**1.3 DISASSEMBLY OF HFIR JP28&29 TENSILE HOLDERS AND VICKERS HARDNESS RESULTS ON F82H IRRADIATED AT 573 K—** M. Ando, D. Hamaguchi and H. Tanigawa (Japan Atomic Energy Agency), R. G. Bowman, G. C. Morris, J. P. Robertson and Y. Katoh (Oak Ridge National Laboratory)

## OBJECTIVE

The objective of this work was to disassemble ten tensile specimen holders from JP28&29 capsules and perform Vickers hardness measurements on 573 K -irradiated SS-J3 specimens. This work is part of the U.S. Department of Energy – Japan Atomic Energy Agency fusion materials collaboration.

## SUMMARY

Ten tensile specimen holders from HFIR irradiation experiments JP28 and JP29 were successfully disassembled in the ORNL 3025E hot cell facility. Some holders needed to be cut along corners of the holder because specimens could not be easily pushed out of the holder. All tensile specimens from the disassembled holders were recovered and identified. The surfaces of the specimens irradiated at 673 and 773 K were oxidized during the irradiation and cannot be hardness tested without polishing. Vickers hardness was measured on some of the tensile specimens irradiated at 573 K.

## PROGRESS AND STATUS

### Introduction

This experiment is being carried out within the fourth phase framework of the U.S. DOE-JAERI Collaboration on Fusion Materials. The goals of the experiment include the investigation of the effects of helium on microstructural evolution, the impact of helium on fracture properties, and the development of engineering data on the fusion candidate material F82H. The HFIR JP28&29 capsules began neutron irradiation in HFIR in 2005 [1]. The capsules achieved an irradiation dose of 80dpa in 2013 and were removed from the reactor after completing (44 cycles). Higher-dose irradiation data on RAFM is very significant for the design of a fusion DEMO reactor [2]. However, mechanical property data for RAFM with high-dose neutron irradiation, above 80 dpa, are not available.

This report summarizes results of the disassembly of the JP28&29 tensile specimen holders and the Vickers hardness measurements for some specimens irradiated at 573 K.

### Disassembly of JP28&29 tensile specimen holders

In this work, two plans were prepared for the disassembly of tensile specimen holders:
Plan 1; Hold the holder with one manipulator and use a special tool to try to push out the center circular spring pin.
Plan 2; Mount the holder in the special cutting machine in cell 6 and cut along the corners on each side of the holder.

At first, plan 1 was tried for each holder. If it could not be disassembled easily, then plan 2 was performed.
These disassembly results are summarized in table 1. Figure 1 shows an example of this cutting process in the hot cell.

Table 1. Disassembly results for JP28&29 tensile holders

| No | Holder No. | Irrad. Temp. (K) | Dose (dpa) | Cut | SS-J3 | APFIM/MMPC | Passive TM |
|---|---|---|---|---|---|---|---|
| | | | | Number of specimens (missing), [broken] | | | |
| 1 | JP28 #7 | 673 | 85.4 | 1 | 16 (0) | 17 (0) | 8 [0] |
| 2 | JP28 #9 | 773 | 81.8-83.4 | 2 | 16 (0) | 16 (0) | 8 [0] |
| 3 | JP29 #7 | 573 | 85.9-86.8 | - | 16 (0) | 16 (0) | 8 [0] |
| 4 | JP29 #10 | 573 | 76.9-79.9 | 1 | 17 (0)* | 17 (0) | 8 [0] |
| 5 | JP29 #13 | 573 | 46.9-52.9 | 3 | 16 (0) | 16 (0) | 8 [0] |
| 6 | JP29 #2 | 673 | 45.7-51.8 | 1 | 16 (0) | 16 (0) | 7 [1] |
| 7 | JP28 #3 | 573 | 66.8-70.8 | - | 16 (0) | 13 (3) | 7 [1] |
| 8 | JP28 #1 | 673 | 41.7-47.9 | 1 | 16 (0) | 15 (1) | 7 [1] |
| 9 | JP29 #3 | 773 | 58.7-63.7 | 1 | 16 (0) | 15 (1) | 8 [0] |
| 10 | JP29 #12 | 573 | 58.7-63.7 | - | 16 (0) | 14 (2) | 8 [0] |

* Including 3 SSJ2 specimens

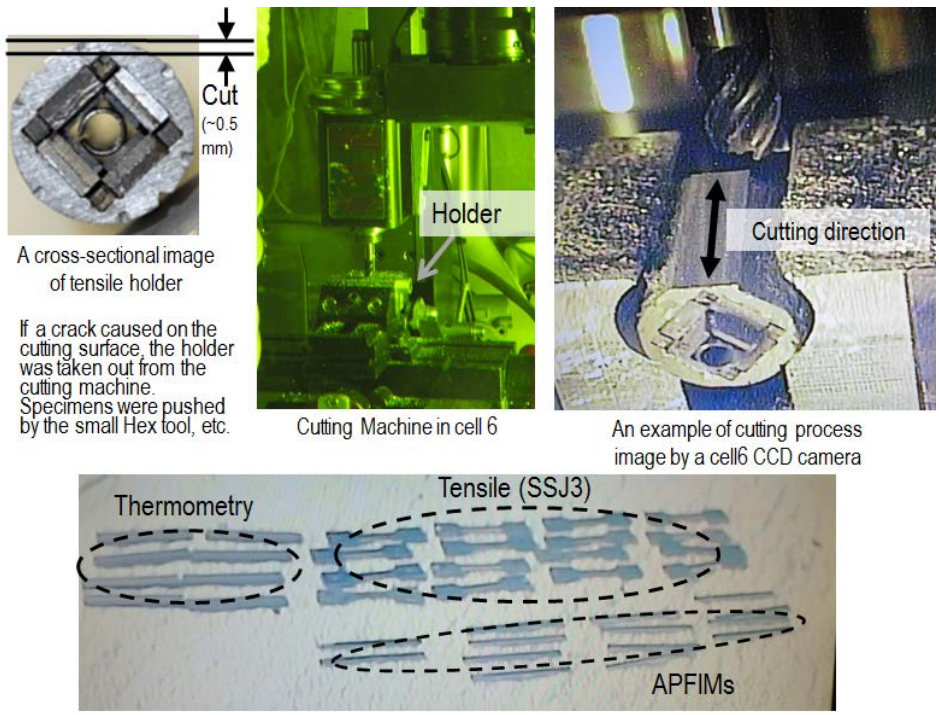


**Figure 1**. An example of the disassembly process for tensile holder by using cutting machine in hot cell

**Experimental**

The materials were F82H IEA heat, F82H Modify-3 and Nickel-doped F82H provided by Japan Atomic Energy Agency. The chemical compositions of these materials are reported elsewhere [3,4,5]. Nickel-doped F82H steels were provided to investigate the effect of helium on mechanical properties. In this experiment, two types of Nickel-doped F82H were prepared [4]. One is 1.4%$^{58}$Ni-F82H which produced helium atoms by the reaction $^{58}Ni(n_{Thermal}, \gamma)^{59}Ni(n_{Thermal}, \alpha)^{56}Fe$ during irradiation. The other is 1.4%$^{60}$Ni-F82H which did not produce helium atoms.

In this work, the hardness tests were performed for tensile (SS-J3 type) specimens irradiated in position 7 in the JP29 capsule. The hardness of these specimens was measured by a Vickers hardness tester (Mitsutoyo AAV-500) at cell2 in Building 3025E, Oak Ridge National Laboratory (ORNL). The hardness tests were performed on a tab section of each tensile specimen (near the engraved ID).

**Results and Discussion**

Table 2 shows results of Vickers hardness for tensile specimens irradiated at 573 K up to 80 dpa.

Table 2. Vickers hardness of tensile specimens from JP29 position 7

| Capsule | Pos. | ID | Material | Irr. Temp K | dpa | Hv | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Max | Min | Range | Avg | Stdev |
| JP29 #7 | UI | 560 | F82H+1.4%Ni58 | 573+ | 85.9 | 386 | 349 | 36 | **372** | 12 |
| JP29 #7 | UI | 561 | F82H+1.4%Ni58 | 573+ | 85.9 | 413 | 376 | 37 | **396** | 13 |
| JP29 #7 | UI | 562 | F82H+1.4%Ni58 | 573+ | 85.9 | 406 | 382 | 24 | **400** | 7 |
| JP29 #7 | UI | 563 | F82H+1.4%Ni58 | 573+ | 85.9 | 417 | 382 | 35 | **399** | 11 |
| JP29 #7 | UO | 060 | F82H IEA | 573- | 85.9 | 392 | 369 | 23 | **383** | 7 |
| JP29 #7 | UO | 061 | F82H IEA | 573- | 85.9 | Not tested | | | | |
| JP29 #7 | UO | 062 | F82H IEA | 573- | 85.9 | 420 | 382 | 37 | **401** | 10 |
| JP29 #7 | UO | 063 | F82H IEA | 573- | 85.9 | 424 | 388 | 36 | **407** | 11 |
| JP29 #7 | DI | 660 | F82H+1.4%Ni60 | 573+ | 86.8 | 370 | 321 | 49 | **348** | 13 |
| JP29 #7 | DI | 661 | F82H+1.4%Ni60 | 573+ | 86.8 | Not tested | | | | |
| JP29 #7 | DI | 662 | F82H+1.4%Ni60 | 573+ | 86.8 | 357 | 320 | 37 | **339** | 10 |
| JP29 #7 | DI | 663 | F82H+1.4%Ni60 | 573+ | 86.8 | 396 | 349 | 47 | **383** | 12 |
| JP29 #7 | DO | H60 | F82H Mod3 | 573- | 86.8 | Not tested | | | | |
| JP29 #7 | DO | H61 | F82H Mod3 | 573- | 86.8 | Not tested | | | | |
| JP29 #7 | DO | H62 | F82H Mod3 | 573- | 86.8 | 385 | 345 | 40 | **362** | 13 |
| JP29 #7 | DO | H63 | F82H Mod3 | 573- | 86.8 | Not tested | | | | |

One of the purposes of a hardness test is to confirm the irradiation temperature by reference to other available hardness value. In the holders containing the tensile specimens, the SS-J3 specimens are groups in two sets of eight specimens each. In the upper section (U) of each holder, there are four inner specimens (UI) surrounded by four outer specimens (UO). In the lower section of each holder (D), there are also four inner specimens (DI) surrounded by four outer specimens (DO). The average hardness for specimens in lower positions had a tendency to be lower than the average hardness of the upper position specimen. However, these results need to be compared to another holder which has a similar irradiation condition. A record of the irradiation temperature also should be examined by analyzing passive temperature monitors.

The irradiation hardening data from this work are shown in comparison to data from the JP25, 26 and 27 capsules in Figure 2. Additionally, 50 dpa irradiation data for F82H will be also obtained in the future from recently completed high dose (50 dpa) rabbit capsule irradiation experiments with similar materials. From reported data [6], the yield stress ($\sigma_y$) is close to the ultimate strength ($\sigma_{UTS}$) for F82H irradiated at 573 K. Therefore, it is expected that $\sigma_y$ for F82H irradiated at 573 K, to- 80 dpa is about ~1100 MPa at room temperature. The hardness testing will be completed on all SS-J3 specimens prior to tensile testing.

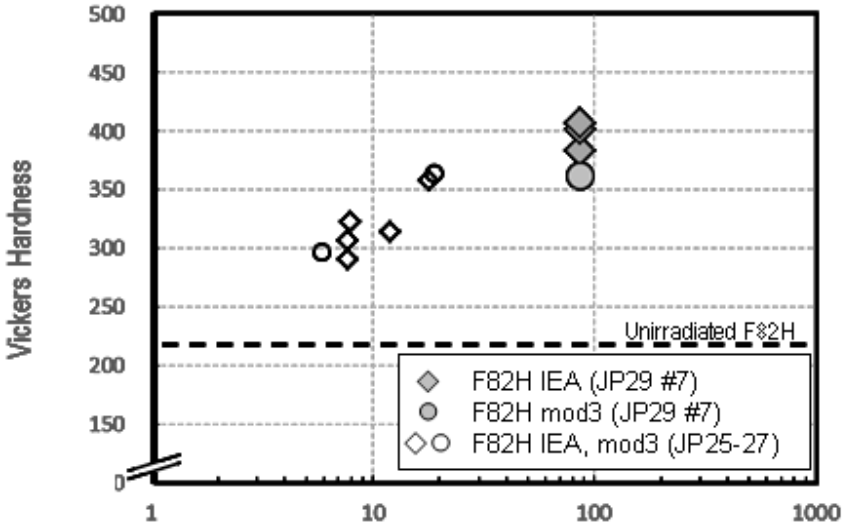


**Figure 2**. Dose dependence of Vickers hardness for F82H irradiated at ~573 K in HFIR.

**Acknowledgements**

This research was sponsored by Japan Atomic Energy Research Institute and the Office of Fusion Energy Sciences, U.S. Department of Energy, under contracts NFE-10-02779 and DE-AC05-00OR22725, respectively, with UT-Battelle, LLC. The authors would like to acknowledge the assistance by Patrick S. Bishop in Building 3025 hot cell facility to the experimental work and the supports of FMNS Gr staffs.

**REFERENCES**

[1] D. K. Felde et al., DOE/ER-0313/38 (2005) 164-182.
[2] H. Tanigawa et al., J. Nucl. Mater. 417 (2011) 9–15.
[3] K. Shiba, et al., JAERI-Tech 97-038 (1997).
[4] K. Shiba et al,. J. Nucl. Mater. 329–333 (2004) 243–247.
[5] T. Sawai et al,. Fusion Science & Technology 44 (2003), 201-205.
[6] K. Shiba et al., DOE/ER-0313/28 (2000) 131-135.