

Reticle protection by thermophoresis, a collective approach

- The EUV reticle has no pellicle. The impact of this on system design, along with the severe particle free operation required, has not been determined, but some particle protection as effective as a pellicle is almost certainly required.
- Nikon is exploring means of reticle protection including thermophoresis.
- Thermophoresis appears to be an effective method of keeping particles off reticles.

Reticle protection by thermophoresis, a collective approach (cont.)

- However thermophoresis can at best only prevent particles from hitting the reticle. Once a particle attaches to the reticle, thermophoresis can't remove it. Some separate inspection and cleaning procedure is required.
- Therefore an effective use of thermophoresis, or an equivalent method, requires its use throughout the reticle lifetime. The alternative is inspection and (possibly) cleaning at each handling step.

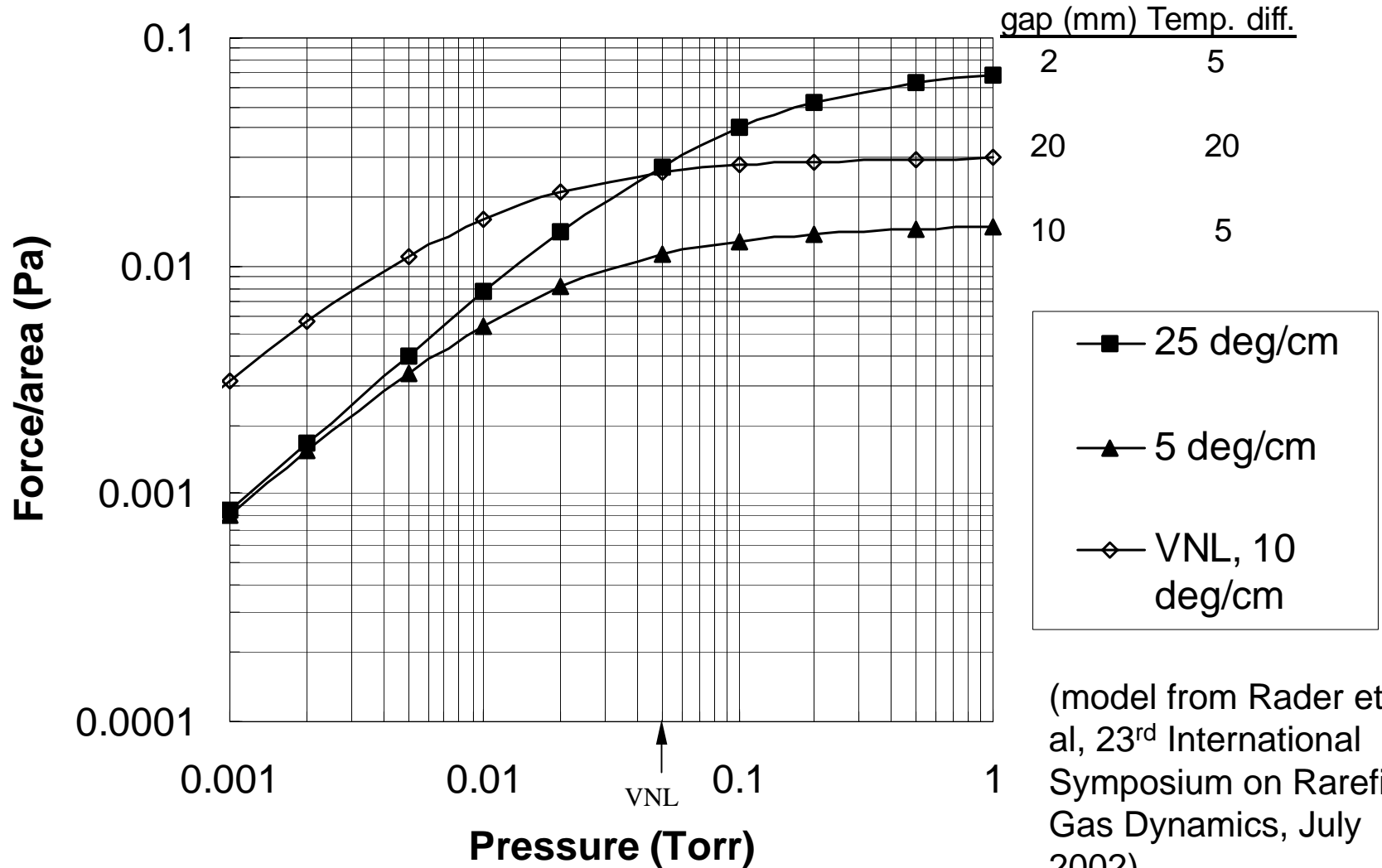
Reticle protection by thermophoresis, a collective approach (cont.)

- It's in the end-customer's best interest to minimize the need for inspection and cleaning, so a collective exploration and development of reticle protection technologies is recommended. Thermophoresis is used here as an example.
- Thermophoresis is covered by some patents, as may be the case for alternative technologies, and collective negotiation may represent the most appropriate model for licensing. (SMIF example)

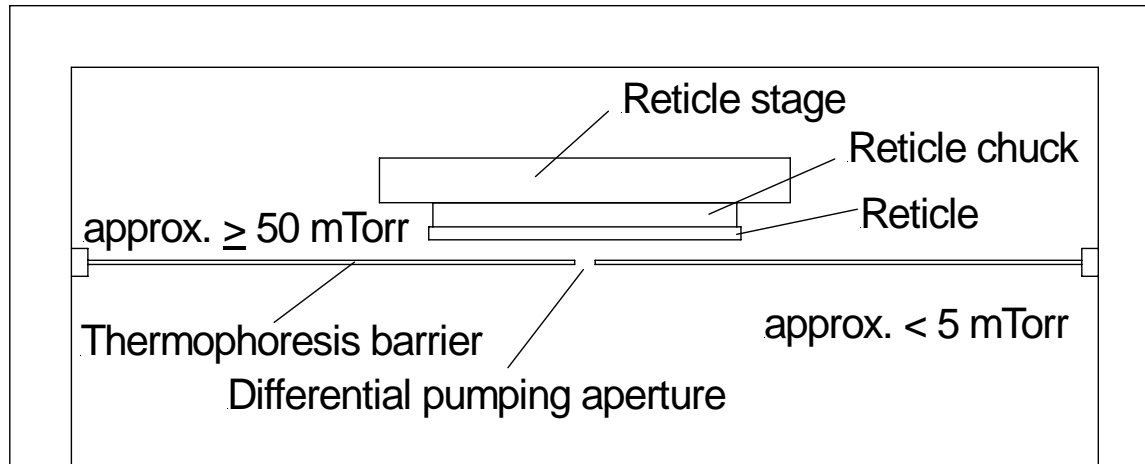
Thermophoresis – technical properties

- A particle in a gas located between two surfaces of different temperatures feels a force, which pushes it away from the hotter surface.
- High pressure: $mfp \ll$ surface separation
 Thermophoretic force \propto temperature gradient, gas properties
- Low pressure: $mfp <, \approx$ surface separation
 Thermophoretic force \propto temperature difference, pressure

Thermophoretic force - Ar gas



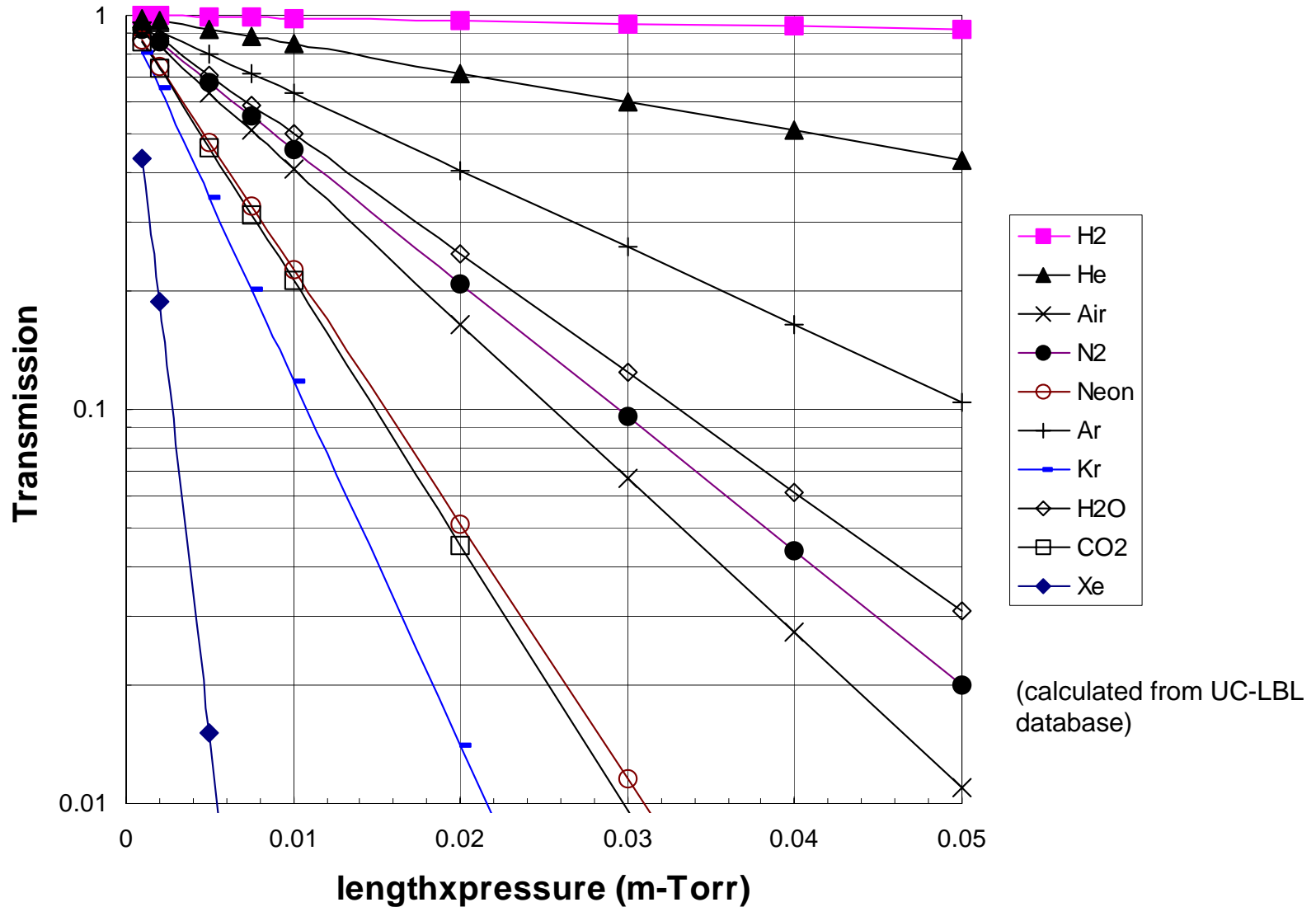
Example of thermophoretic reticle protection – low pressure regime



D. Rader et al,
 Proc. SPIE 4688, 182(2002)



Gas pressure in projection optics limited by EUV transmission losses



Summary

- Experimental results from VNL show promise for thermophoretic reticle protection within the exposure tool.
- Similar work needed to demonstrate thermophoretic protection capability at earlier stages of reticle lifetime.
- Collaborative work would probably be fruitful for further development.
- Eventually intellectual property aspects have to be settled.