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Preparation Technique of Antiresonant Hollow Core Microstructured Optical Fibers for Chemical Sensing

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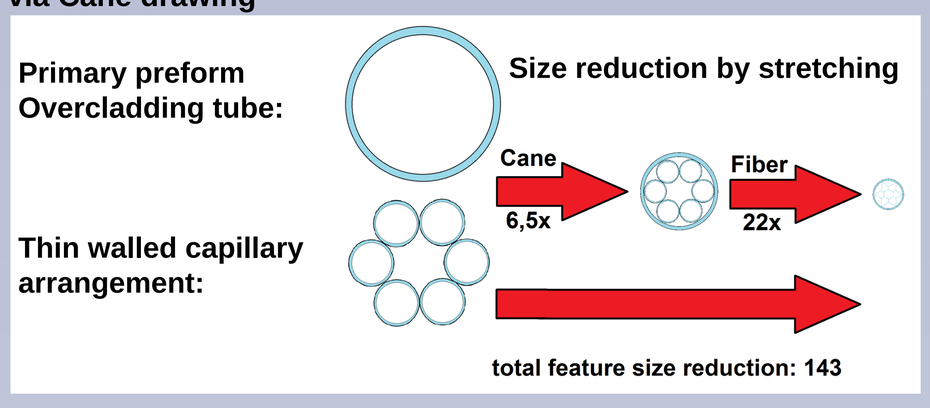
Introduction

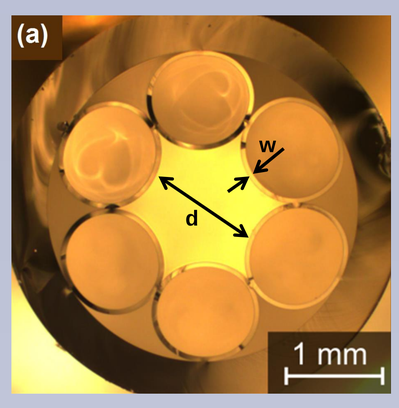
Hollow Core Microstructured Optical Fibers (HCMOFs) enable single mode guidance with large mode field diameters. HCMOFs can be applied for chemical sensing by filling the hollow core with appropriate analytes. We demonstrate preparation approaches for square shaped and hexagonal HCMOFs with a core diameter up to 30 µm. The prepared HCMOFs show a minimum loss of 3 dB/m and effective single mode propagation in the wavelength range 270 nm – 1500 nm. The HCMOFs are manufactured with very thin web bridges, typically 300 nm – 340 nm. We report on a preparation technique without supporting tubes to manufacture extremely thin bridges. The key is an intermediate cane drawing step. We show that the composition of the gas inside the preform cavities influences strongly the composition profile of the glass bridges by diffusion effects. As an example it is shown, that the OH concentration of the “dry” starting material Heraeus F300 can be shifted to over 1000 wt. ppm using a water saturated core cavity atmosphere during the fiber drawing step. This high OH concentration of the bridge silica is advantageously for RAMAN probe fabrication due its low RAMAN scattering tendency

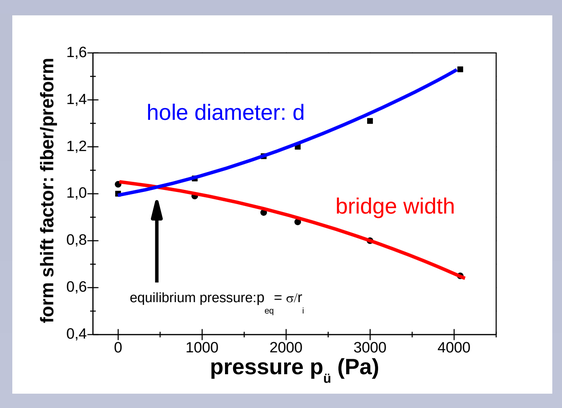
HCMOF Preform preparation – Geometrical shift effects by drawing

Fiber production steps : Stack-and-Draw method via Cane drawing

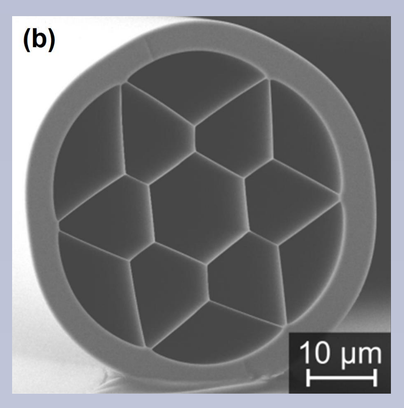


Cane





Fiber



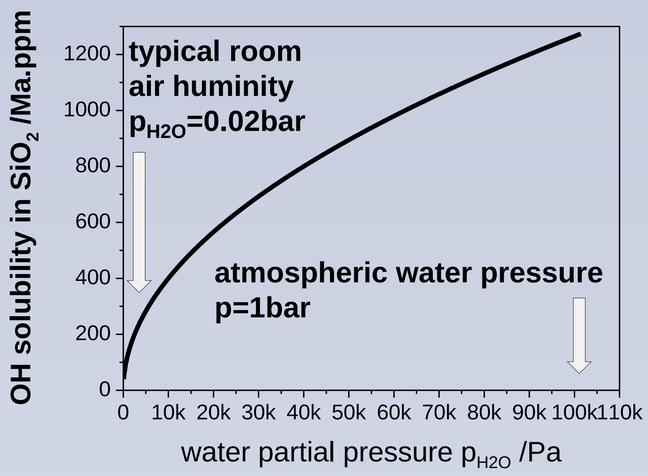
For exact adjustment of the parameters hole diameter **d** and bridge width **w** the a defined overpressure has to applied during fiber drawing procedure.

Hydroxide Equilibrium in Silica and OH Diffusion approximation

H_2O-SiOH equilibrium in SiO_2

$$H_2O + Si\text{-}O\text{-}Si \Leftrightarrow 2\,SiOH$$

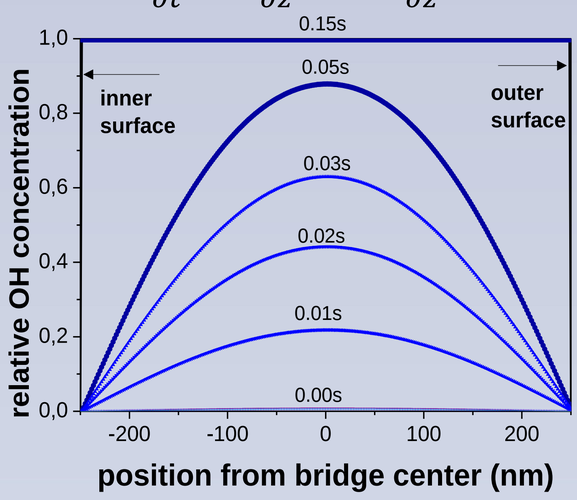
$$K_{OH} = \frac{[SiOH]^2}{p_{H2O}}$$



OH Diffusion into the bridges

Simulation parameter::
wall thickness w =500nm
drawing speed v_f =20 m/min
draw temperature T_{max}=1900° C
OH saturation in t_D = 0.15 s

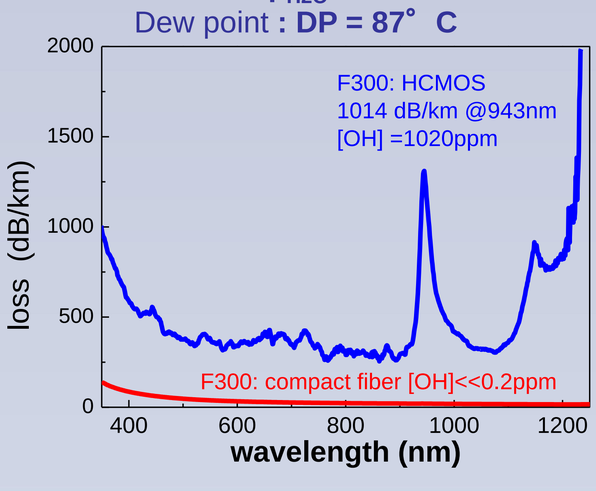
$$\frac{\partial c_{OH}}{\partial t} = \frac{\partial}{\partial z}\left(D * \frac{\partial c_{OH}}{\partial z}\right)$$

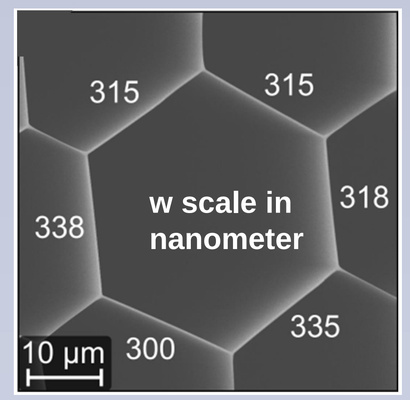


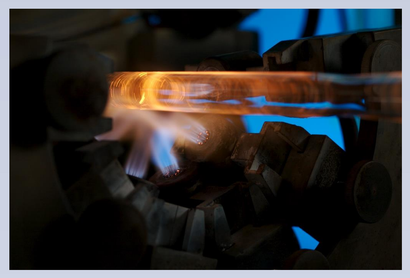
OH enrichment during drawing: Experimental results

Starting with Silica Heraeus F300: [OH]<<0.2ma.ppm

H_2O-supersaturation by H_2-O_2-torch-treatment !
[OH] = 1020 ma. ppm
Equlibrium H_2O partial pressure:
p_{H2O} = 62.8 kPa
Dew point **: DP = 87° C**

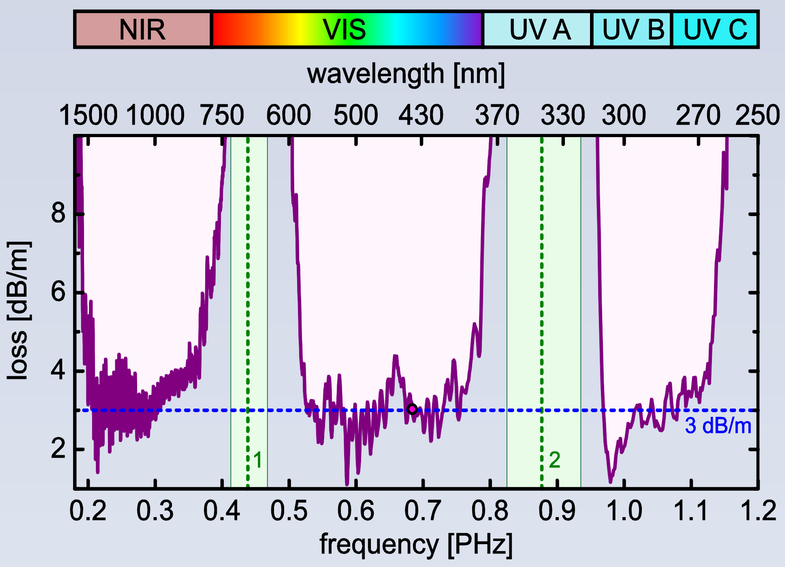




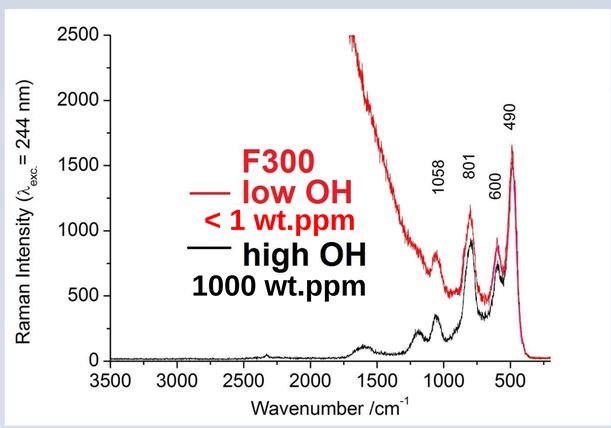


H_2-O_2-torch for preform preparation

Spectral Light Propagation and RAMAN scattering



Spectral distribution of the loss of the core mode. Except at the strand resonances, an almost constant loss of 3 dB/m (indicated by the horizontal blue dashed line) was measured for all transmission windows, covering a domain from the near infrared down to ultraviolet wavelengths. The vertical dashed green lines indicate spectral locations of the silica strand resonances (green numbers are the respective resonance order) assuming a thickness of 320 ±20 nm nm. [3]



RAMAN scattering behavior of High OH Silica and Low OH Silica (Heraeus F300)

References

[1] A. Hartung et al., "Double antiresonant hollow core fiber – guidance in the deep ultraviolet by modified tunneling leaky modes," Opt. Express 22, 19131-19140 (2014)

[2] A. Hartung et al.,"Origins of modal loss of antiresonant hollow-core optical fibers in the ultraviolet", Opt. Express 23, 2557-2565 (2015)

[3] A. Hartung et al.,“ Low-loss single-mode guidance in large-core antiresonant hollow-core fibers”, Optics Letters 40(14) , 3432-3435 (2015)

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