**Editorial comments:**  
  
The manuscript has been modified by the Science Editor to comply with the JoVE formatting standard. Please maintain the current formatting throughout the manuscript. The updated manuscript (52952\_R1\_120214.docx) is located in your Editorial Manager account. Please download the .docx file and use this updated version for any future revisions.   
  
Changes made by the Science Editor:  
  
1. There have been edits made to the manuscript.   
  
Changes to be made by the Author(s):  
  
1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues. The JoVE editor will not copy-edit your manuscript and any errors in the submitted revision may be present in the published version.

**We have read though and fixed any typos, thank you.**  
2. Please highlight 2.75 pages or less of the Protocol (including headings and spacing) that identifies the essential steps of the protocol for the video, *i.e.,* the steps that should be visualized to tell the most cohesive story of the Protocol. The highlighted steps should form a cohesive narrative with a logical flow from one highlighted step to the next. Remember that non-highlighted Protocol steps will remain in the manuscript, and therefore will still be available to the reader.  
  
Currently, there are just over 3 pages of highlighted protocol text.

**We have un-highlighted all sub-steps from Step 1 (material preparation), as this is a much more standard procedure. This brings us down to 2.5 pages of highlighted text, and will make for a more focused, compact video.**  
  
3. Additional detail is required in a number of places:   
-3.4: Place the insulating cap where?

**Clarified, thank you.**

-4.2: Spell out the first instance of “PID”

**Fixed, thank you.**

-Line 480: Spell out SEM/FIB at first instance

**These were already spelled out for the first time in lines 159 and 160.**

-Figures 8-11: Please include a description of the error bars in the figure legends.

**Figure captions for 8-11 were updated to show both the number of averaged data points making up each plotted point, and an explanation of the sizes of the error bars.**  
  
4. In the Discussion, what are the critical steps of the procedure?

**Clarified on page 14, to say that the calibration of each AFM-FS tip, both in air and in wáter, represent the most critical steps in the procedure. Otherwise the data are meaningless, relative at best.**  
  
**Reviewers' comments:**  
  
**Reviewer #1:**   
*Manuscript Summary:*   
The submitted manuscript entitled to "Experimental Multiscale Methodology Predicting Material Fouling Resistance" deals with the detailed experimental methods to prescreen the CRUD-resistant materials and to characterize the CRUD resistance with multiscale methods. The experimental procedures established by the authors will definitely benefit the readers as all the procedures were performed very rigorously based on accurate information and evidences. The results are expected as reliable as to be used in relevant research area efficiently. Also the manuscript was written very clearly and succinctly and certainly satisfies the journal criterion for the publication. Therefore this reviewer recommends the submitted manuscript for the publication in JoVE. However, to improve the quality of the manuscript this reviewer suggests following comments:   
  
*Major Concerns:*  
(1)Lines 266-270: This is the last process to prepare potentially CRUD-resistant materials and the authors recommended a sputtering technique. The sputtering process may involve variety of operating conditions of vacuum pressure and temperature, which may affect the surface morphology significantly. So it is necessary to address the desirable pressure and temperature range to properly simulate the PWR CRUD morphology.

**The sputtering technique used by our outside vendor was in a high vacuum environment, and is not actually set up to recreate conditions and morphology found in PWR CRUD. Rather, we designed this suite of experiments to separate out effects of morphology, surface chemistry, and everything else to study only the effects of surface chemistry on the AFM-FS data. For reference, our vendor was PVD products, and we independently purchased high-purity, 2” diameter sputtering targets for this work. We believe that if down the line, our predictions of CRUD-resistance are different from those observed in larger, more integrated tests, then we will have to come back and investigate whether film morphology played a role in fouling resistance. However, we won’t know until we perform some of the studies in the Future Work section, where we both predict which materials should be CRUD-resistant, and test them in a PWR-equivalent flowing water loop.**  
  
(2) Lines 330: Temperature set point of the bath is 97 oC and this reviewer assumes that the pool boiling experiment was conducted under atmospheric pressure. Considering the PWR is operated at 15.5 MPa, a big gap exists between the PWR CRUD formation condition and authors' experimental condition. So please justify that the authors' experimental condition is reasonable for the CRUD formation of the typical PWR.

**Admittedly these experiments are not at PWR pressures. The experiment is designed this way in part to simplify the experimental setup and in part because this experiment is meant to help develop a baseline understanding of CRUD growth. Materials that perform well in these tests will be placed in another experimental setup under pressure.**

(3) It is curious whether repeatability of the adhesion force data was satisfied. Please explain how the repeatability test was conducted. If not, please also explain how the test results can be accepted.

**Repeatability was ensured by averaging between 16 and 36 points for each AFM-FS measurement. We have updated the figures captions for Figures 8-11 to reflect this suggestion by the reviewer, thank you. The force measurements are taken at a fixed spacing grid, so that local morphology effects, if any, are averaged out.**  
  
*Minor Concerns:*  
(1) Line 132: please give the specific value for the corrosion rate.

**This is a rule of thumb, not a true calculation. An accurate number can be found by taking the ratio of two diffusion coefficients, each with the same value of D0 and activation energy, but one with a temperature *T* and another with a temperature *T+15K*. We have added the word “roughly” on line 132 to mention that this is not a precise number.**  
  
(2) It is recommended to treat Figure 3 as a table. The authors might as well make a list of variety of materials being tested and name it as Table 1.

**Good suggestion, thank you. This has been updated. Figure numbers have also been updated accordingly.**  
  
(3) Lines 286-289: please give a reference for the simulate PWR water chemistry.

**This reference has been added, thank you, on line 294 immediately adjacent to a description of real PWR water conditions.**  
  
  
**Reviewer #2:**   
*Manuscript Summary:*   
This manuscript draws a correlation between macroscale CRUD adhesion on particular materials using faster measurements on the nanoscale with AFM force spectroscpy to measure the adhesion of 2 different materials in air and water.  
  
*Major Concerns:*  
The force curve in figure 7 looks a bit strange. Why does the approach curve overshoot the retract curve at point of contact with the surface and in first part of the repulsive wall?

**This curve, by a different study from the literature, illustrates all the possible features in an AFM-FS curve. The overshoot region at the point of contact on the approach curve represents what is known as “pop-in,” where longer-range attractive forces, such static electricity, cause the tip to move towards the surface before making contact. Therefore, the force-distance curve registers this as an overshoot, as the tip deflects to contact the surface, while the z-piezo controlling the cantilever back is still registering the tip as above the sample. By the way, this is now Figure 6 due to the figure renumbering.**

there is also quite a bit of noise in the adhesion dip, so it is important to explain how that adhesion is being measured.

**Yes, thank you. This is done briefly in the introduction and a sentence has been added at line 515.**

Due to the very large error bars of the measurement, no conclusions can be drawn with respect to function of dwell time. Finally, although the ZrC does seem to have lower adhesion than the TiO2 in water, that is not conclusive due to again, the large error bars of the measurement. The error bars need to be tighter to reach the conclusions drawn in the paper.

**The data represented here are only preliminary. While their error bars are indeed quite large, in this paper we are reporting representative data and trends and trying to explain what we think these trends mean. Extra qualifying words have been added throughout the paper to make sure this is clear.**  
  
*Minor Concerns:*  
Why not conduct the force curves also at temperature? Since the macroscale CRUd measurement is being done in heated water, one could do a more appropriate simulation with the AFM.

**This is something we also have considered. Unfortunately, the AFM at our disposal does not have this functionality. We have two active proposals out, to build a high-pressure, high-temperature AFM stage to conduct these measurements at both temperature and pressure. To our knowledge, only one other group has crossed the 100 bar pressure threshold so far, and they did their measurements in high pressure CO2.**

The AFM calibration is described with vendor (Asylum Research) jargon that is not appropriate to a generic audience. Suggest the calibration be stripped of jargon and written in more general terms (i.e. terms like inVOLS, LDX, etc.)

**Removed, thank you.**

No information is provided on the functionalization of the tip, how robust it was, and how it was confirmed.

**All procedures we complete with the tip are described in this paper. Any other procedures were completed by Novascan, the company from which we purchased the tips. We examined the tips by SEM after analysis, to ensure that the particle remained attached to each tip.**

How many force curves went into each measurement?  
**For all data points except those with a dwell time of 60 seconds there are 36 force curves. For data points with dwell times of 60 seconds there are 16 force curves. This information has been added in lines 525 and 526.**  
**Reviewer #3:**   
*Manuscript Summary:*   
A smart technique for predicting material fouling resistance in energy systems is presented in this paper. The method will be of interest to scientists active in this field and that wish to apply this technique.  
The principle of the technique (AFM tip modification for measurement of adhesion force) can be successfully applied to other fields of scientific research.  
The paper is clear and well written. The procedure is clearly described.  
  
*Major Concerns:*  
Table in Figure 3 presents a number of different materials investigated during the research.  
However, it appears that only AFM data related to the adhesion of Fe3O4 tip to TiO2 in Air/Water and Fe3O4 tip to ZrC in Air/Water are presented (Figure 8, 9, 10, 11).  
If possible, it would beneficial for the sake of completeness to present data related also to other material combinations.  
Eventually, a ranking of material fouling resistance based on the proposed method could be made and possibly compared with results from other methods.

**This is indeed the ultimate goal of our research. Here we have presented preliminary and representative results alone because some of the data and images for a complete dataset analysis have not yet been taken. In addition, the full dataset of AFM-FS measurements, along with a theoretical analysis of the data, will be the subject of a future paper in preparation for submission.**  
  
*Minor Concerns:*  
Figure 2 and 3 should be inverted in the text (lines 152 and 163).  
Moreover, the rest of Figure references appear on a not-ordered sequence (e.g. Figure 12, line 328, and Figure 13, line 333, appear before reference to Figure 4 at line 482).  
Order of references to Figure should be corrected for the sake of clarity in the final version of the paper.

**Figures have been reordered, so that they appear in order in the paper.**  
  
Image quality of Figure 3 and 4 should be improved for the sake of clarity.  
Please avoid red text on a black background (see Figure 1) as well as black text on a red background (see Figure 3).

**Thank you for these suggestions. We have re-implemented Figure 3 as a Table in text, removing the blurriness altogether. Figures have been renumbered accordingly throughout the text. We have also changed the red scale bars to white ones in Figure 1.**  
  
*Additional Comments to Authors:*  
N/A