Vacuum Pumping Via Titanium-Zirconium-Vanadium Thin Films

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The 13th ICFA Beam Dynamics Mini-Workshop

Beam Induced Pressure Rise in Rings

Brookhaven National Laboratory, Upton, NY

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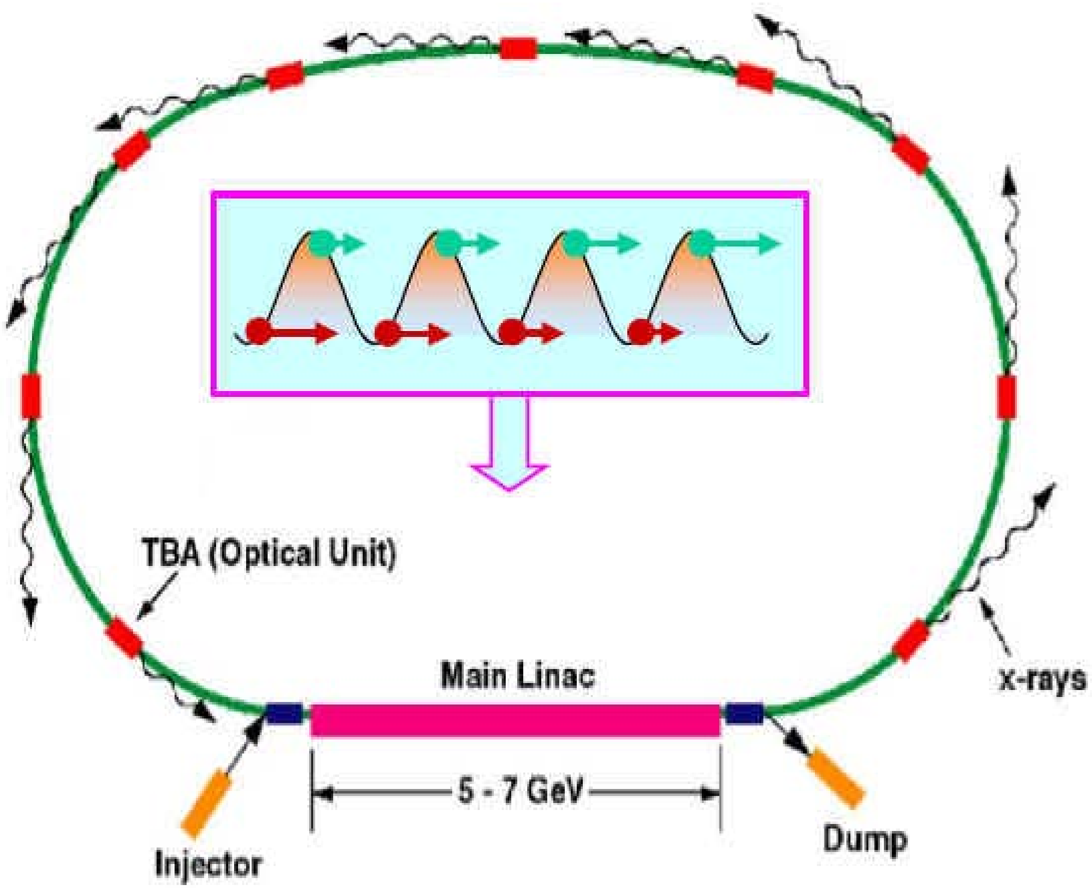
Energy Recover Linac as a Light Source



- Very low electron beam emittance in 6-D to increase SR brilliance & coherence
- Very short pulse to enable fast time-resolved exp'ts
- Ultra-small round beam
- Steady SR output with no decay over time
- Flexibility of operation to enable easy tailoring of SR beams to applications
- Easy upgrade path

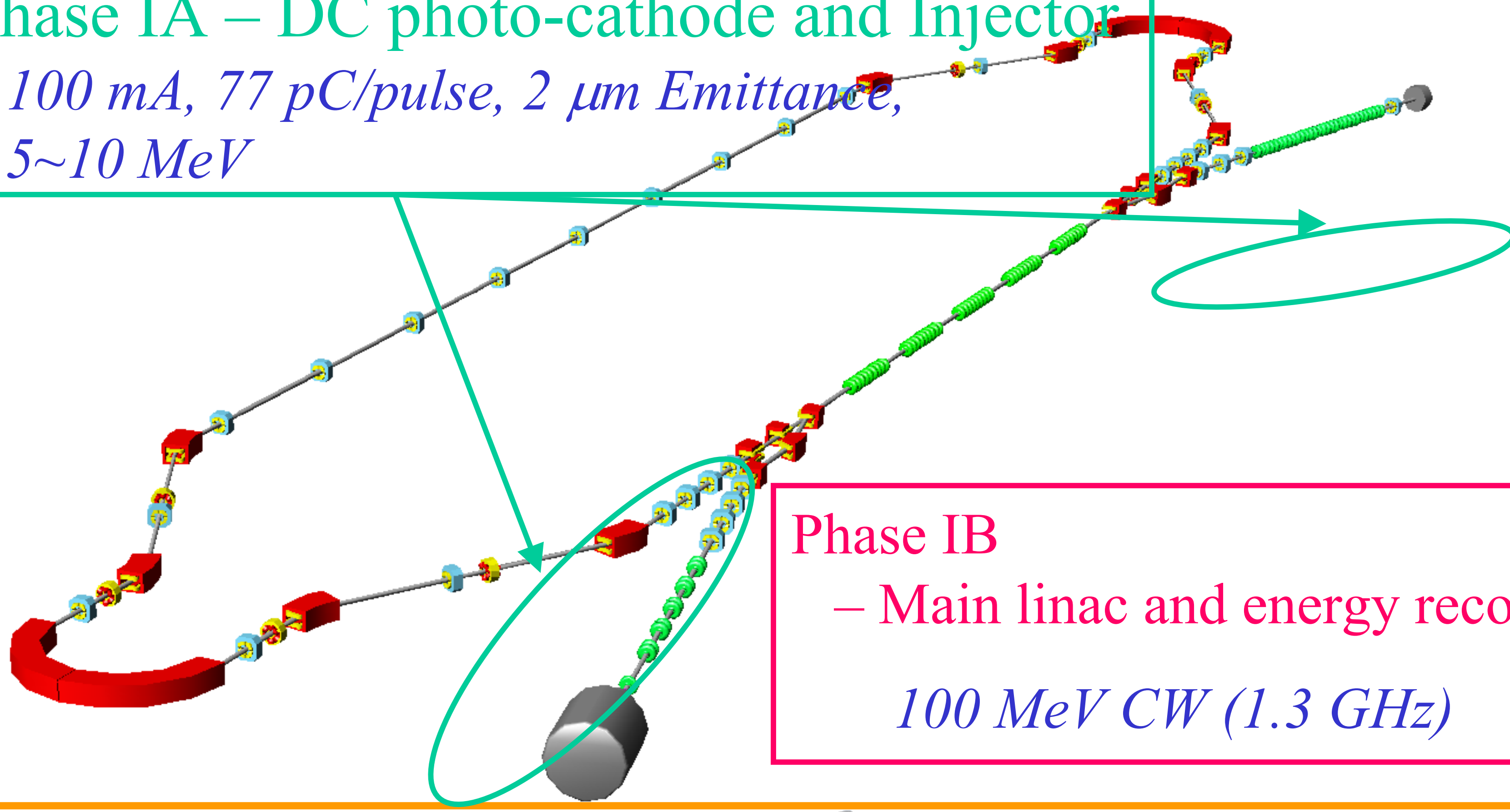
Challenges to be resolved

- Low emittance production and preservation
- Photocathode longevity at high average current (*vacuum issue*)
- Longitudinal phase space preservation in bunching
- BBU in the main linac (*HOMs damping*)
- Beam loss ~ μA (beam halo)
- Highest Q_L possible (*microphonics, RF control*)
- Diagnostics …

Cornell Prototype ERL Project

Phase IA – DC photo-cathode and Injector

100 mA, 77 pC/pulse, 2 μm Emittance,
5~10 MeV



Phase IB

– Main linac and energy recovery

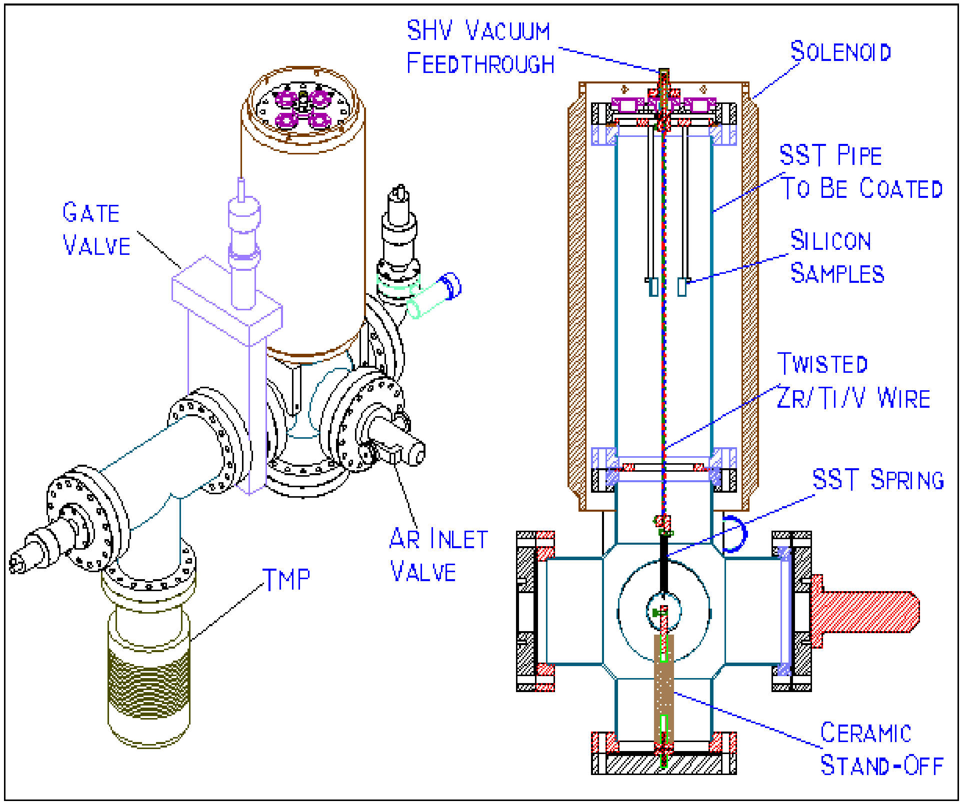
100 MeV CW (1.3 GHz)

Vacuum Pumping with NEG Thin Films

- Benvenuti *et al* demonstrated many advantages of vacuum pumping using NEG thin films, including LOCAL pumping, very low outgassing, low secondary electron yield, etc.
- Particularly, the Titanium-Zirconium-Vanadium thin film has relatively low activation temperature
- Ti-Zr-V thin film deposition and vacuum pumping performance are studied, as part of the Cornell ERL R&D efforts

Ti-Zr-V Thin Film Deposition

DC Magnetron Sputtering



- Cathode – 1-mm twisted Ti/Zr/V wires
- Typical Parameters – P_{Argon}~20mtorr Fields ~600V_{DC}/200 Gauss, $I_{sputtering} \approx 30$ mA
- Sputtering gas (Ar) purity must be adequate
- Two 4.00”-dia. SST Tubes coated, with 0.6 and 2.0µm NEG film thickness

Deposition of NEG Thin Films

Film Deposition Rate :

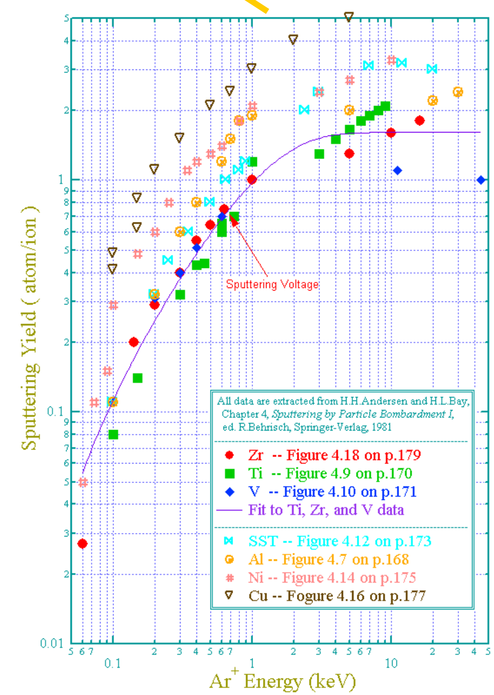
$$R_{growth} = \frac{I_{ion} \cdot Y_{yield}}{2\pi r L \cdot q_e \cdot n_{NEG}}$$

Sputtering Ion Current depends plasma density, (P_{gas}, B-, E-fields)
Higher the better, but limited by cathode heating.
Sputtering gas purity very important. Maximizing I_{ion} at lower P_{gas}.

Target Area

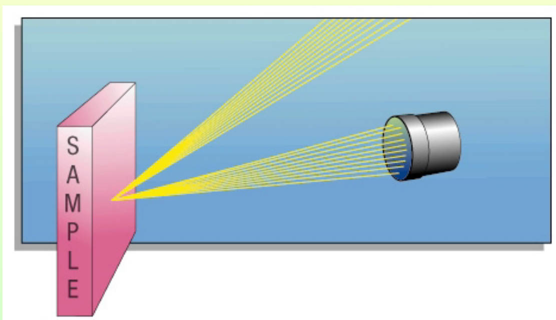
Film atomic density

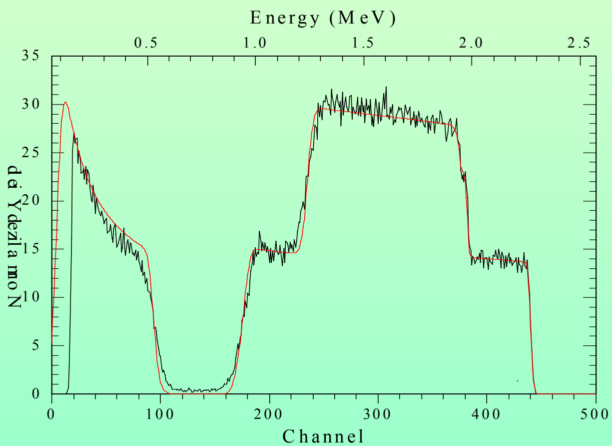
$$n_{NEG} = \frac{x n_{Ti} + y n_V + z n_{Zr}}{x + y + z}$$



NEG Film Characterization – RBS

Rutherford Backscattering Spectrometry (RBS)





Average Composition :

$$Ti_{27\%}V_{47\%}Zr_{26\%}$$

Deposition Rate :

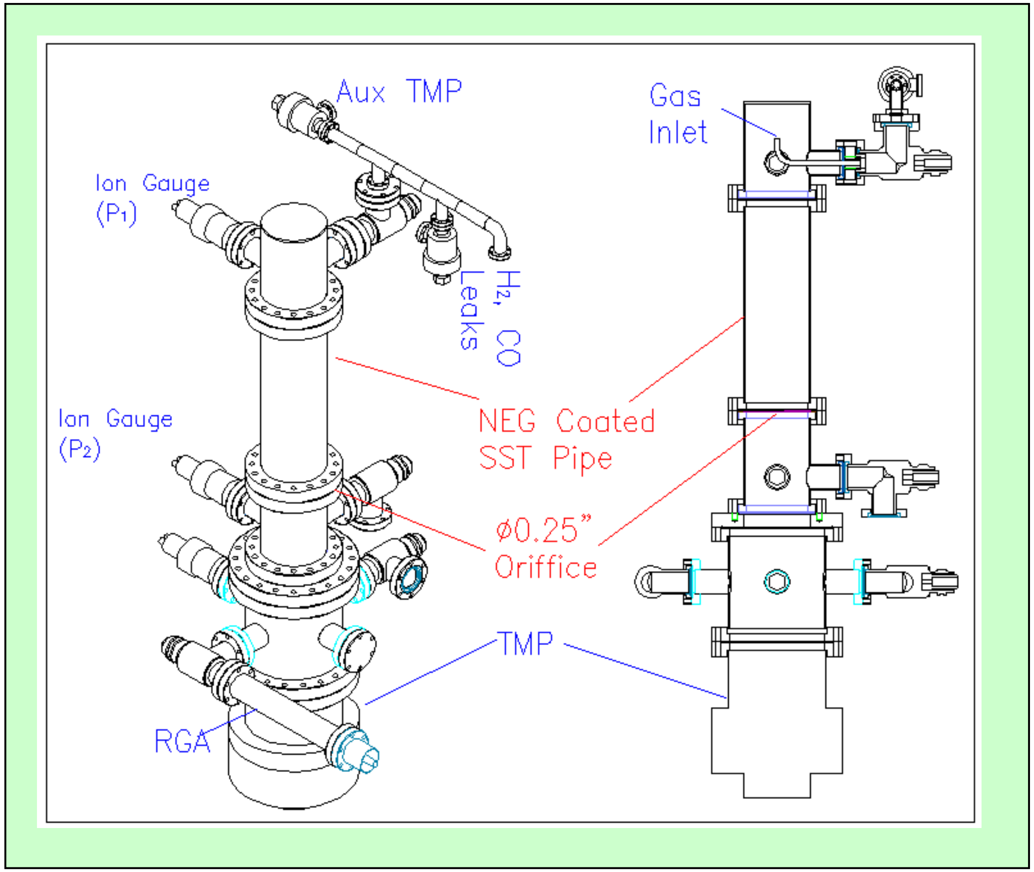
$$R_{growth} = \frac{I_{ion} \cdot Y_{yield}}{2\pi r L \cdot q_e \cdot n_{NEG}}$$

$$= 4.70 \frac{I_{ion} \cdot Y_{yield}}{r} (nm/\sec)$$

$$\approx 100 nm/hr$$

NEG Thin Film Pumping Performance

Experimental Setup



- Throughput method used to measure pumping speed
- Calib. H_2 & CO leaks used
- All pumping tests at R.T.

Pumping Speed:

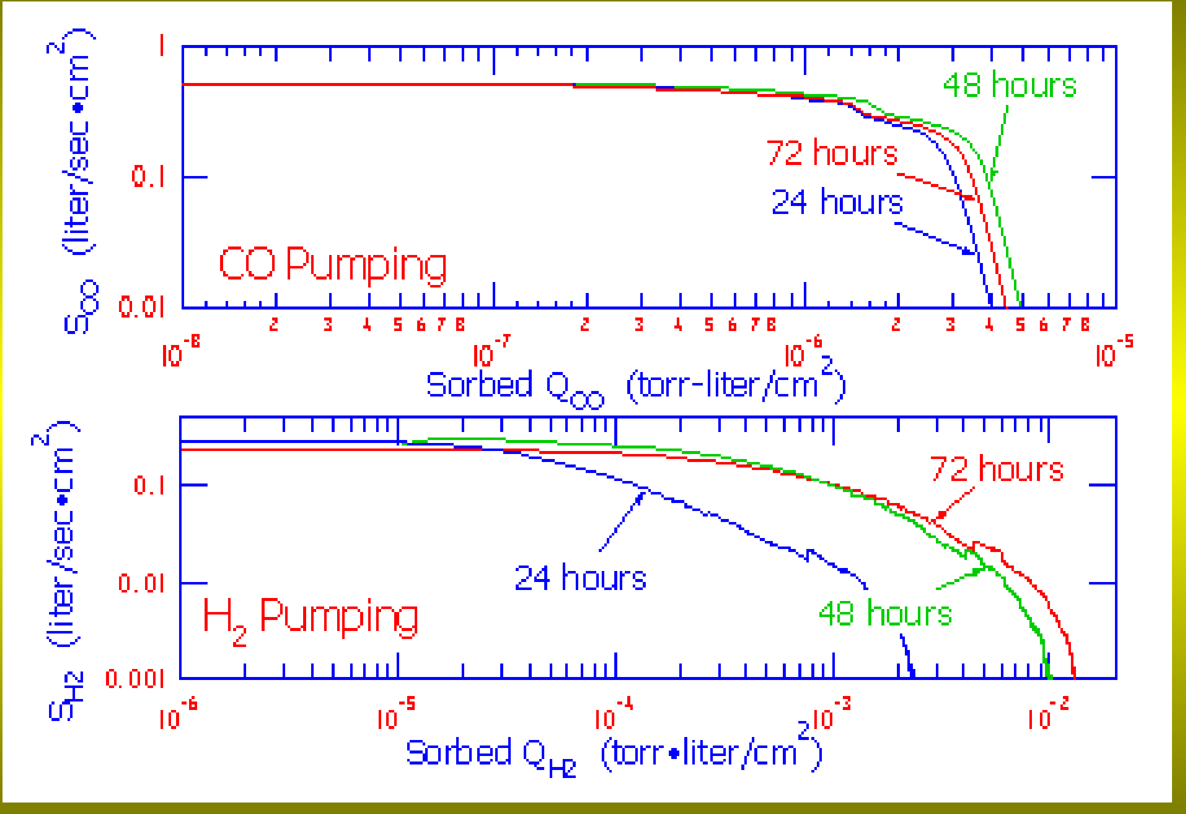
$$S_{NEG} = \frac{\dot{Q}_{leak} - C(P_1 - P_2)}{P_1}$$

Throughput :

$$Q^{CO,H_2}_{pumped} = \int (S^{CO,H_2}_{NEG} \cdot P_1)\, dt$$

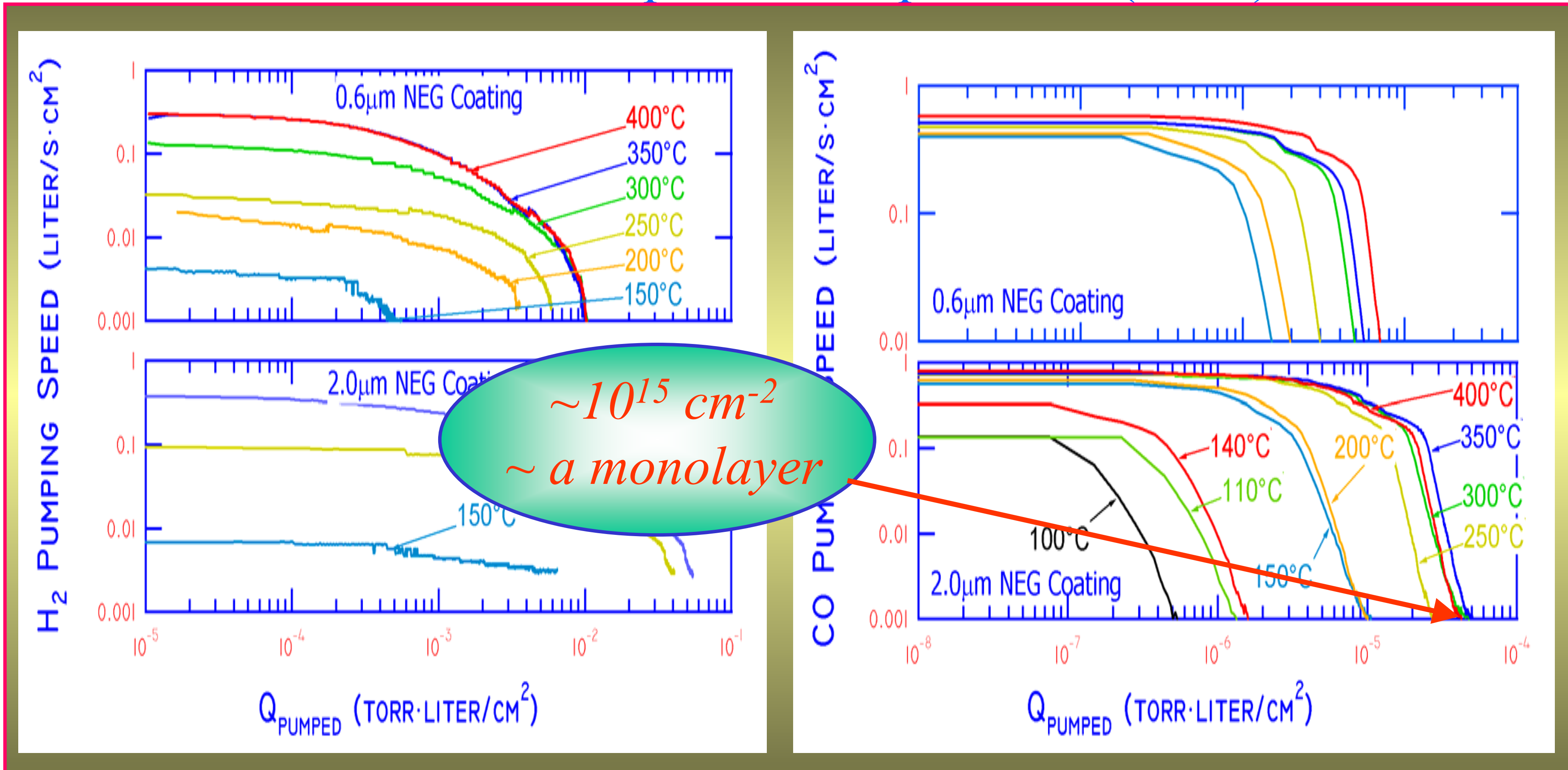
Pumping Speed vs. Gas-load

Activation Duration Dependence (@350°C)

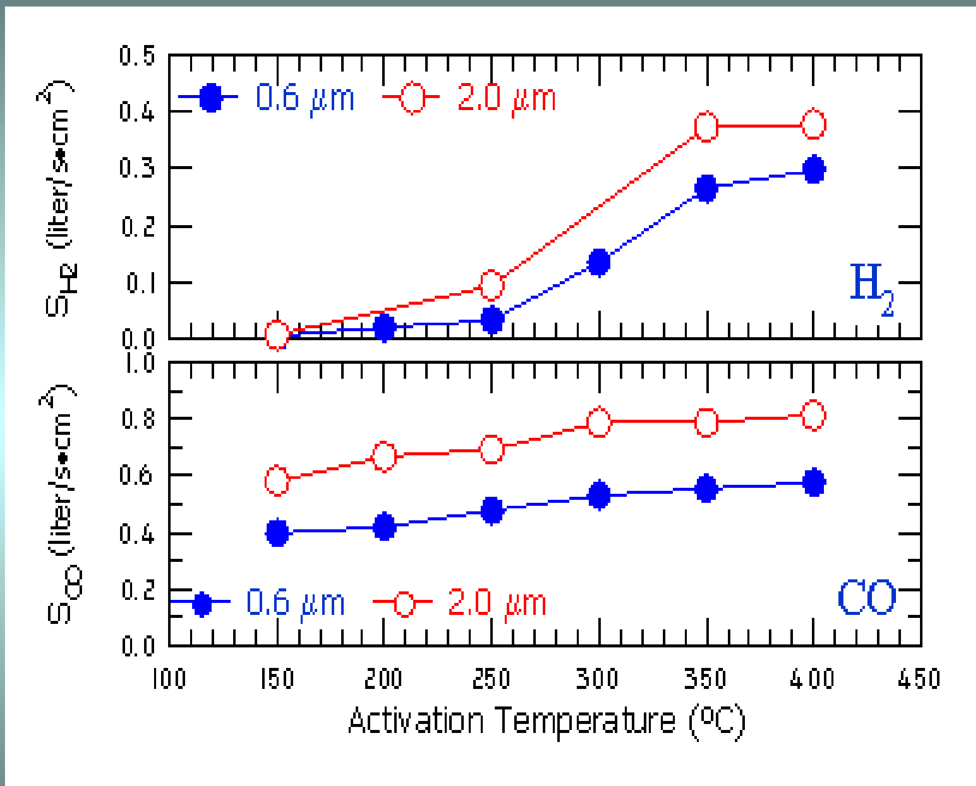


Pumping Speed vs. Gas-load

Activation Temperature Dependence (48-hr)

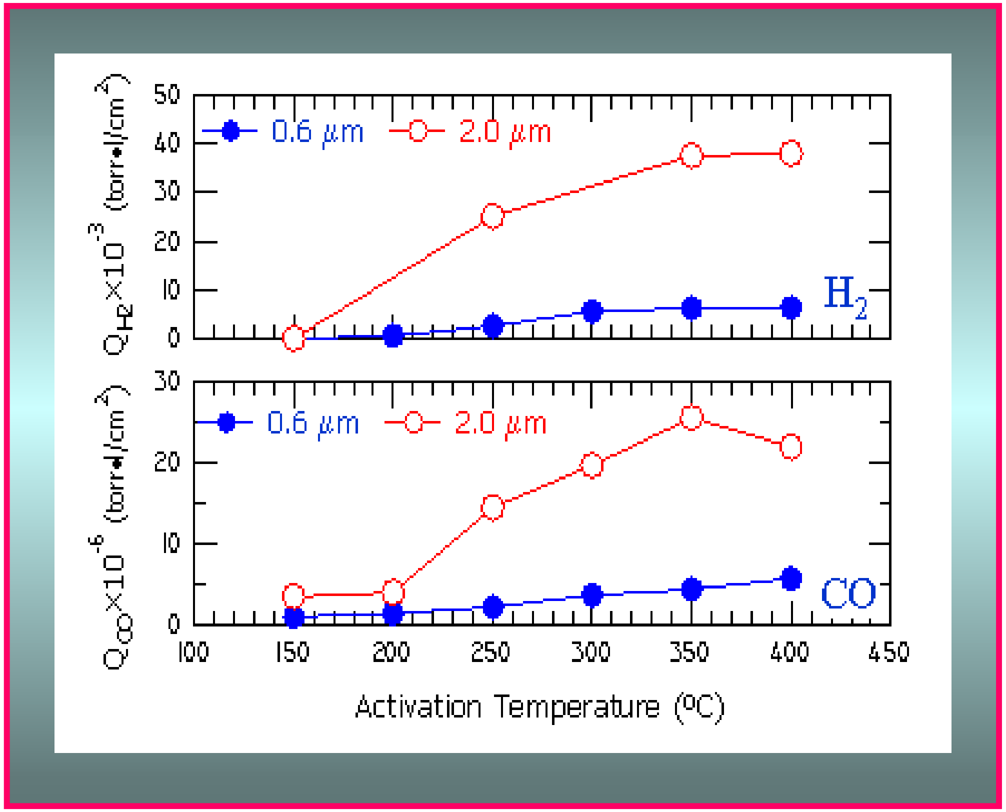


NEG Film Initial Pumping Speed



- 'Initial' pumping speed to a gas reflects NEG surface reactivity to the gas, and NEG surface roughness
- Pumping of CO & H_2 at T_{act} as low as 150°C
- Weak dependence for CO on T_{act} (~20% increase)
- Significant increase in H_2 pumping with T_{act} >250°C
- Higher S_0 on thicker film due to increased NEG surface roughness

NEG Film Pumping Capacity



- Pumping capacity defined as a throughput to reduce S_{NEG} to a lower value, S_f

$$S_f^{CO} = 0.1 \;\; l/s{\cdot}cm^2$$

$$S_f^{H_2} = 0.01 \;\; l/s{\cdot}cm^2$$

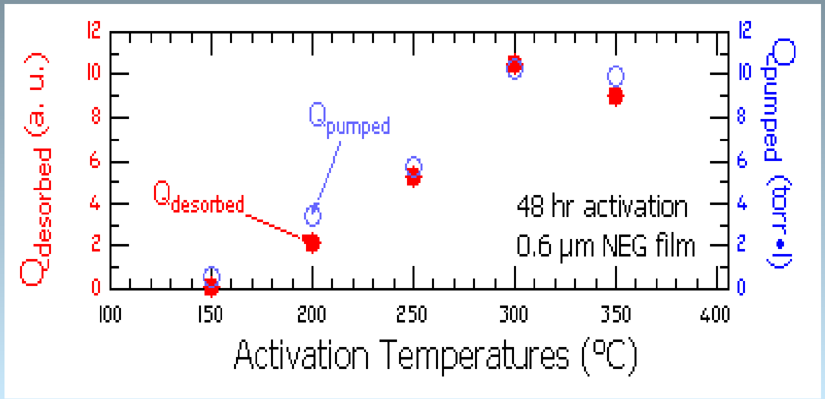
- Orders of magnitude higher throughput for H_2 than CO
- Significant throughput improvement for both H_2 and CO with T_{act} > 250°C

Discussion – H_2 Pumping

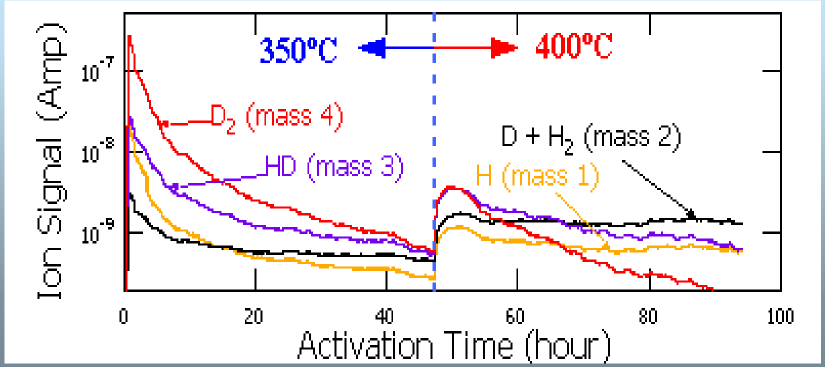
Factors affect NEG's H_2 pumping capacity :

- NEG film hydrogen solubility $Q_{H_2}^{max} / n_{NEG}$
  ~ 14.2% for 0.6 µm film
  ~15.1% for 2.0 µm film
- Residual hydrogen content in the NEG film

- Desorption vs. Pumping

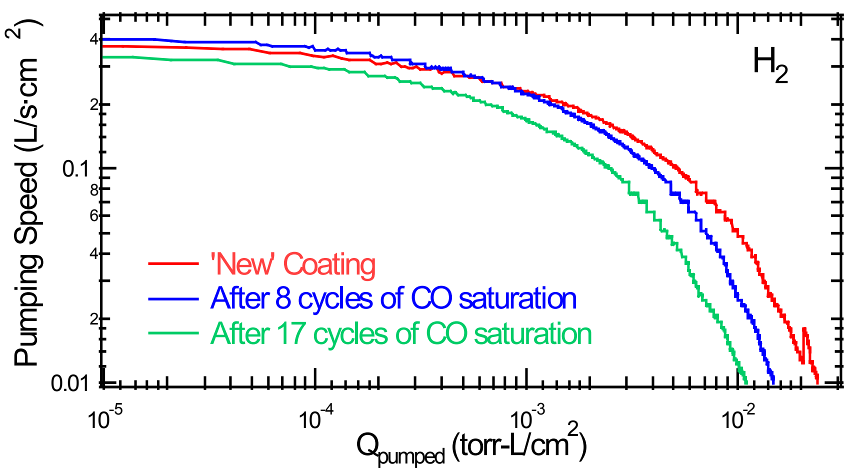


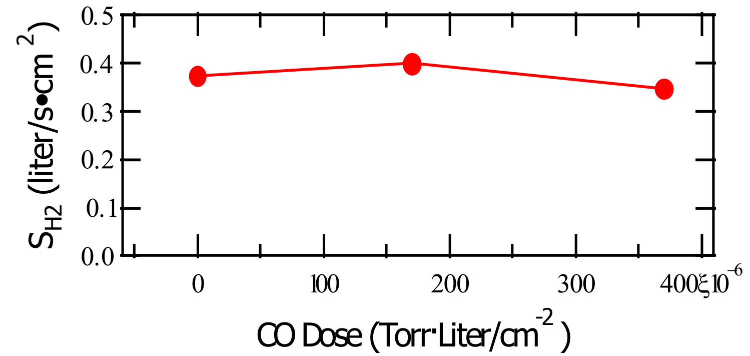
- Desorption vs. Pumping



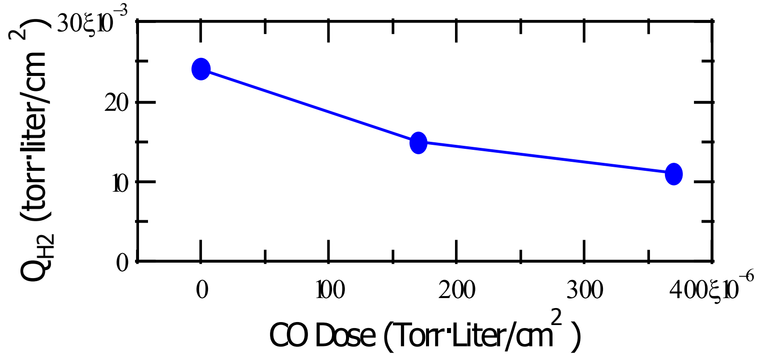
Film Aging – H_2 Pumping as a Probe

2 μm NEG Film on SST





Very Small S_0 Reduction



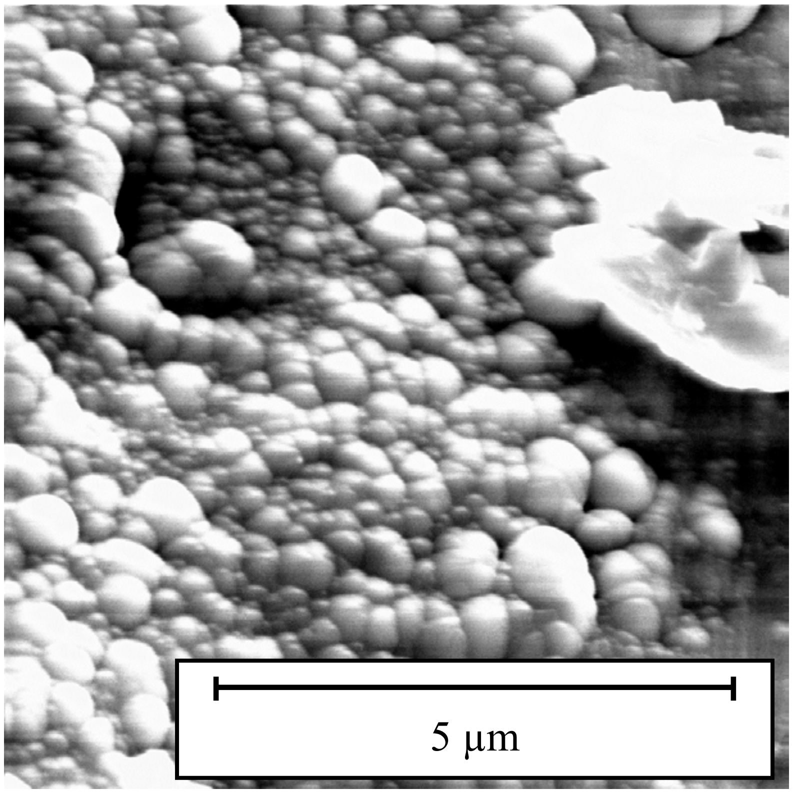
Decrease in H_2 Solubility

Word of Caution

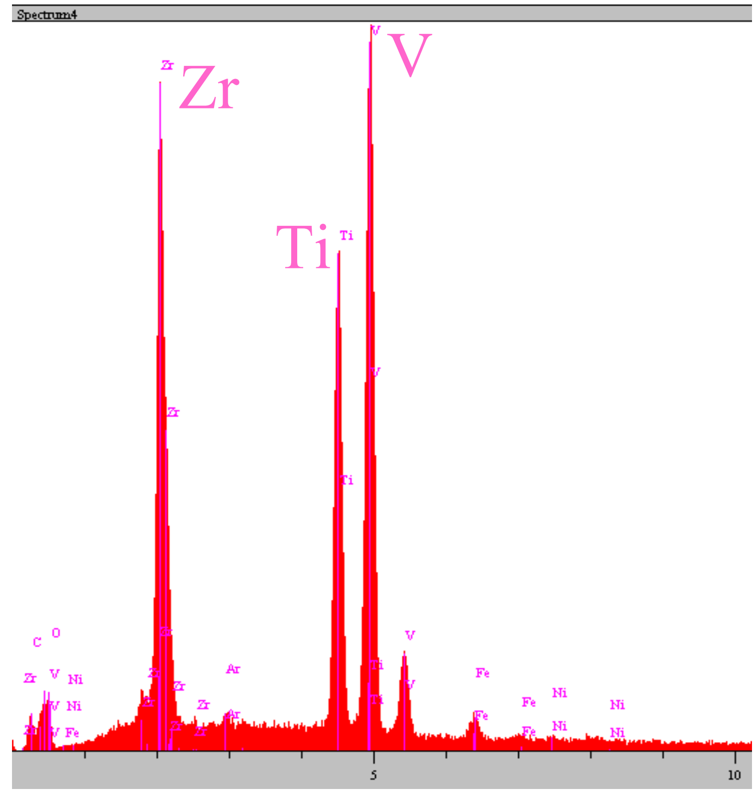
Powder substance were found on the orifice disk, as well as on the coated surface, after extensive pumping tests

- *The original coating had excellent bonding, by visual inspection and/or via 'tape testing'*
- *Believe the coating was damaged by excessive H_2 sorption. More investigation planned*

Powder Confirmed to Be NEG



Powder SEM Image



Powder EDX Spectrum

Conclusions

- Ti-Zr-V thin films were deposited on SST tube using DC magnetron sputtering technique and characterized using RBS
- Vacuum pumping performance of the NEG thin films was measured, as functions of film thickness and activation conditions
- Effective pumping observed @T_{act}~150°C, and significantly enhanced performance with T_{act}>250°C
- Further works are needed to study the NEG film aging effect

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