# Simulating Wet Etching of Optical Fiber to Fabricate NSOM Probe

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COMSOL CONFERENCE 2020 NORTH AMERICA

## Introduction

Wet etching of optical fiber with Hydrofluoric acid (HF) forms cone shaped Near-field scanning optical microscopy (NSOM) probe and the cone angle of the probe is dependent on etching time.

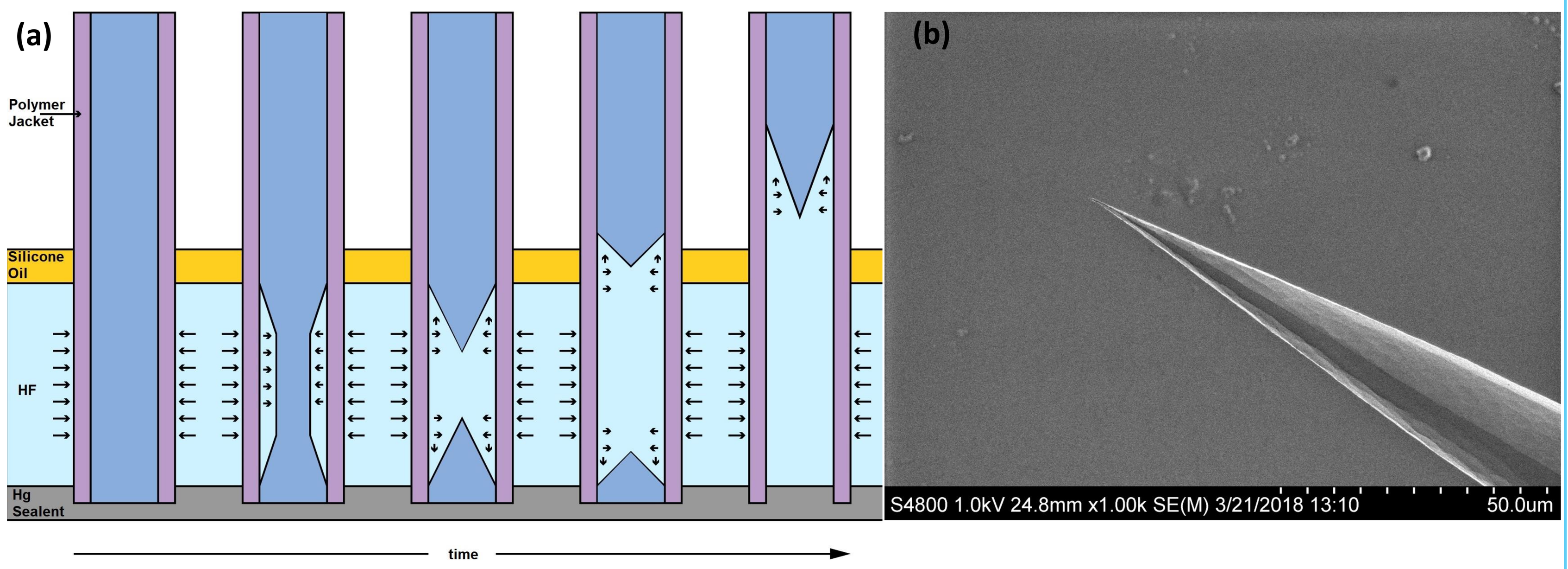


**Figure 1.** (a) Schematic of wet chemical etching process of optical fiber by Sealed Tube Method, (b) SEM image of NSOM probe.

## Numerical Model

The 2D model simulates etching of $SiO_2$, the primary composition of optical fiber, inside the polymer jacket when it is submerged in HF solution. The simulation model is scaled down from actual experimental dimensions.

2D diffusion model was simulated using Transport of Diluted Species (tds).

Movement of etch front was implemented using Deformed Geometry (dg) interface.

Geometry of the model consists of the following:

- 40% HF solution.
- Hg sealant height is 0.1 mm.
- Optical fiber is submerged in HF and Hg.

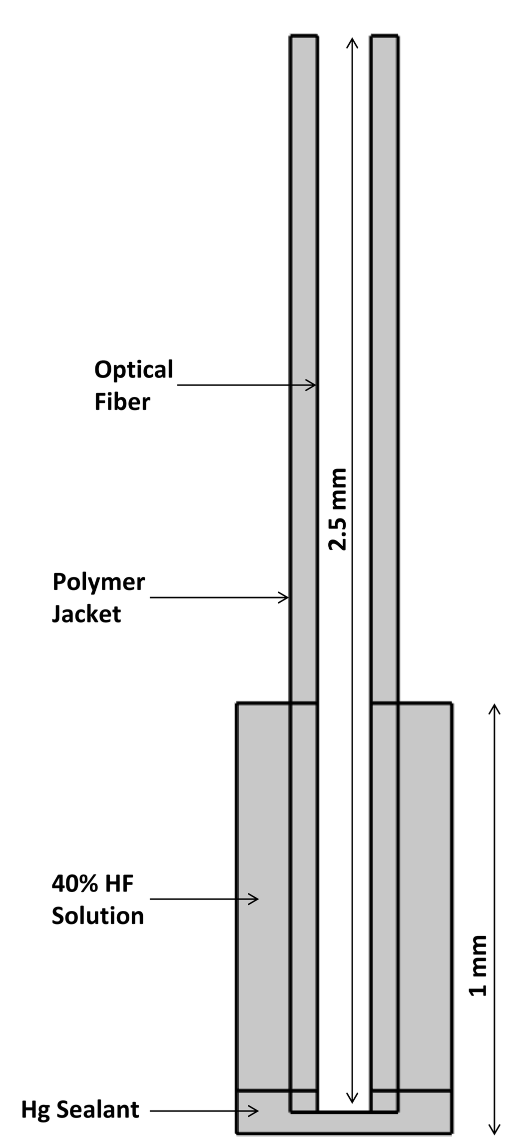


**Figure 2.** 2D COMSOL model geometry.

### Governing Equations

**Convection-Diffusion Equations:** (Transport of Diluted Species)

$$\frac{\partial c_i}{\partial t} + \nabla \cdot \mathbf{J}_i + \mathbf{u} \cdot \nabla c_i = R_i$$

$$\mathbf{J}_i = -D_i \nabla c_i$$

### Diffusion Model

**Etching Reaction:** $SiO_2 + 6HF \longrightarrow H_2SiF_6 + 2H_2O$

Etch front movement (1st order reaction):

$$R = k \cdot c \qquad v_n = R \cdot K_D \qquad K_D = \frac{M_{Sio2}}{n_F \cdot \rho_{Sio2}}$$

where $R$ – reaction rate at the interface HF solution-optical fiber

$k$ – reaction rate constant,

$c$ – HF solution concentration,

$n_F$ – quantity of F atoms consumed for dissolution of one Si atom.

## Results

Simulation result in Fig. 3 shows the formation of the cone shaped NSOM probe after etching for 160 minutes. Results in Fig. 4 show that cone angle of the formed NSOM probe becomes wider with increasing etching time.

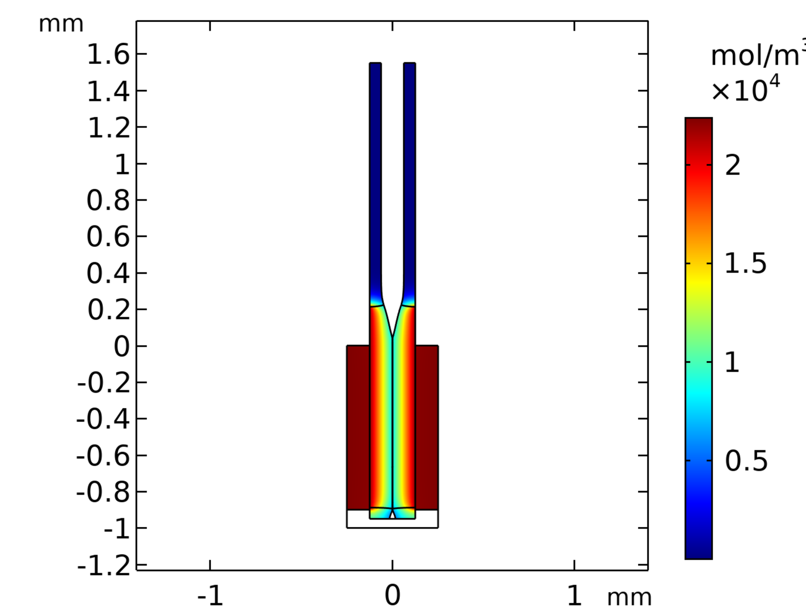


**Figure 3.** Probe formation.

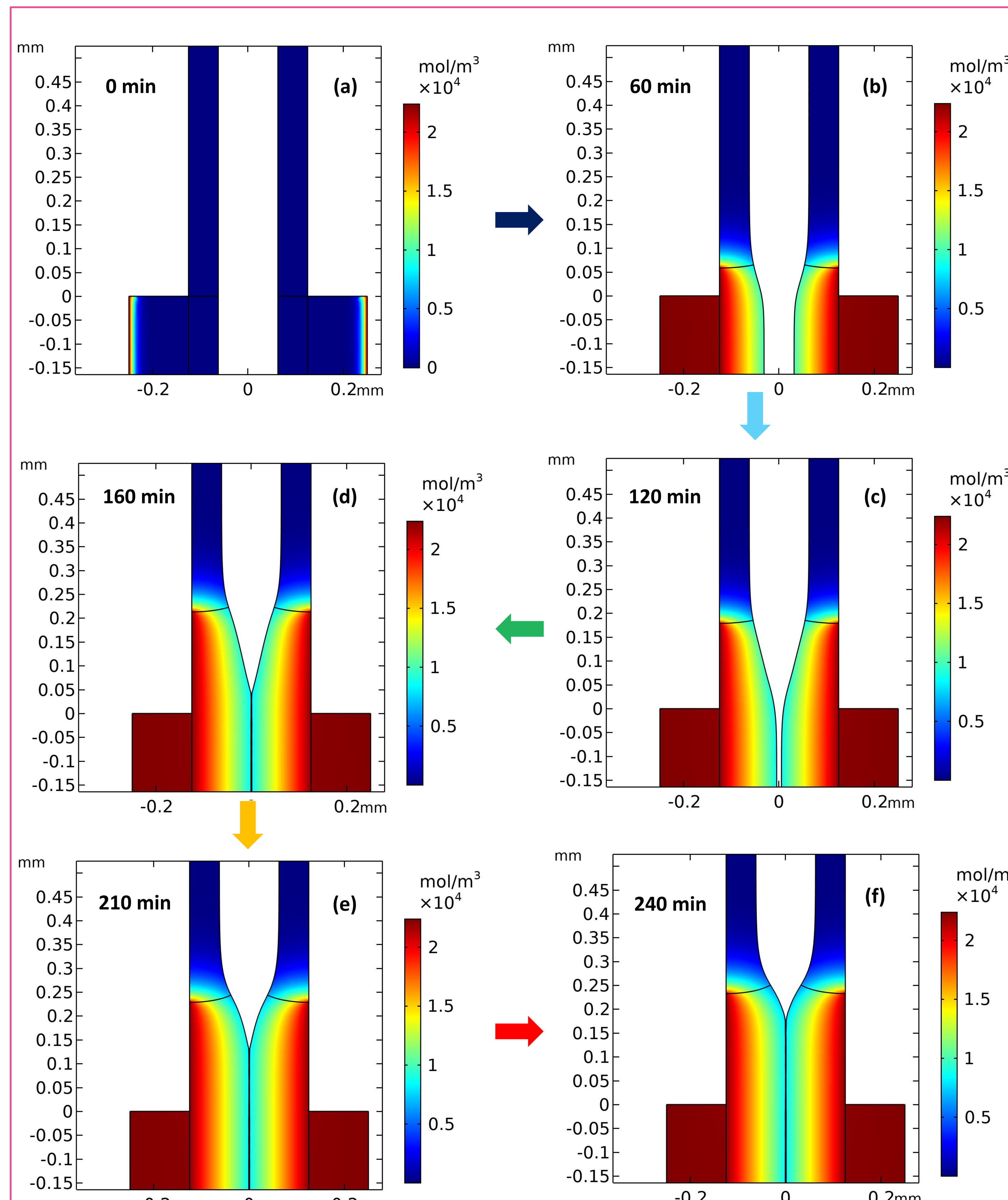


**Figure 4.** (a-f) Simulated probe formation and change in cone angle of the formed probe over time.

## Conclusions

The simulated results suggest that the etching of optical fiber creates a cone shaped NSOM probe and the cone angle of the probe will become wider with increasing etching time. It has been observed experimentally that by increasing the etching time for optical fiber it is possible to create NSOM probes with wider cone angle.

## References

1) Dunn, R. C. *Chem. Rev.* *1999*, *46*, 2891-2927.
2) Hecht, B. et al. *J. Chem. Phys.* 2000, *112*, 7761-7774 .
3) Novotny and Stephan *Annu. Rev. Phys. Chem.* 2006, *57*, 303–31.
4) A. Ivanov and U. Mescheder *COMSOL Conference Paper* 2012.