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Sensitivity of micromachined Joule-Thomson cooler to clogging due to moisture

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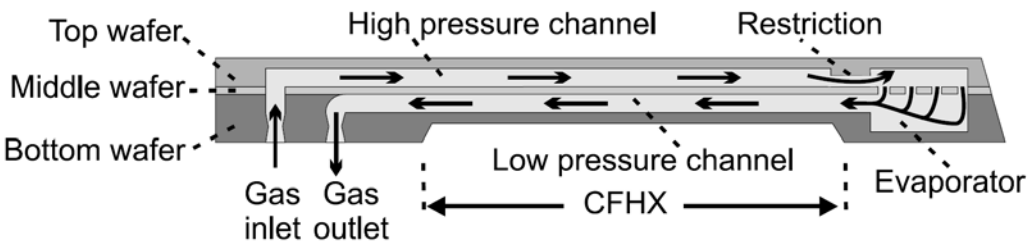
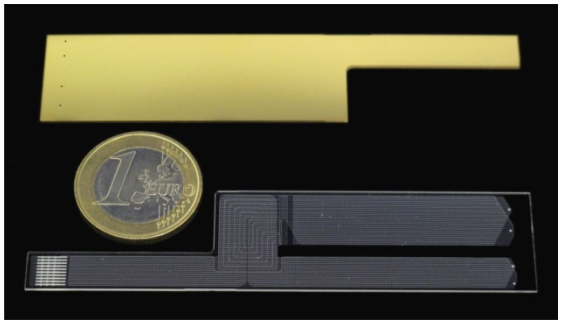
Microcooling development at UT

30 K

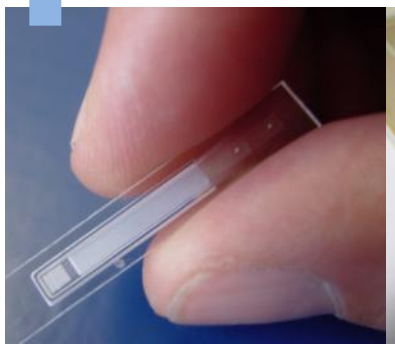
temperature reduction

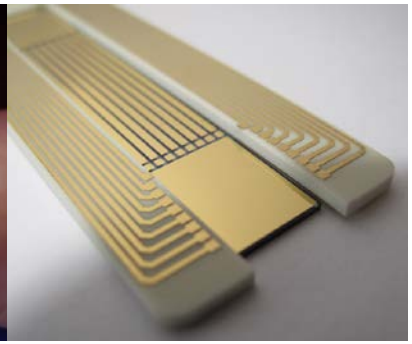
165 K





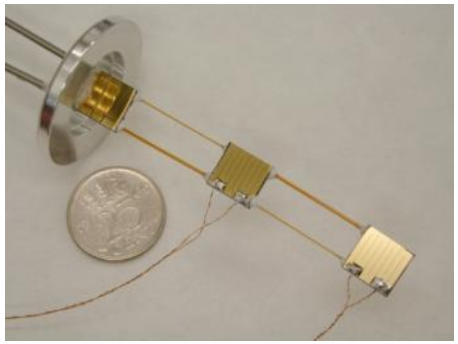
PhD: Haishan Cao





PhD: Pieter Lerou

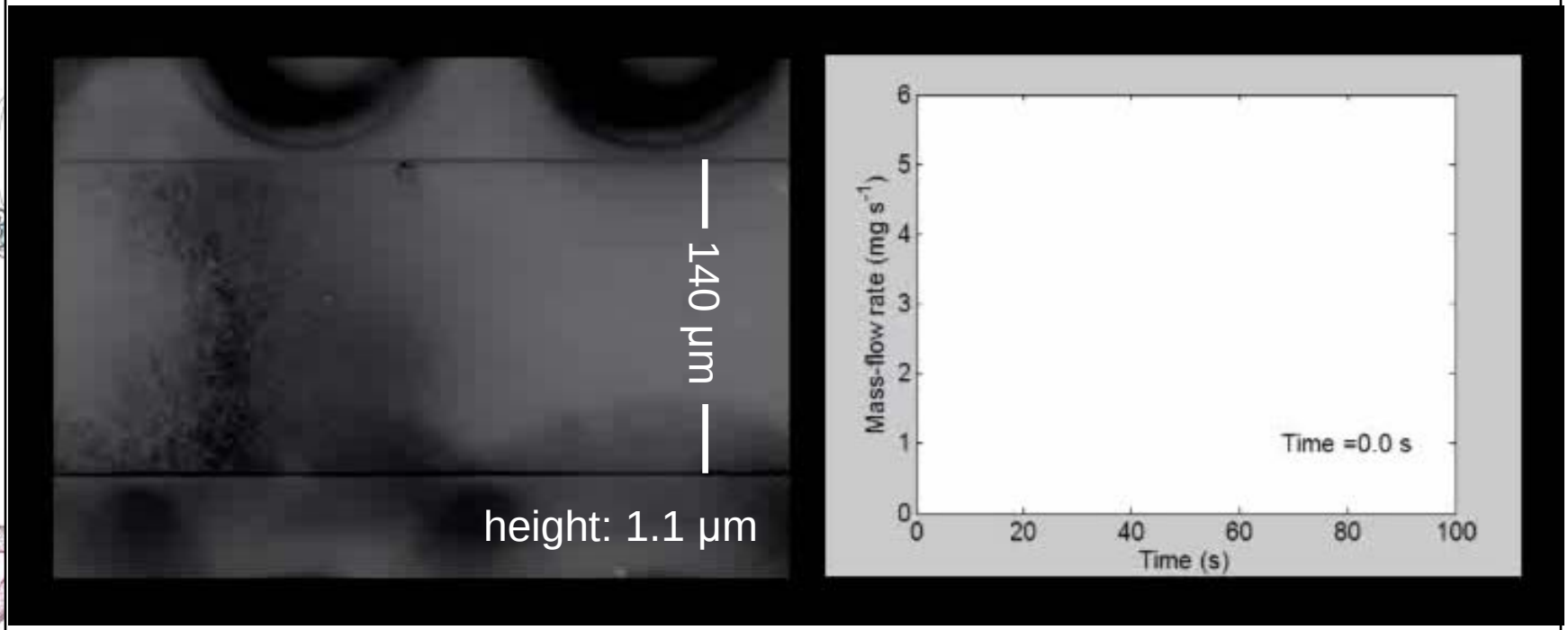
PhD: Hendrie Derking



PhD: Johannes Burger

1997 2001 2003 2007 2009 2011 2013

Clogging phenomenon: Observation



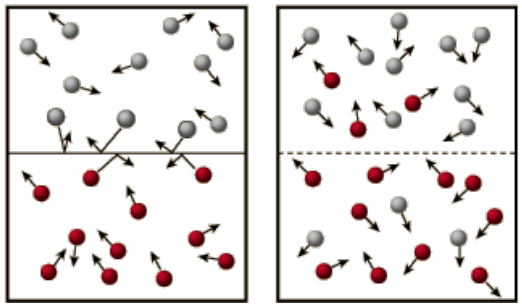
First clogging, results in too low mass-flow rate and warm-up followed by declogging (sublimation).

Clogging phenomenon: Theory

- Molecular diffusion process

Fick's law: (Mass diffusivity, $m^2 \cdot s^{-1}$)

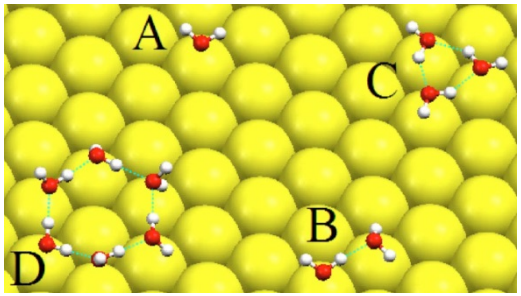
$$\dot{n}_{dep} = D_{12} \frac{(p_c - p_b)}{0.5hRT}$$



- Surface kinetic process

Hertz-Knudsen-Langmuir formula: (Mass accommodation coefficient, 1)

$$\dot{n}_{dep} = \alpha \frac{(p_b - p_{sat})}{\sqrt{2\pi MRT}}$$



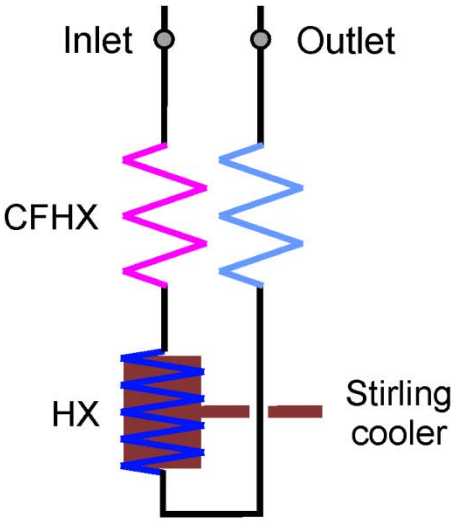
- Diffusion and kinetics process

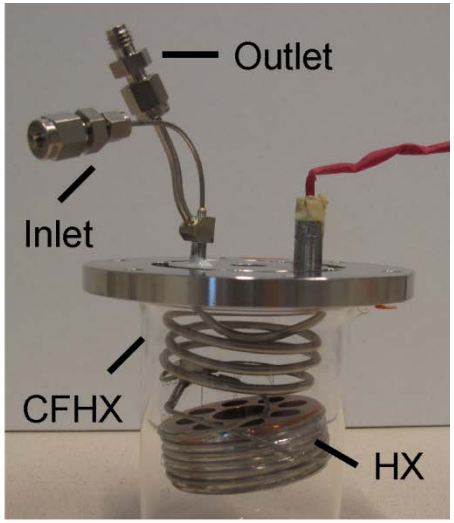
$$\dot{n}_{dep} = (p_c - p_{sat}) \Big/ \left(\frac{0.5hRT}{D_{12}} + \frac{\sqrt{2\pi MRT}}{\alpha} \right)$$

Cao, H.S., Vanapalli, S., Holland, H.J., Vermeer, C.H., Brake, H.J.M. ter (2013) **Applied physics letters, 103 (3). 034107.**

Investigation on clogging rate: nitrogen purifiers

Getter-filter

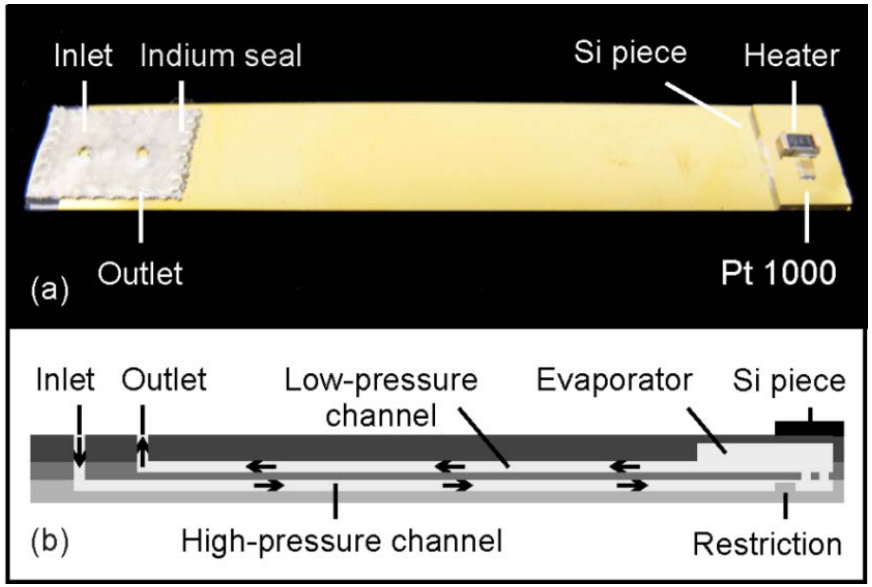




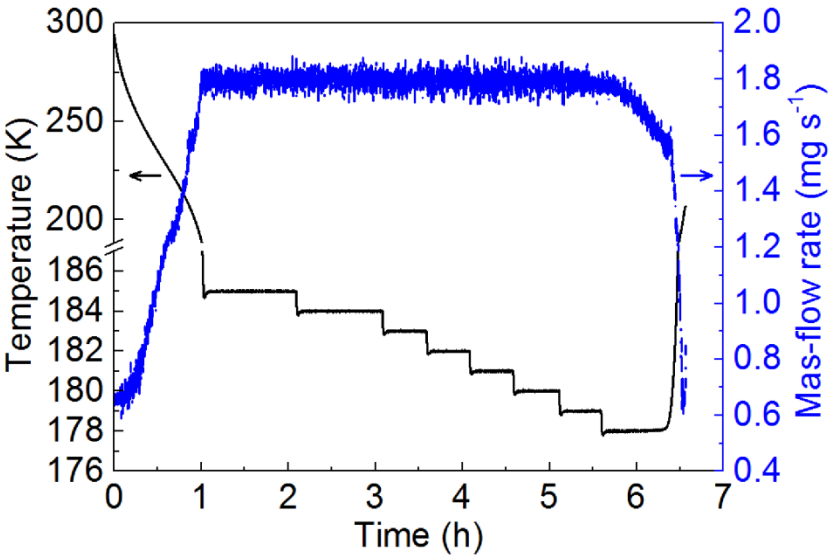
Cryo-filter

Purifier	Purification theory	Outlet moisture level
Getter-filter	Adsorption	Fixed, 1 ppb
Cryo-filter	Deposition	Unfixed, temp. dependent

Investigation on clogging rate: microcooler

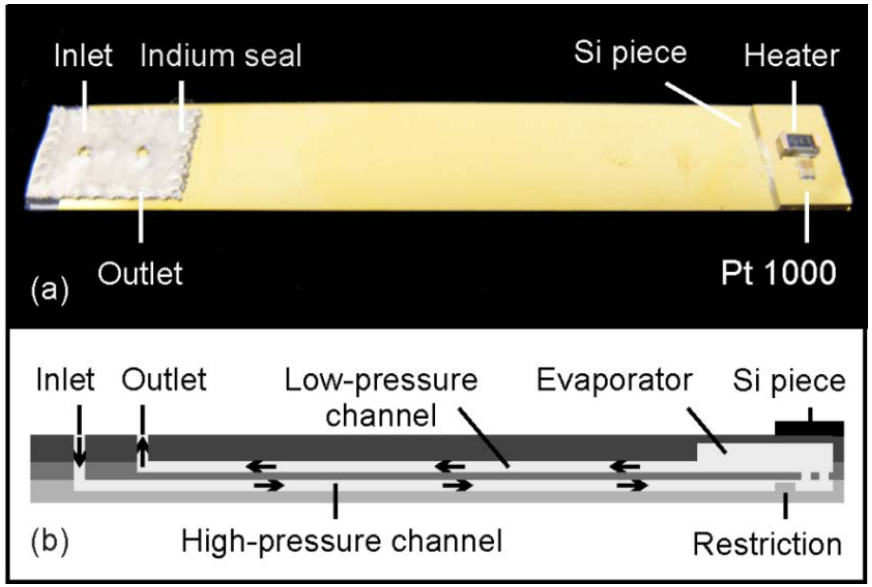


Cryo-filter temp. (K)	Clogging temp. (K)	Saturation pressure (Pa)	Moisture level (ppb)
150	<= 179	4.4E-3	0.5
180	<= 192	4.9E-2	5.6



High pressure (MPa)	Low pressure (MPa)	Working fluid
8.7	0.6	N_2 (5.0)

Investigation on clogging rate: microcooler



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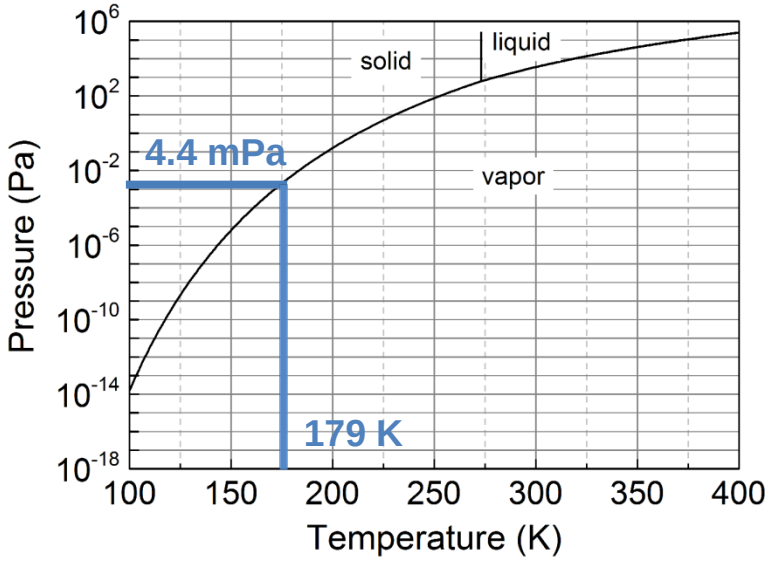

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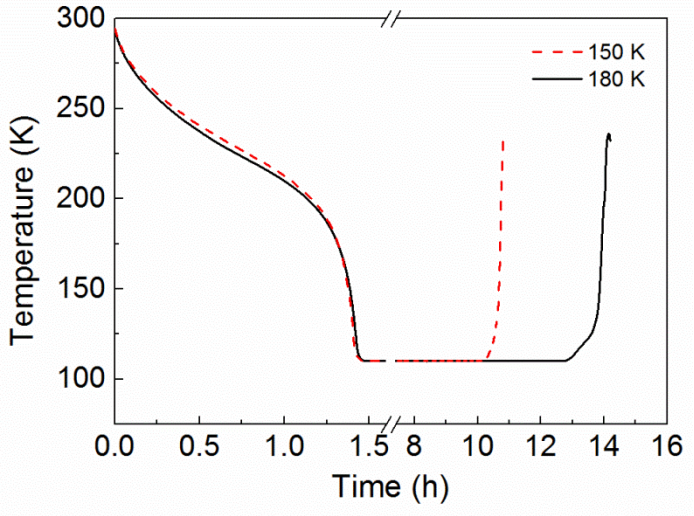
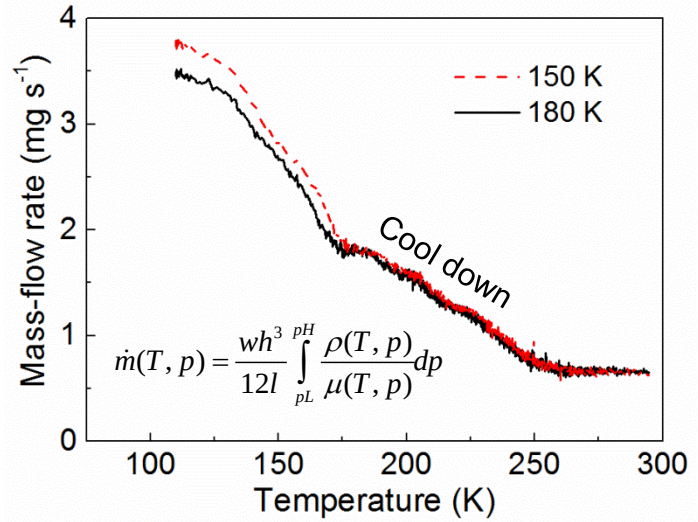
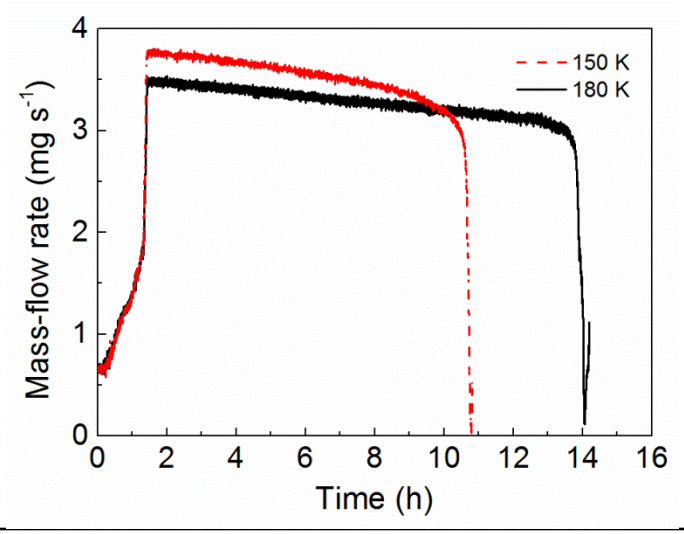
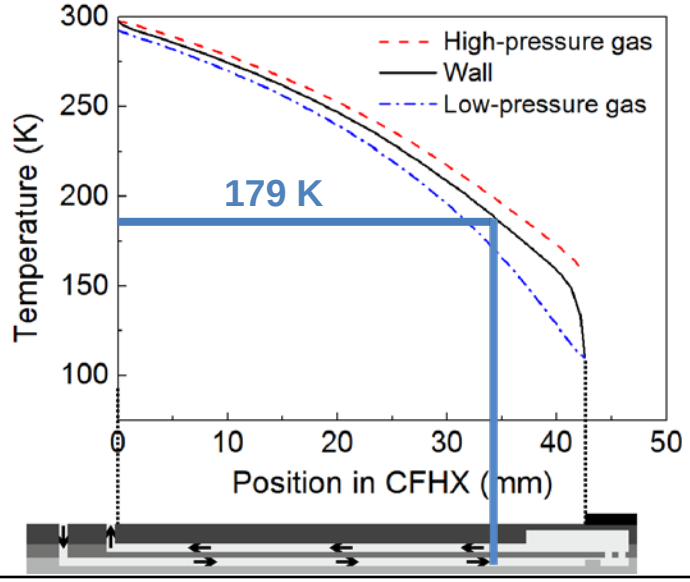
Influence of moisture level in nitrogen gas

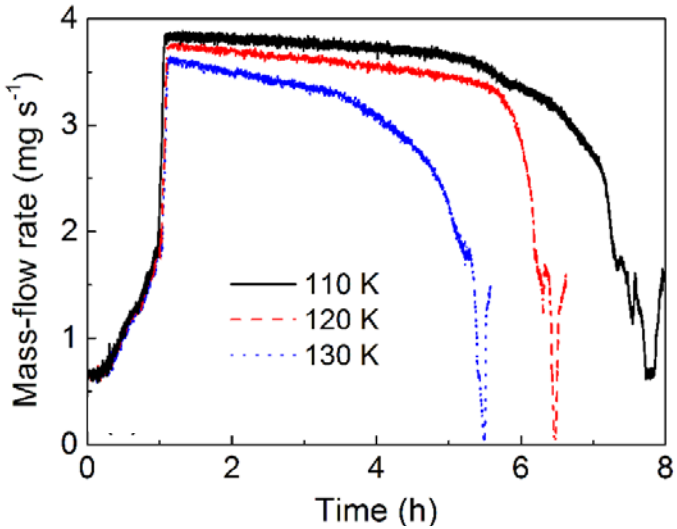


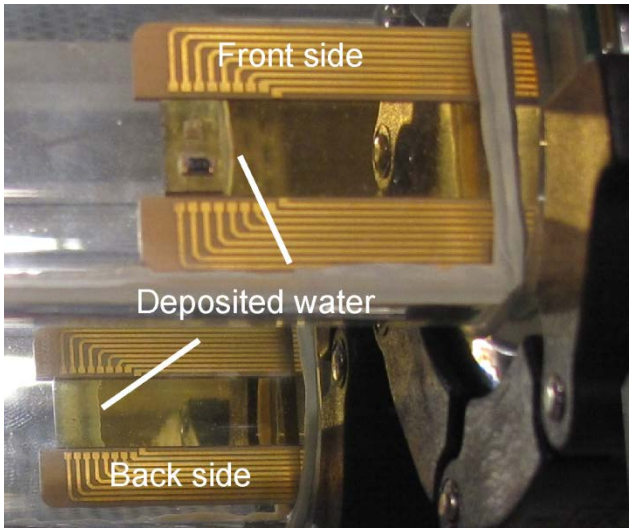


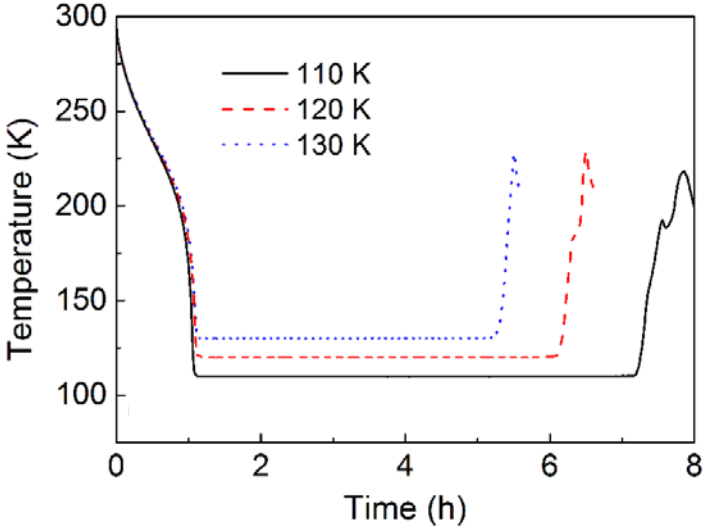


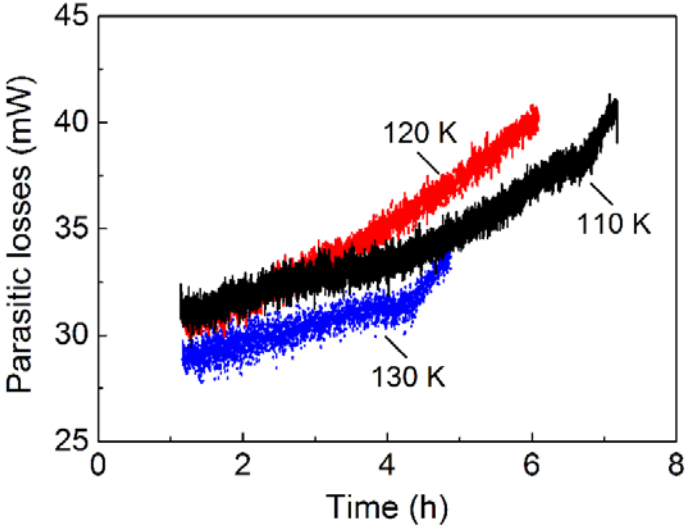


Influence of cold-end temperature of microcooler









Conclusions

- Reason of clogging: Deposition of water molecules.
- Influence of moisture level in nitrogen gas: Mass-flow rate during the cool down.
- Influence of cold-end temperature of microcooler: Clogging rate during the operation.
- Measures to increase the operation time: Decrease the amount of H_2O in N_2 gas and vacuum; Decrease the temperature along the restriction.

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Thank you for your attention!