# An elastomer dosimeter for monitoring ozone exposures in museum storage rooms

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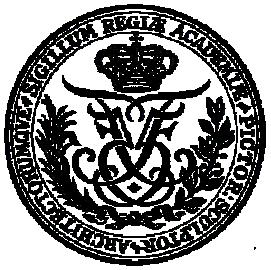
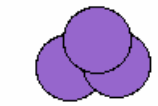


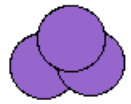
# Ozone: $O_3$

Mainly **outdoor** sources (photochemical reactions between nitrogen oxides and volatile organic compounds in the presence of sunlight )

Typical outdoor level:

- **20 ppb – 60 ppb** (150 ppb)
- Highest during summer



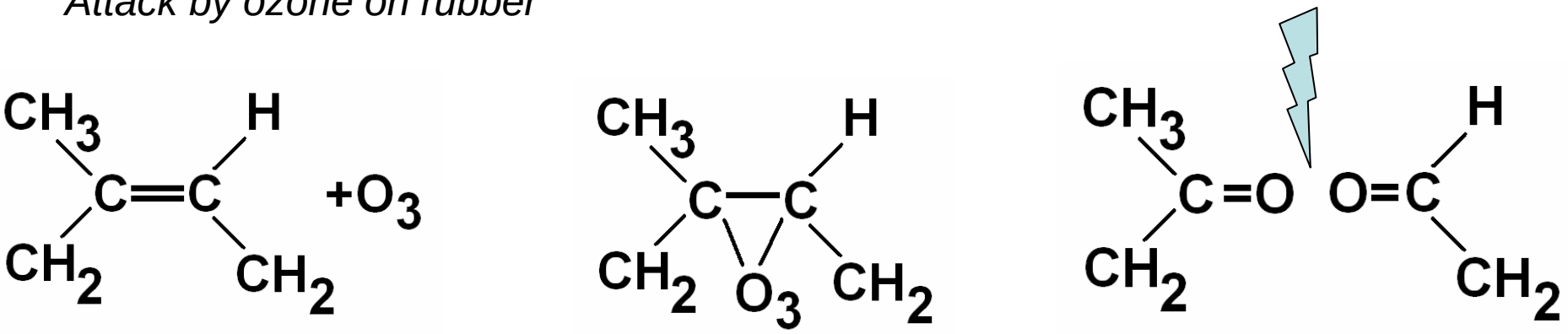


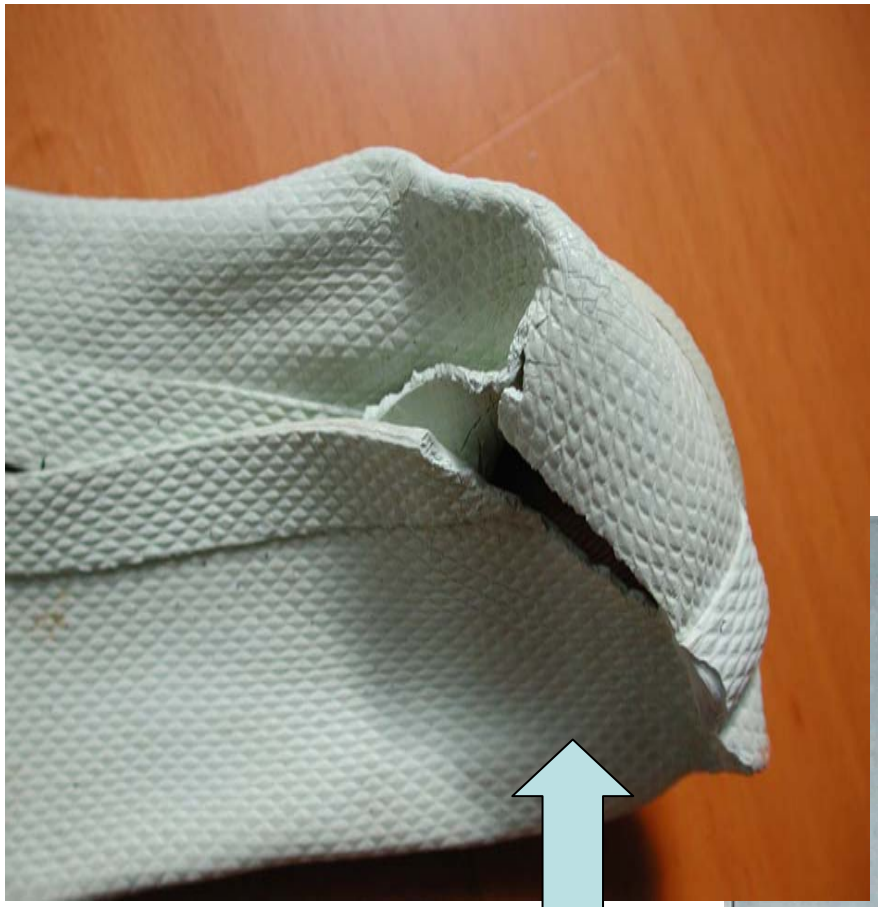
Typical indoor levels: **5 – 80% of outdoors**, but often **lower range**, especially with low air exchange rate, or when ventilation air is filtered

# Ozone is a strong oxidant, which engage in material deterioration

- It attack rubber by breakage of molecular bonds, which causes surface cracks (Jaffe, 1967)
- However, it will also attack other types of materials, for example, colorants (Whitmore,Cass,Druzik, 1987)

*Attack by ozone on rubber*





Stiff, oxidized rubber shoe

Shooting gloves, latex
Danish Defence Museum
*Right glove very oxidized*
*Left glove in good condition*

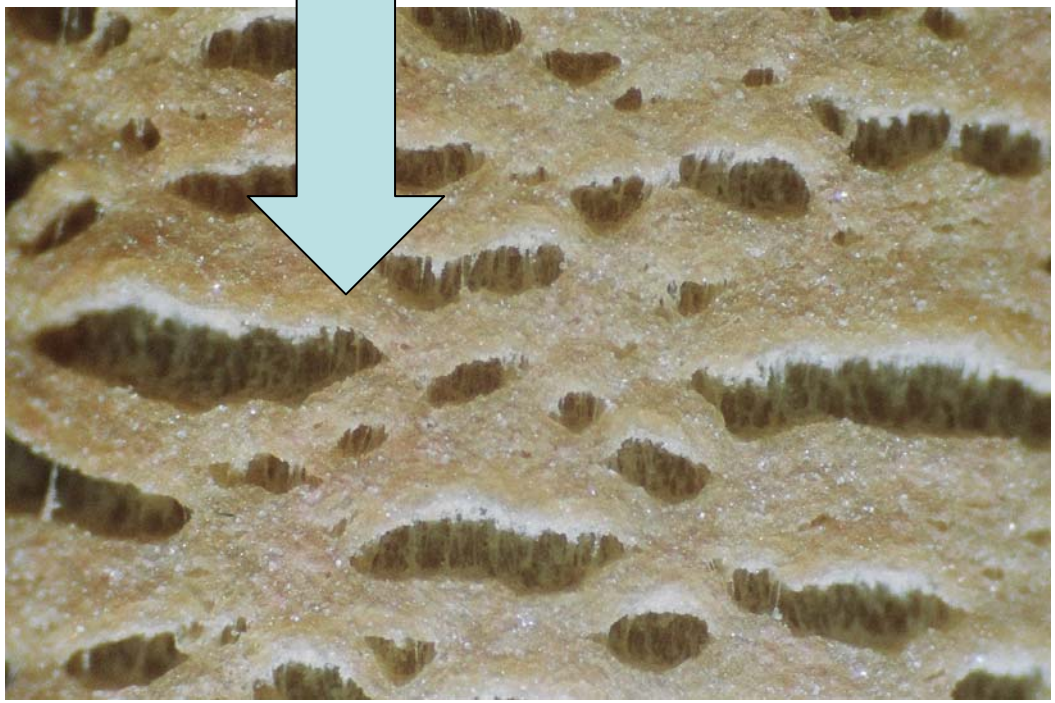
*Photos: Yvonne Shashoua*

# Previous work on ozone and rubber
# Dosimeter methods

- Depth of cracks (Rugg, 1952)
- Strain measurements (Beatty & Juve, 1954)
- Thickness measurements (Schaef, 1962)
- Crack lenght and width (Veith, 1972)
- Image analysis of crack pattern (Serrano et al, 1993)
- Opacity measurements (Mott & Roland, 2001)
- …

# Normal rubber bands are highly usable as a dosimeter material

- Stretched to double lenght
- Exposed for 3 – 6 months
- Surface examined by light microscopy



# EDGE CRACKS

**Phase 1**
**<100 ppb*d**
**No cracks, edge sharp**
**Surface keep materials color**

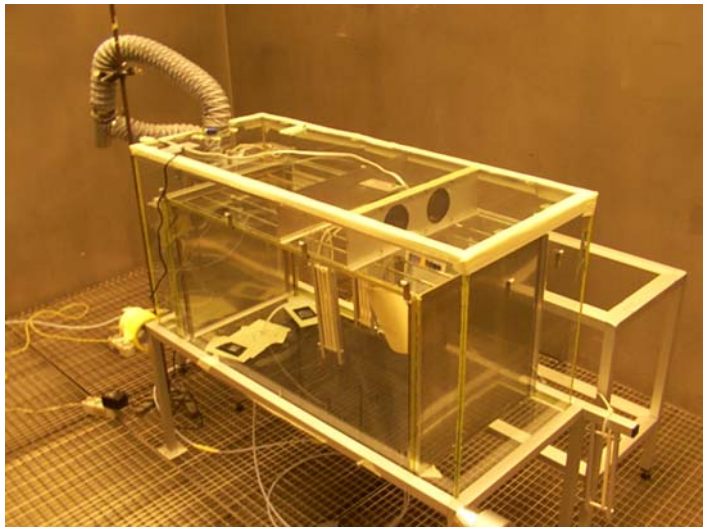
**Phase 2**
**<500 ppb*d**
**Edge rough**
**surface whitish**

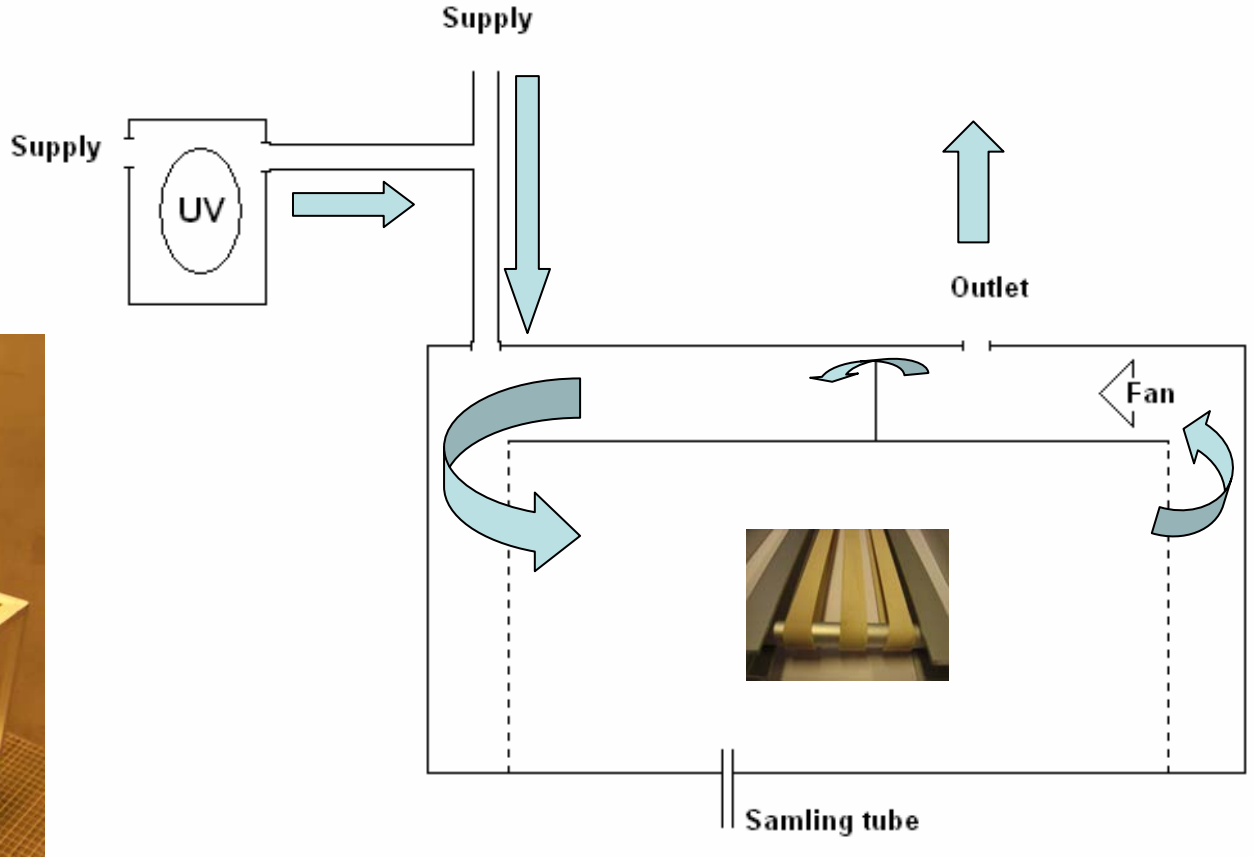
**Phase 3**
**500-1000 ppb*d**
**Edge cracks 1-5 um**
**White surface**

**Phase 4**
**>1000 ppb*d**
**Edge cracks 10-40um**
**Large cracks all surface**

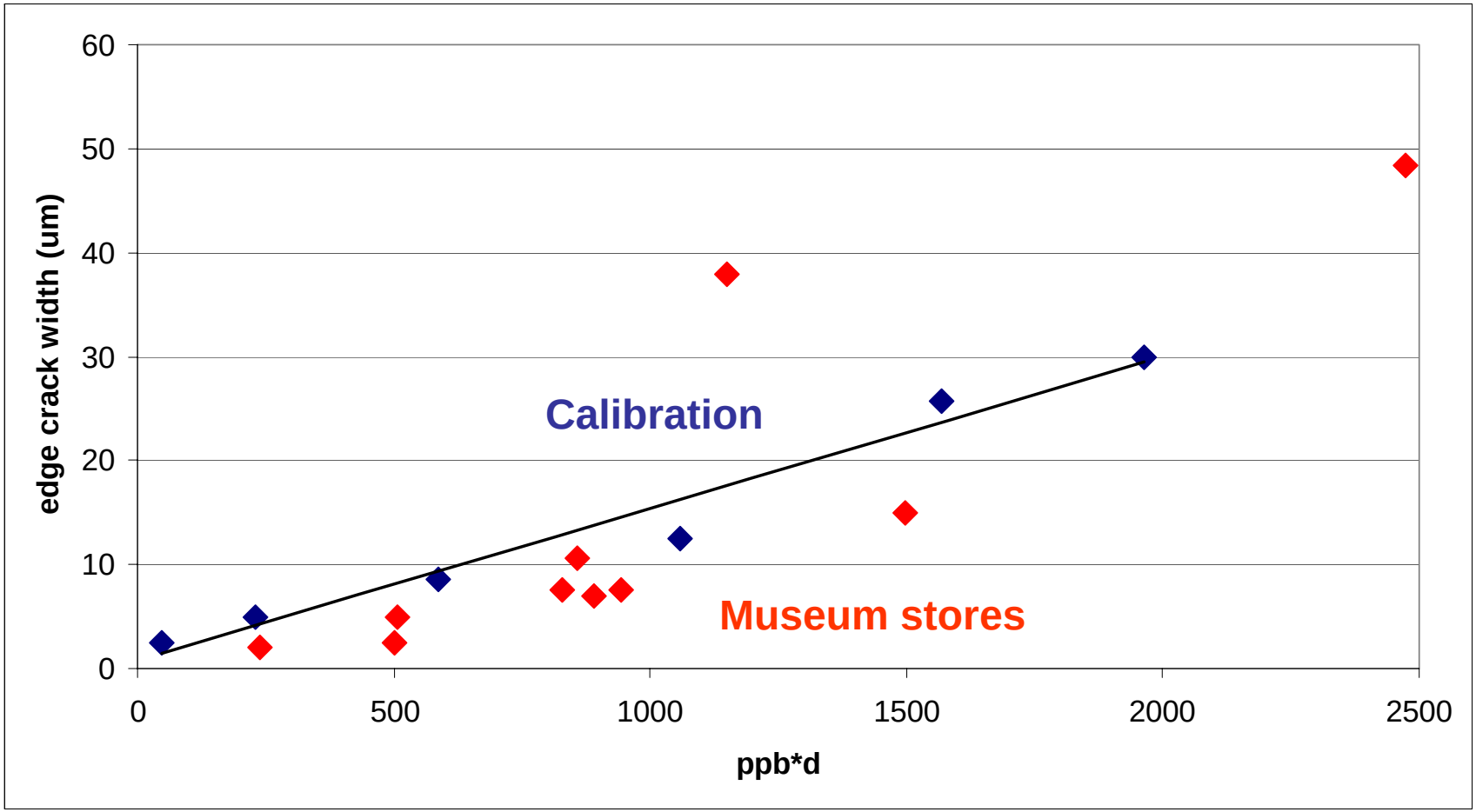
Scale
One tick = 10 um

Rubber samples were exposed to controlled ozone levels in laboratory, and exposed in real museum buildings





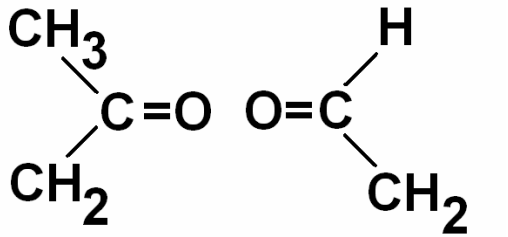
# Ozone exposure vs. edge crack width
# Rubber bands: lab and field results



# ATR-FTIR of surface

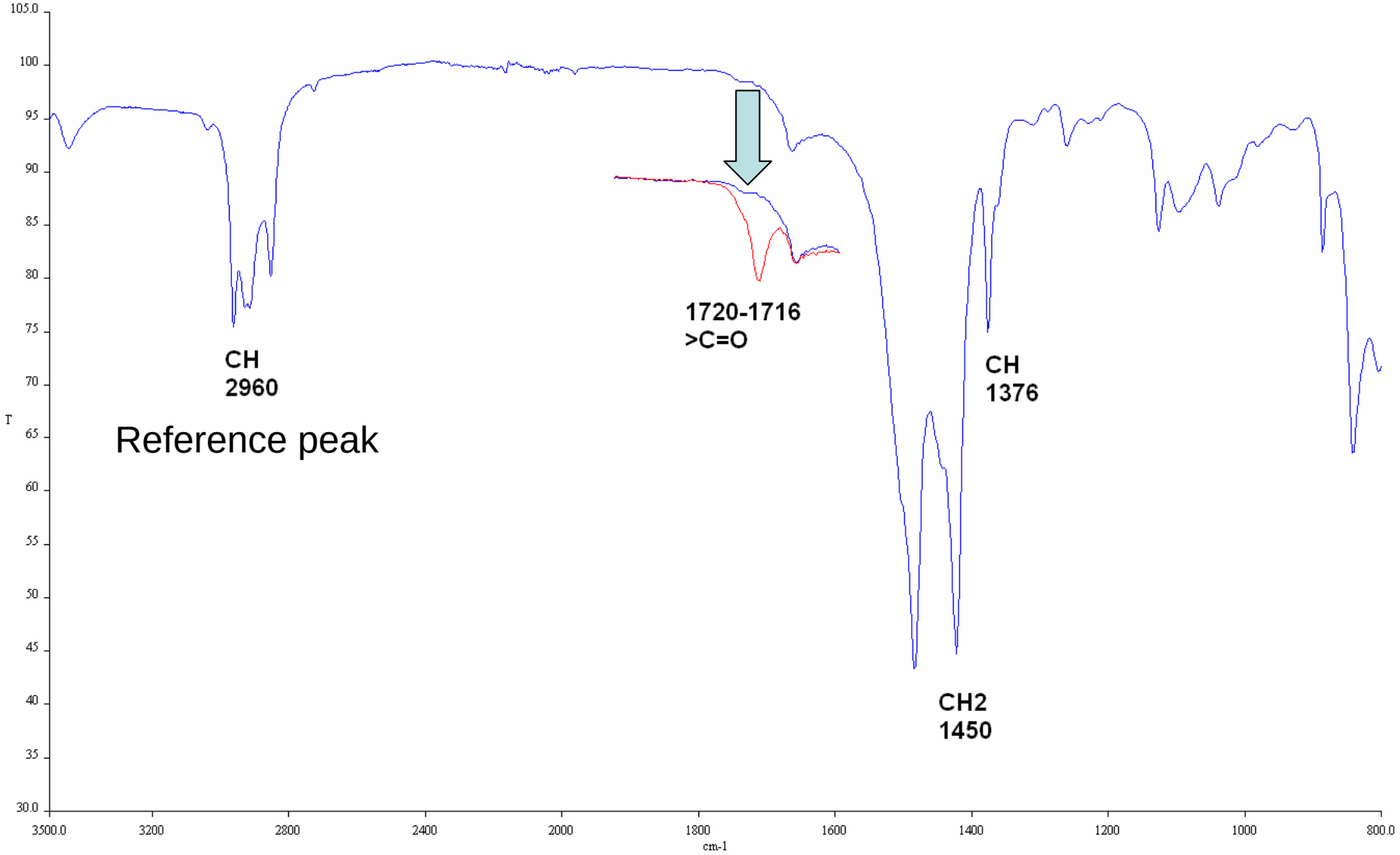
- For low exposures (<500 ppb*d,  Phase 1+2), quantification by the edge crack method is difficult

- However, the formation of carbonyl bonds is detectable by surface spectroscopy

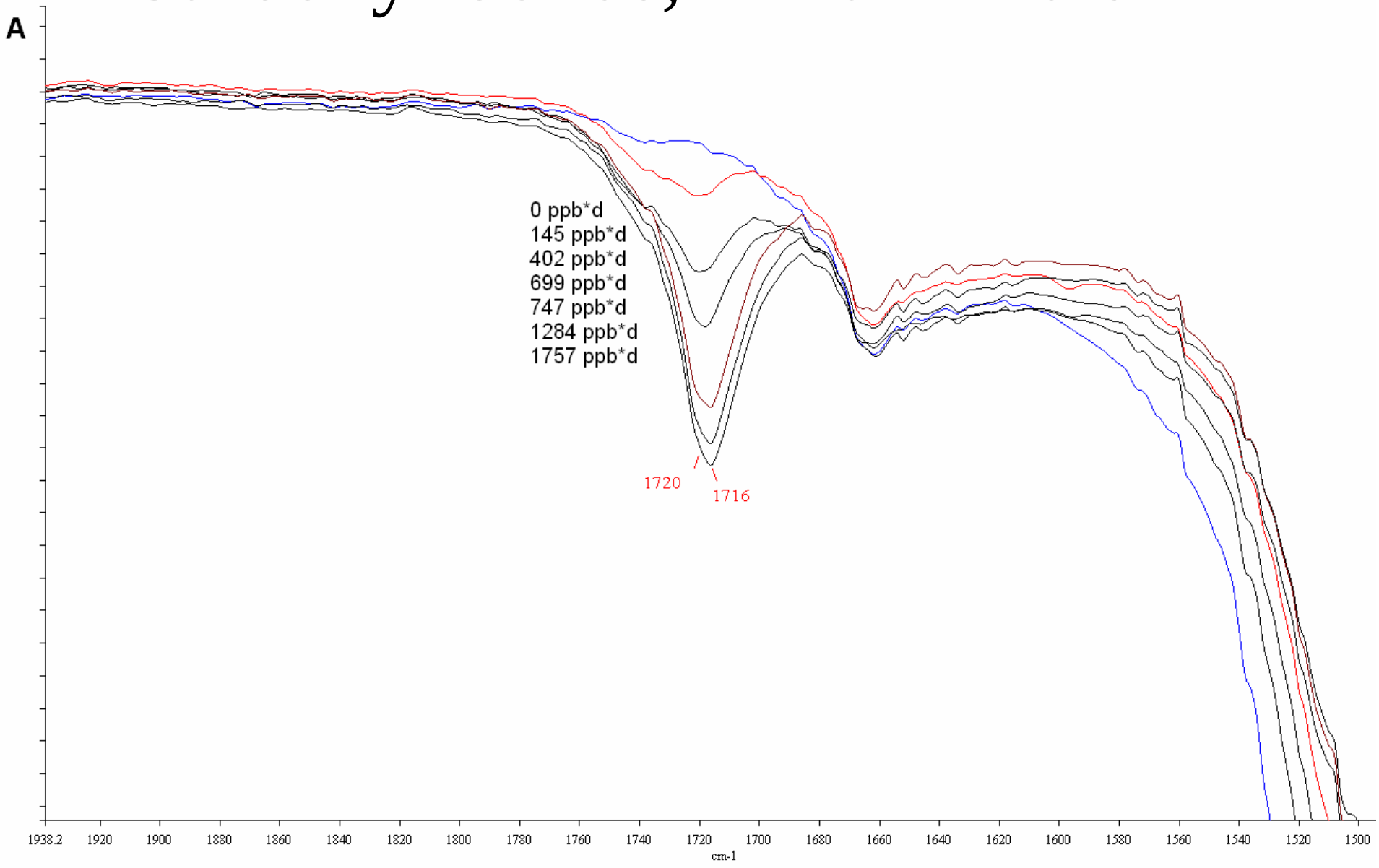



- Rubber bands contain talc and other additives, which disturbs the latex spectre, but pure latex sheets are usable

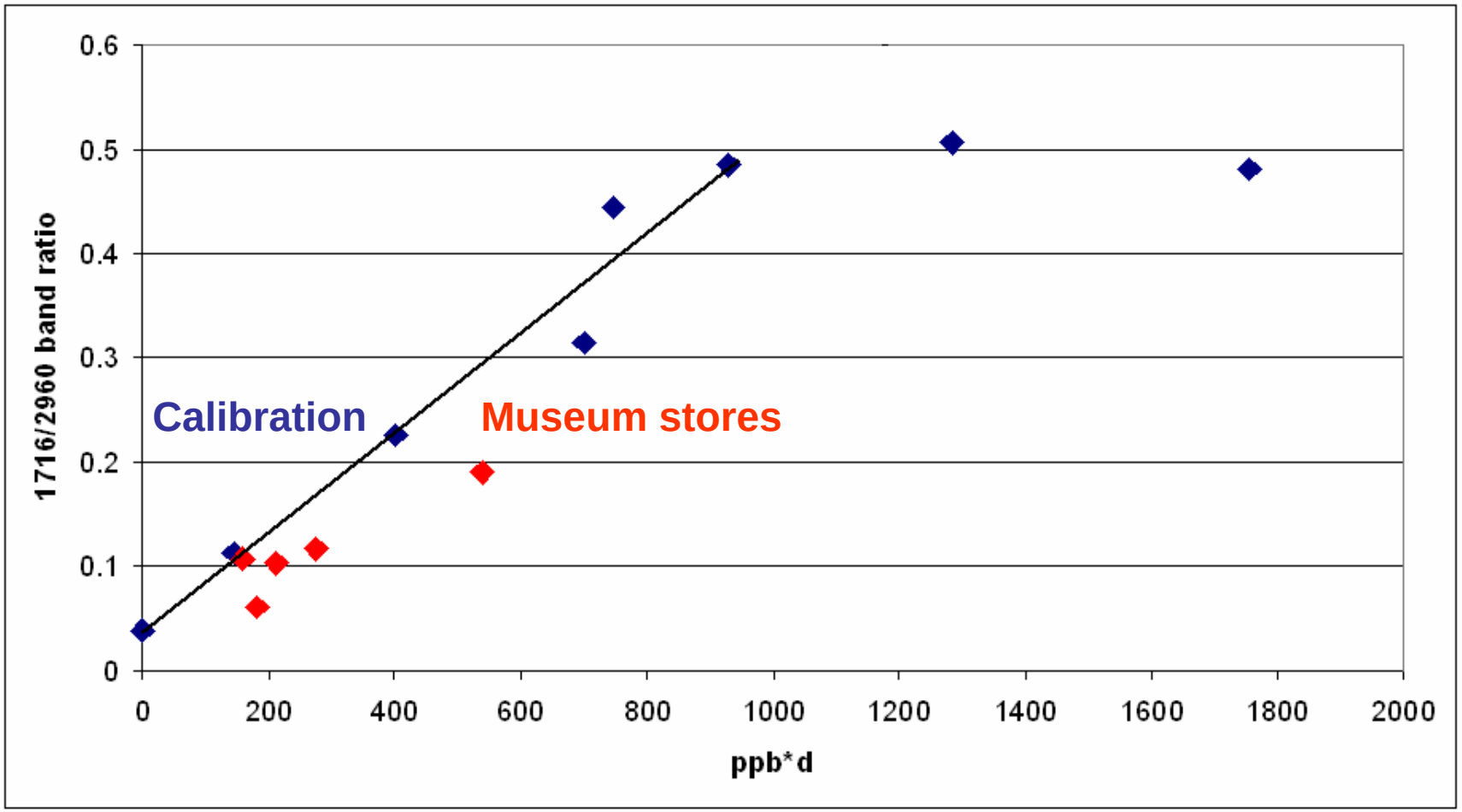
# Carbonyl bonds, 1720-1716 $cm^{-1}$



# Carbonyl bonds, 1720-1716 $cm^{-1}$



# Absorbence ratio :1716/2960 $cm^{-1}$
# Latex sheets: lab and field results



# Conclusion

- Rubber bands are usable as simple ozone dosimeters
- By optical microscope analysis it is possible to distinguish between *Phase 1-4* exposures

  *0-100 / 100-500 / 500-1000 / >1000 ppbh*
- For low ozone exposure ATR-FTIR is a promising quantification method, however, better latex quality than rubber bands must be used

# Acknowledgements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- Danish Museum of Photographic Art
- Arnamagnaean Manuscript Collection

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Ozone lab, exposure chamber
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