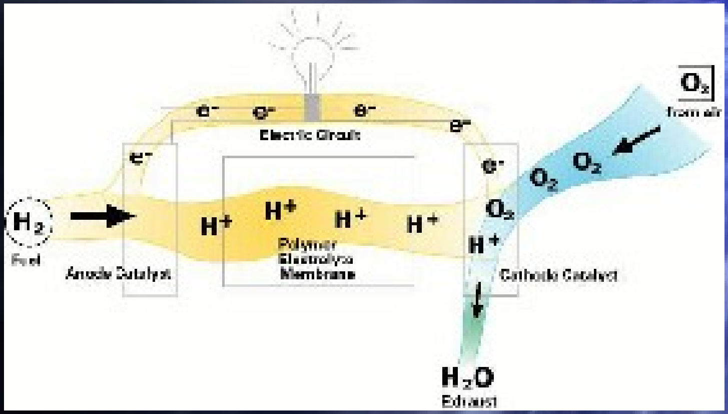
Objectives

- Understand the importance of alternate methods of hydrogen storage in strong hydrocarbon compounds such as artificial diamond.
- Perform surface treatment on the diamond surface with a fluoride compound with plasma.
- Place the diamond powder pellets into the heat transfer chamber for hydrogen absorption at 650°C.
- Compare the treated samples with untreated samples after reactor analysis for increase in mass percentage of hydrogen absorbed.

Fuel Cell Diagram



A hydrogen fuel cell consists of a positively charged cathode, a negatively charged anode, a proton exchange membrane, and a catalyst. The hydrogen molecules enter the fuel cell through the anode side at high pressure and encounter the catalyst. The catalyst is a material usually made of platinum powder on carbon paper that facilitates the reaction of the hydrogen and oxygen atoms.

When the hydrogen atoms encounter the catalyst, the H2 molecule is separated into two H+ ions and two electrons (e-). These electrons are conducted through the anode to the exterior load placed in the circuit. This is where the electricity is harnessed for a motor or any other application. The electrons eventually return to the cathode side and join the hydrogen ions and oxygen to create water. Simultaneously, oxygen gas, O2, is separated into single oxygen atoms on the cathode side of the fuel cell. The oxygen atoms hold a strong negative charge that attracts the positively charged hydrogen ions through the proton exchange membrane. The

Fuel Cell Limitations

- Current Fuel cell systems have inefficient and potentially unsafe methods of storage, such as compressed tanks.
- The catalyst material's can be improved.
- Costs are too high.

Materials

- 99% pure diamond powder
- sodium fluoride (NaF)
- Plasma Machine
- High-pressure hydrogen tank
- Glass beakers, plastic beakers
- Electronic balance
- Distilled water
- Vacuum filter
- Vacuum oven
- High pressure cylindrical press
- polyvinyl butyral (PVB)
- Conduction machine (stainless steel belljar)

Methodology

For the treatment surface of diamond powder the experiment use various steps:

The ratios between the diamond powder and sodium fluoride are established, all are measured in grams:

Ratio, 1 : 1 (NaF)

Ratio, 1 : 0.5

Ratio, 1 : 0.25

The compound then is put inside the plasma machine,for one hour.

After treating the compound, the residue sodium that is left on the surface of the mixture is filtered out utilizing distilled water.

Methodology

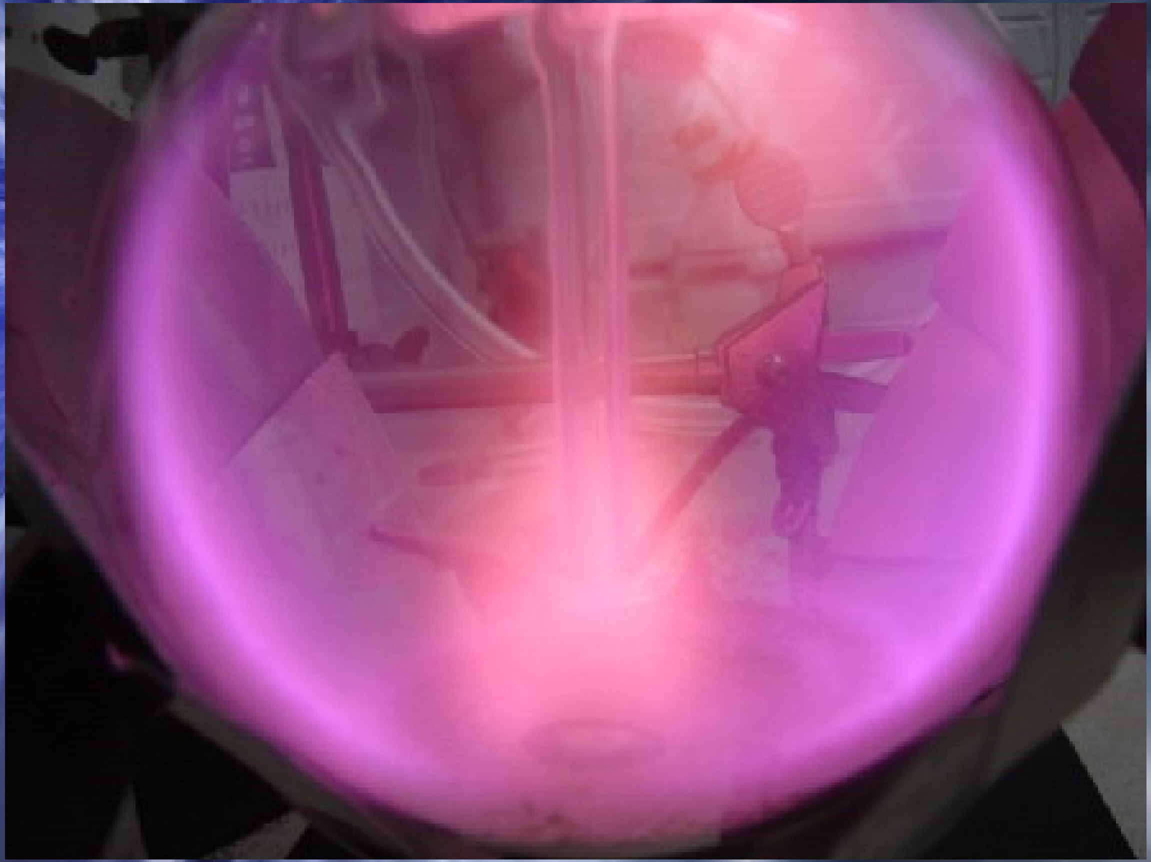
Two pellets were made for each ratio. One of these pellets is treated at 450°C and the others is treated at 650°C. The reason for the 450°C treatment is to eliminate the Polyvinyl Butyral compound from the pellet mixture.

All the pellets are subjected to the heat conduction in the bell jar, including the control pellets, which are not treated in the plasma machine, but consist of a mixture of NaF and diamond powder at a 1 to 1 ratio. The treatments of each batch last approximately one hour.

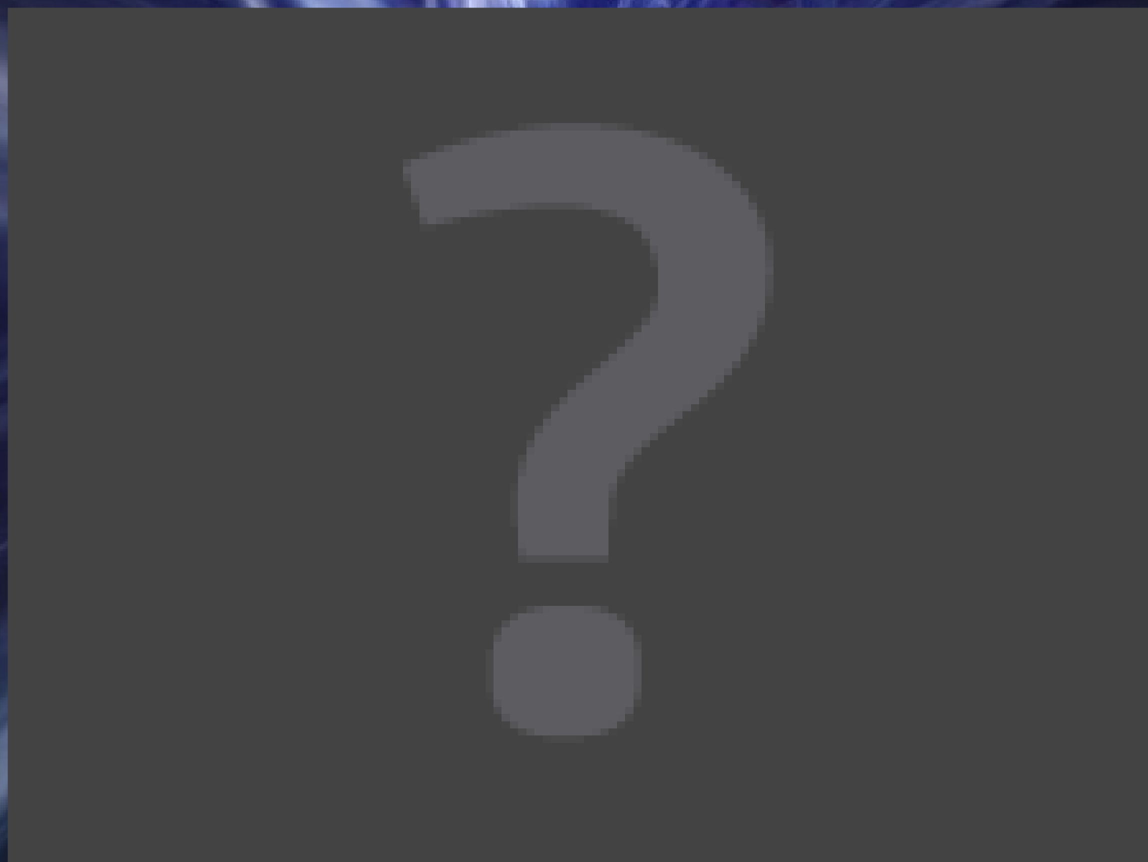
Once the hydrogen storage is finished, the samples are sent to the reactor and are subjected to the PGNAA analysis. Hydrogen was measured by PGNAA on 2223-kev gamma ray. Count time was 4 hours per sample. Hydrogen background is about 30% of counts in each spectrum. After background hydrogen was subtracted, the sample was compared to Urea standard with 6.7%

Methodology

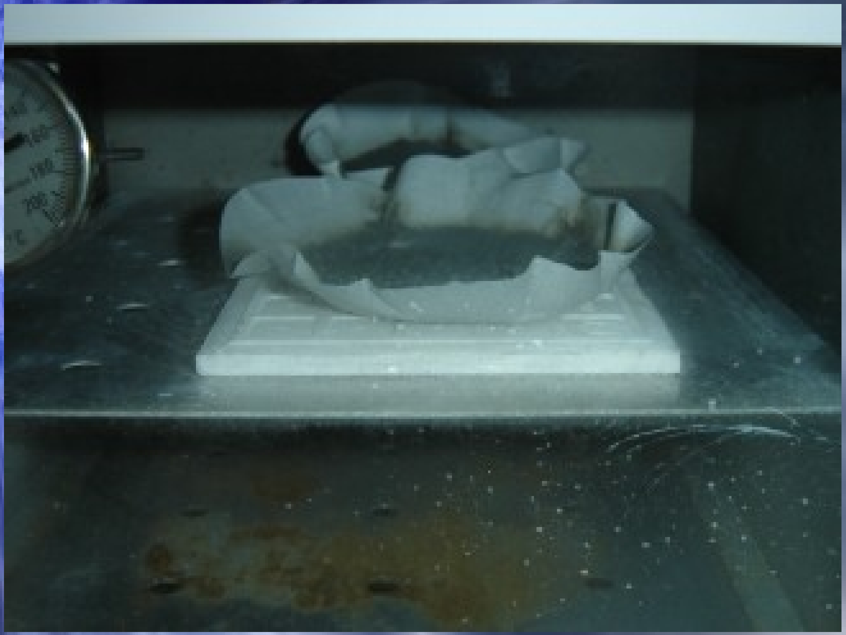
Methodology



Methodology



Methodology

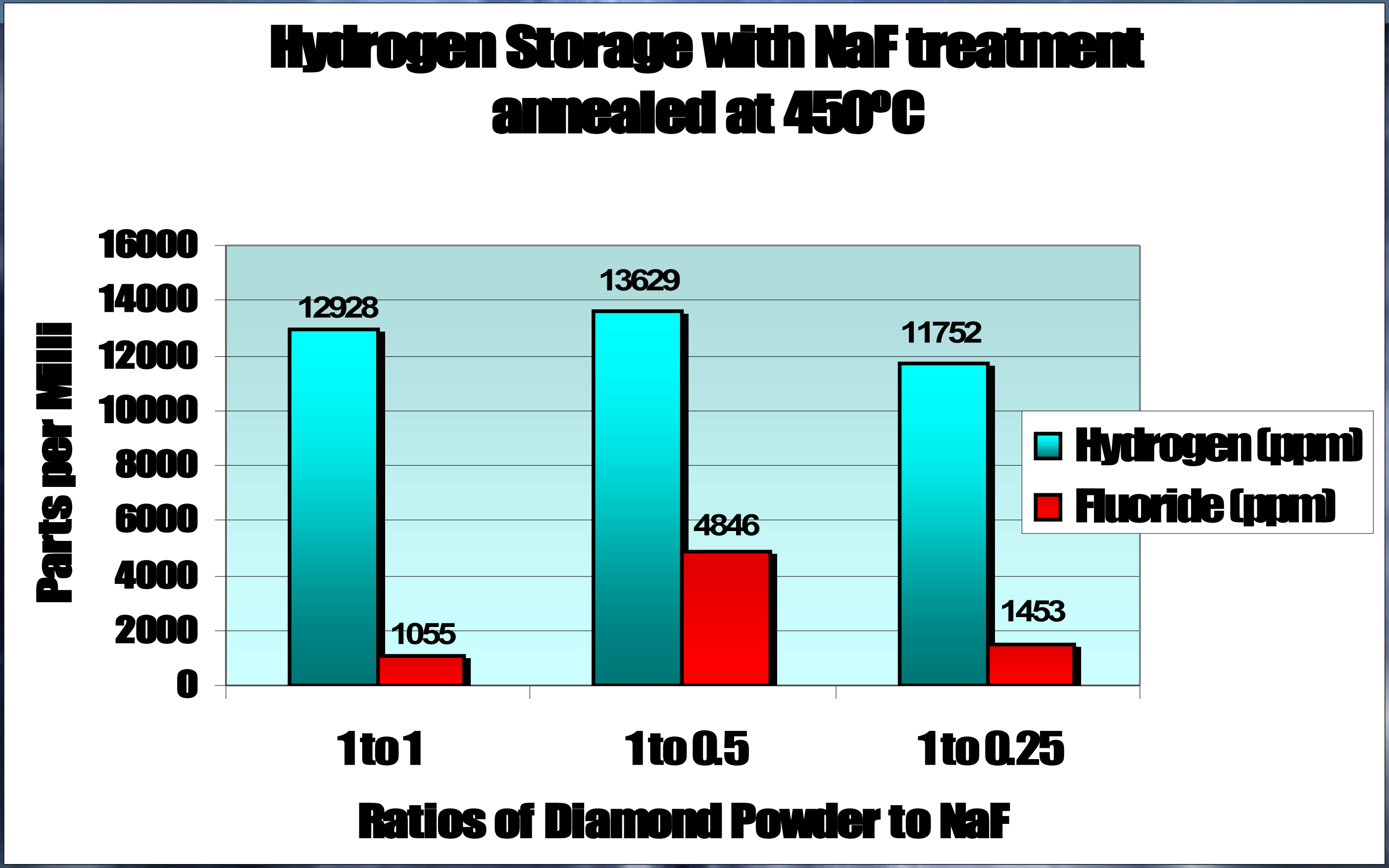


Methodology

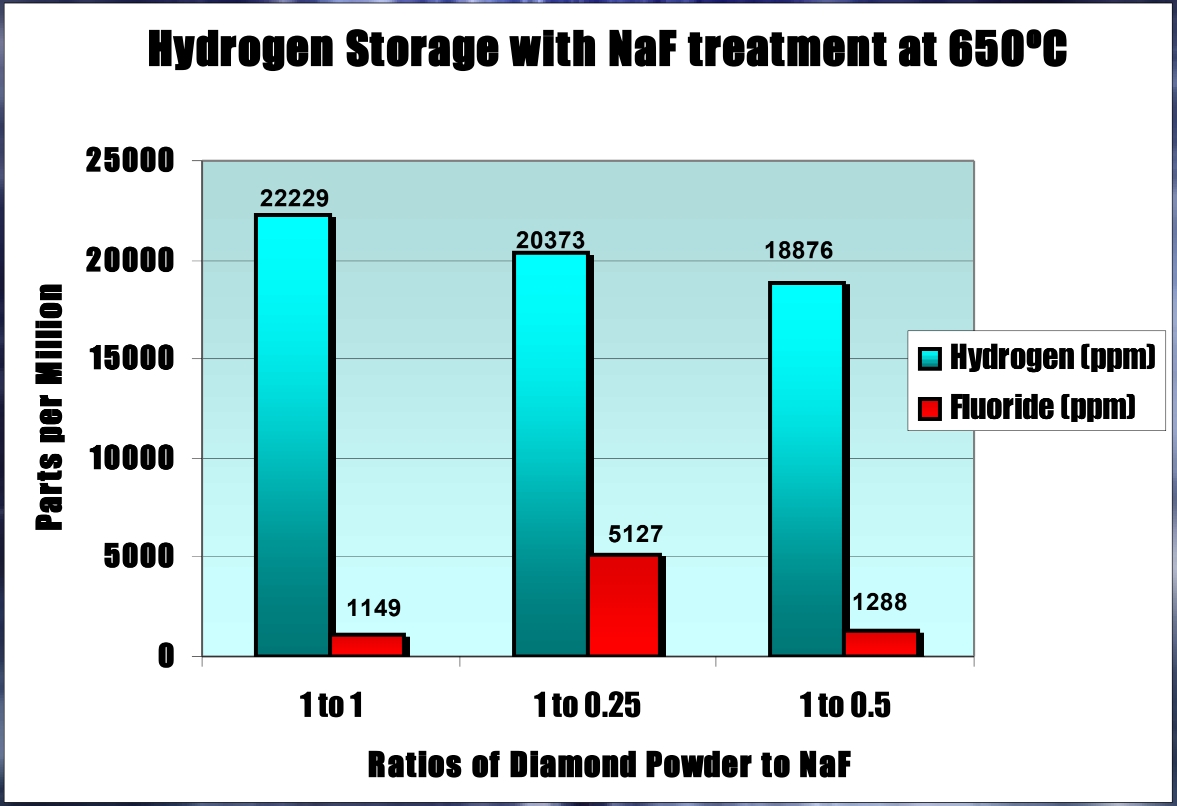
Results

Sample ID	Ratio of Diamond and NaF	Temperature of Treatment	Hydrogen (ppm)	% Hydrogen per weight	Fluoride (ppm)
1L	1 to 1	450ºC	12928	1.2928	1055
2L	1 to 0.5	450ºC	13629	1.3629	4846
3L	1 to 0.25	450ºC	11752	1.1752	1453
4L	1 to 1	650ºC	22229	2.2229	1149
5L	1 to 0.25	650ºC	20373	2.0373	5127
6L	1 to 0.5	650ºC	18876	1.8876	1288
7L	Control Sample without NaF	650ºC	17020	1.702	257

Results

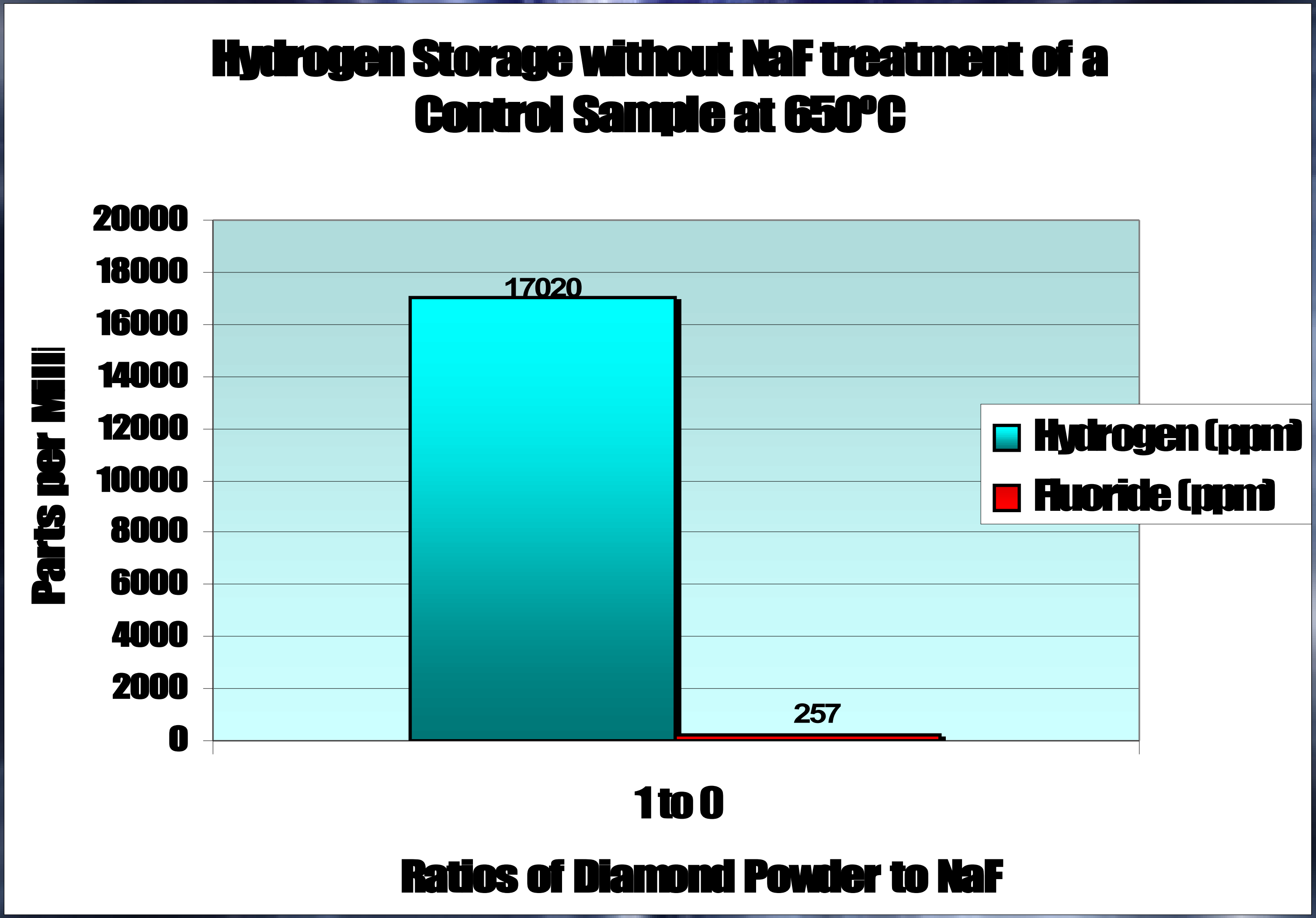

Hydrogen Storage with NaF treatment annealed at 450°C
16000
14000
12000
10000
8000
6000
4000
2000
0
Parts per Milli
12928
1055
13629
4846
11752
1453
Hydrogen (ppm)
Fluoride (ppm)
1 to 1
1 to 0.5
1 to 0.25
Ratios of Diamond Powder to NaF

Results



Hydrogen Storage with NaF treatment at 650°C
25000
20000
15000
10000
5000
0
Parts per Million
22229
1149
20373
5127
18876
1288
Hydrogen (ppm)
Fluoride (ppm)
1 to 1
1 to 0.25
1 to 0.5
Ratios of Diamond Powder to NaF

Results


Hydrogen Storage without NaF treatment of a Control Sample at 650°C
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Parts per Milli
17020
257
Hydrogen (ppm)
Fluoride (ppm)
1 to 0
Ratios of Diamond Powder to NaF

Discussion

- A colloid formed when the samples were filtered a second time, indicating the presence of Fluorine in all the samples.
- One of each sample was sent to the reactor after annealing at 450°C.
- One of each sample was placed in the bell jar for hydrogen storage at 650°C.
- All the samples, including an untreated control sample were sent to the reactor.
- The results show that for each ratio, the sample's exposed to higher temperatures have higher quantities of hydrogen.
- All the samples stored relatively high amounts of Fluorine on the surface.
- The control sample also had a previously small amount of Fluorine on the surface.
- The results display that the samples treated at 650°C have higher amounts of hydrogen than the control sample.
- The results show that annealed samples at lower temperatures store less hydrogen than the control samples.
- The highest amount was the 1 to 1 ratio at 650°C with 2.2229% mass percentage of hydrogen.
- This is a significant increase in hydrogen storage.

Conclusion

- Surface treatment of diamond powder utilizing Sodium Fluoride is a vital step towards the practical usage and commercialization of fuel cell systems.
- The surface treatment at high temperatures, such as 650°C, increases the percentage of hydrogen storage in a sample of diamond powder.
- The comparison of the data of treated specimens vs. control samples of untreated samples displays that treating the surface of the diamond powder with an electronegative element such as fluoride activates the surface of the material allowing for the more loose bonds to be made between the hydrogen molecules and the surface of the diamond powder.

Conclusion

- The best ratio for hydrogen storage with surface treatment with Sodium Fluoride was a 1 to 1 mass ratio at 650°C and the flow of hydrogen in the steel bell jar at a constant flow for one hour.
- This allowed for 2.223% mass in hydrogen storage.
- At low temperatures diamond powder easily releases stored hydrogen, making diamond a good material for the practical use of hydrogen storage in a fuel cell system.