

# Construction of a Sapphire Cell for NMR Study of Hydrogen Fuel Storage

Michael Good

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- Project's Supervisors: Dr. Yue Wu , Dr. Alfred Kleinhammes.
- Director of Graduate Studies: Dr. Hugon Karwowski.

**Requirement:** Students of theoretical physics must fulfill an experimental physics requirement by working on a research project with one of the experimental groups. After completion of this work the student will write a brief summary of the work which will be evaluated and approved by the project's supervisor and the Director of Graduate Studies.

**Purpose:** Hydrogen fuel cell research for the construction of non-polluting, more economically feasible, renewable transportation. Nanotechnology research involving carbon nanotube properties and high pressure nuclear magnetic resonance.

**Challenge:** Hydrogen is not easily stored. High pressure tanks and ultra-cold storage techniques are not the technology of the future. Better methods of storing hydrogen are needed to make hydrogen cars superior to gasoline powered cars. One promising avenue is the storage of hydrogen in carbon. It is likely that some carbon nanotube structure will be able to hold hydrogen without dangerously high pressures and conditions. The major technical barrier to on-board hydrogen storage is storing enough hydrogen to enable greater than 300 mile driving range without impacting cargo or passenger space.

**Objective:** My task is to build a probe to study how well hydrogen can be stored in certain carbon nanotube structures. The hydrogen storage will be investigated by nuclear magnetic resonance. The probe will need to hold a sample of carbon nanotubes under relatively high pressure, roughly 100 atmospheres, in order to have a range of testing options.

**Completed Work:** This experimental project involved the planning and design of a high pressure vessel. I also helped design the overall pressure system which will deliver gas to the vessel as well as create vacuum to prepare the autoclave for measurement. I decided on and ordered the parts for the vessel

and instructed the mechanics at the UNC shop on how it was to be built. The vessel is very nearly complete (as of July 29th) and should be capable of holding hydrogen gas at roughly 100 atm, along with the carbon nanotube sample. It is made out of a titanium alloy, namely 6AL/4V RED, which is a very strong, light, and machinable metal. The cells themselves, that hold the nanotube sample, are made of strong quartz glass. We also have the option of using much stronger sapphire. Testing will be needed to see which quartz tubes fail, and which ones hold up under our desired pressure. Most, if not all of the necessary equipment has been ordered and we should be ready for experiments using the system by mid-September.

## Sketch of Weekly Progress

### 1 Week 1: June 1-4

- Obtained resources on high pressure NMR studies: pressure vessels, cells, autoclaves, etc.
- Read key papers by Jonas, Yamada, Arnold.

### 2 Week 2: June 7-11

- Decided on sapphire cell method.
- Contacted companies: Saphikon, President Titanium.
- Selected key paper by Arnold as guide to sapphire cell.
- Produced list of items needed to construct cell.

### 3 Week 3: June 14-18

- Began physics shop course 8am-12pm M-Thurs
- Prepared presentation for Wu's group
- Found *High Pressure Techniques* at Duke's library
- Gave presentation to Wu's group

### 4 Week 4: June 21-25

- Finished physics shop course 8am-12pm M-Thurs
- Decided on Ti supplies
- Requested purchase order for Ti

- Decided on testing quartz

## **5 Week 5: June 28-July 2**

- Performed mini-experiment on o-ring
- Setup netnmr
- Ordered Ti supplies, \$155.00
- Ordered epoxy
- Requested purchase orders for sapphire/quartz
- Planned pressure system, needle and safety valve, pressure gauge
- Ordered 3 Sapphire tubes, \$1500.00

## **6 Week 6: July 6-9**

- Received Titanium
- Researched maximum pressure
- Regulator ordered
- Found teflon tubes, quartz tubes
- Calculated pressure for testing quartz
- Talked to groups of prospective grad students
- Requested PO for teflon tubing

## **7 Week 7: July 12-16**

- Received Epoxy
- Ordered Quartz tubes
- Comprised list of contact/order info
- Ordered Teflon burst protection
- Began detailed plans for machining of autoclave

## **8 Week 8: July 19-23**

- Drew detailed plans for Ti vessel
- Conveyed plans to machine shop
- Recieved Regulators
- Planned overall setup of experiment
- Discussed plans with Autoclave Engineers

## **9 Week 9: July 26-Aug 2**

- Quartz tubes recieved
- Group meeting 7-27
- Ordered valves, fittings, etc from Autoclave Eng's
- Requested PO for Viton O-rings
- Ordered Viton O-rings
- Correspondence with Autoclave Eng's on gas fitting
- Autoclave shell built