High Density Plasma Enhanced CVD of Polysilicon Thin Films

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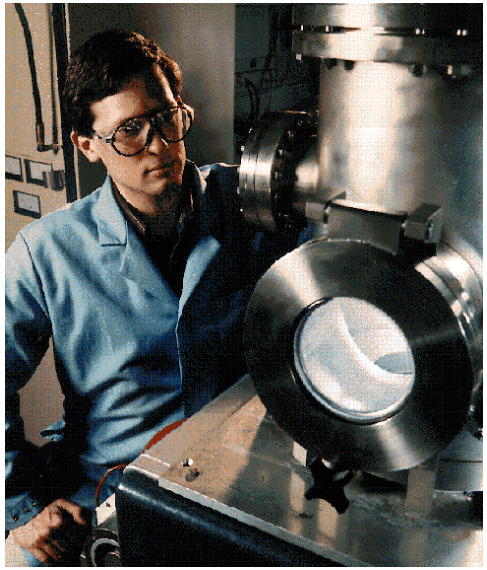
Agenda

- Inductively coupled high density plasma source description
- Deposition rates vs operating parameters (up to 80 nm/min, Tsub = 350 ^{o}C)
- Film quality
  - Raman results (>80% crystallinity)
  - X-ray diffraction results (highly peak <110>)
  - FTIR absorbance for H% (< 2%)
- Summary



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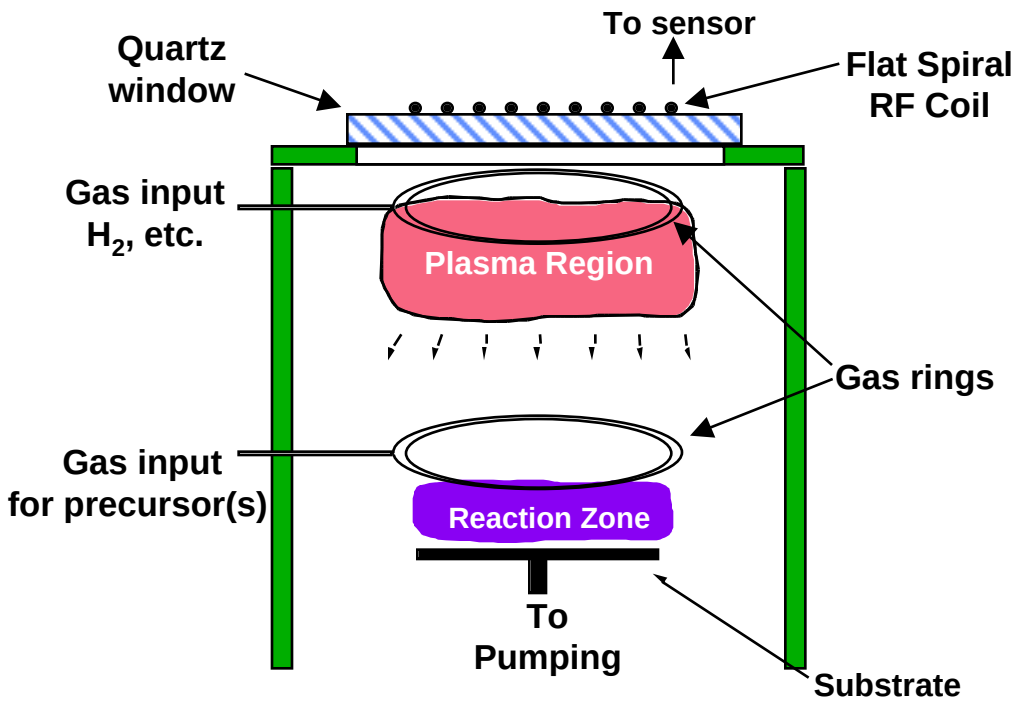
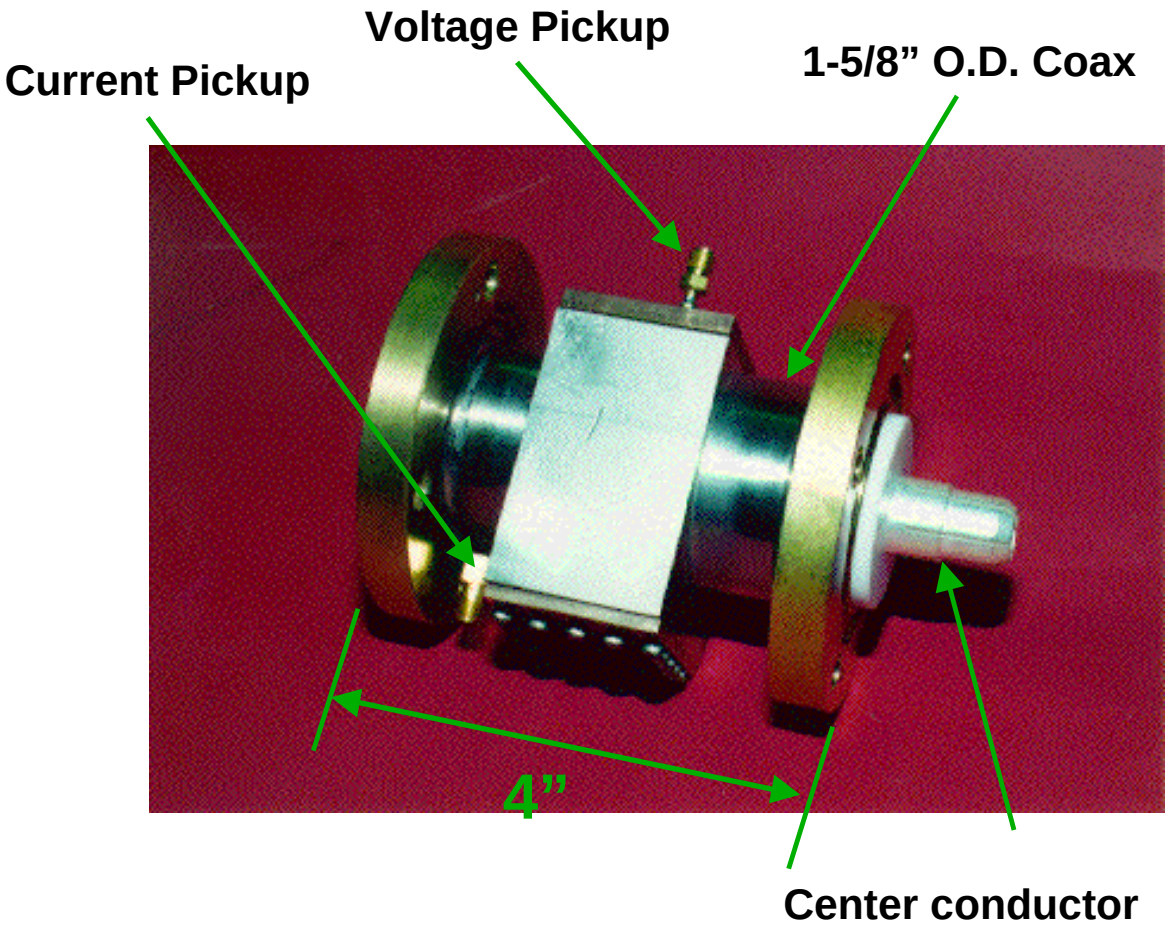
Our approach uses an inductively coupled plasma to produce atomic hydrogen to drive process improvements

- Atomic hydrogen produced in high density plasma region
- High efficiency for dissociation of hydrogen (60-70%)
- Plasma density and ion energy are decoupled
- Silane (100%) is injected from a gas ring downstream (up to 10 sccm)
- Evidence for high flux of atomic hydrogen bombarding the surface during film growth
- Low hydrogen incorporation in the film
- Sensor at coil input used to determine power coupling



Efficiency and loading are measured with a high power sensor

- Capable of handling several 10's of kW of reactive power
- Current pickup via Faraday shield in outer conductor of coaxial line
- Voltage pickup via small disc capacitively coupled to center conductor
- Machined from a solid piece of stainless steel and nickel plated to give a through impedance of 50 ohms
- Calibrated by terminating into a 50 ohm load and using network analyzer and calorimeter load



Sensors located at input and output of upper coil

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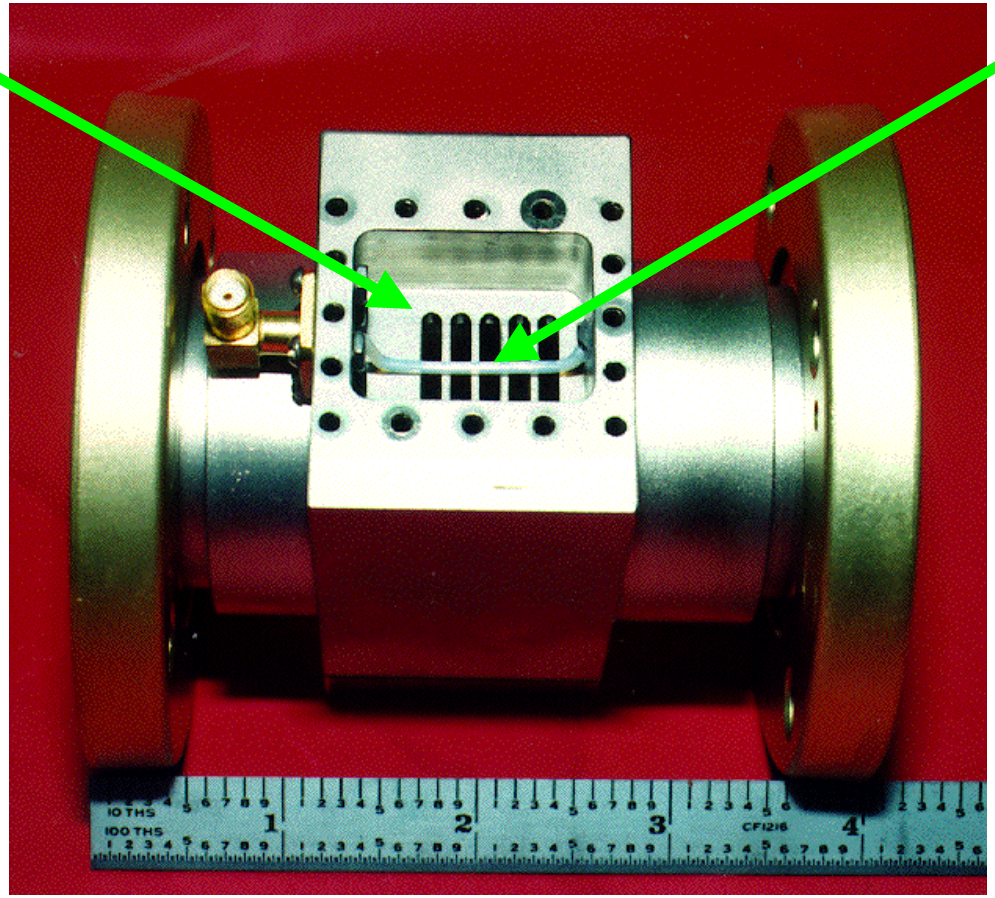
Current pickup is through a Faraday shield (reduces capacitive pickup)

Slots for flux coupling

Wire used for coupling



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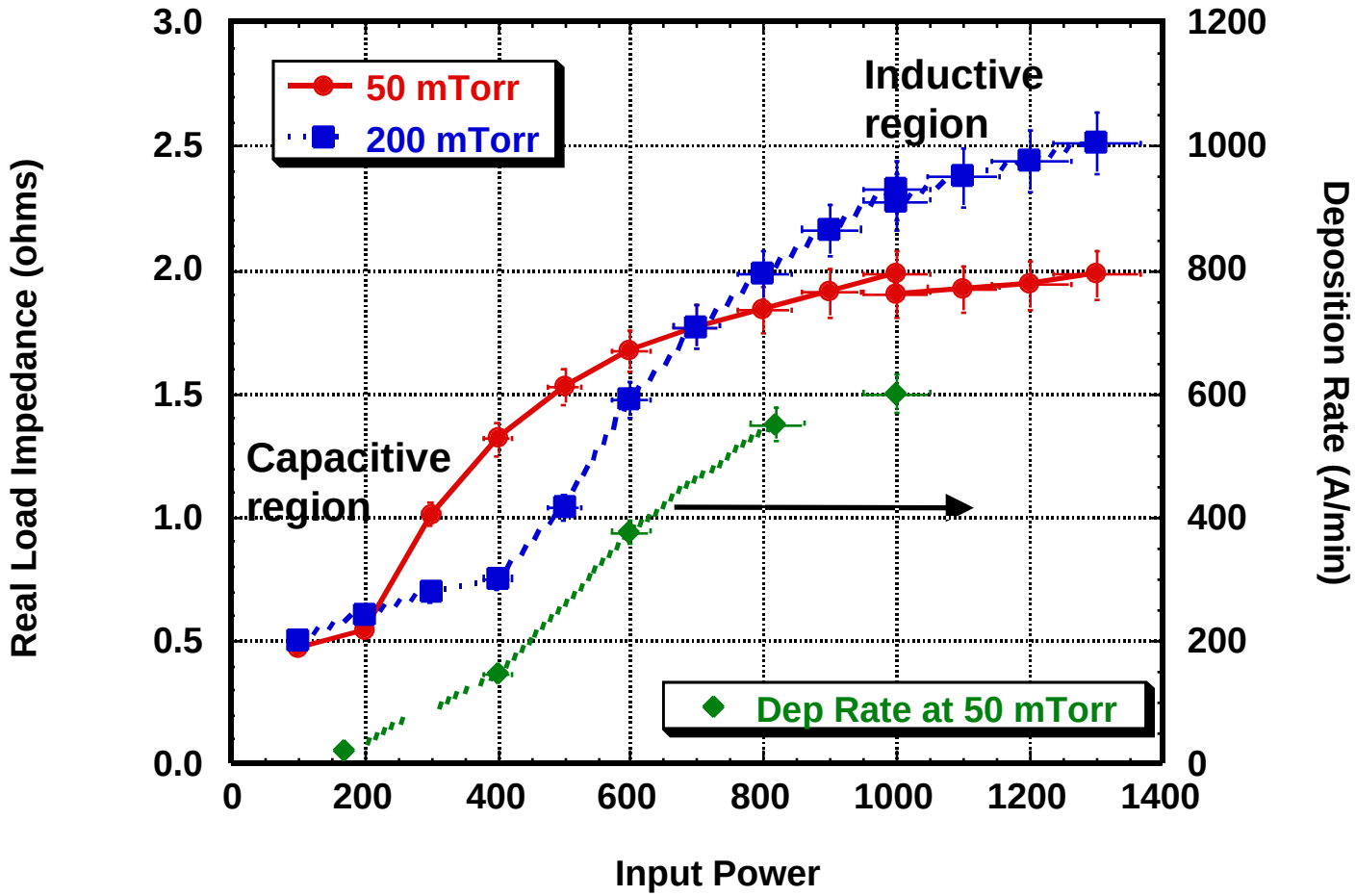
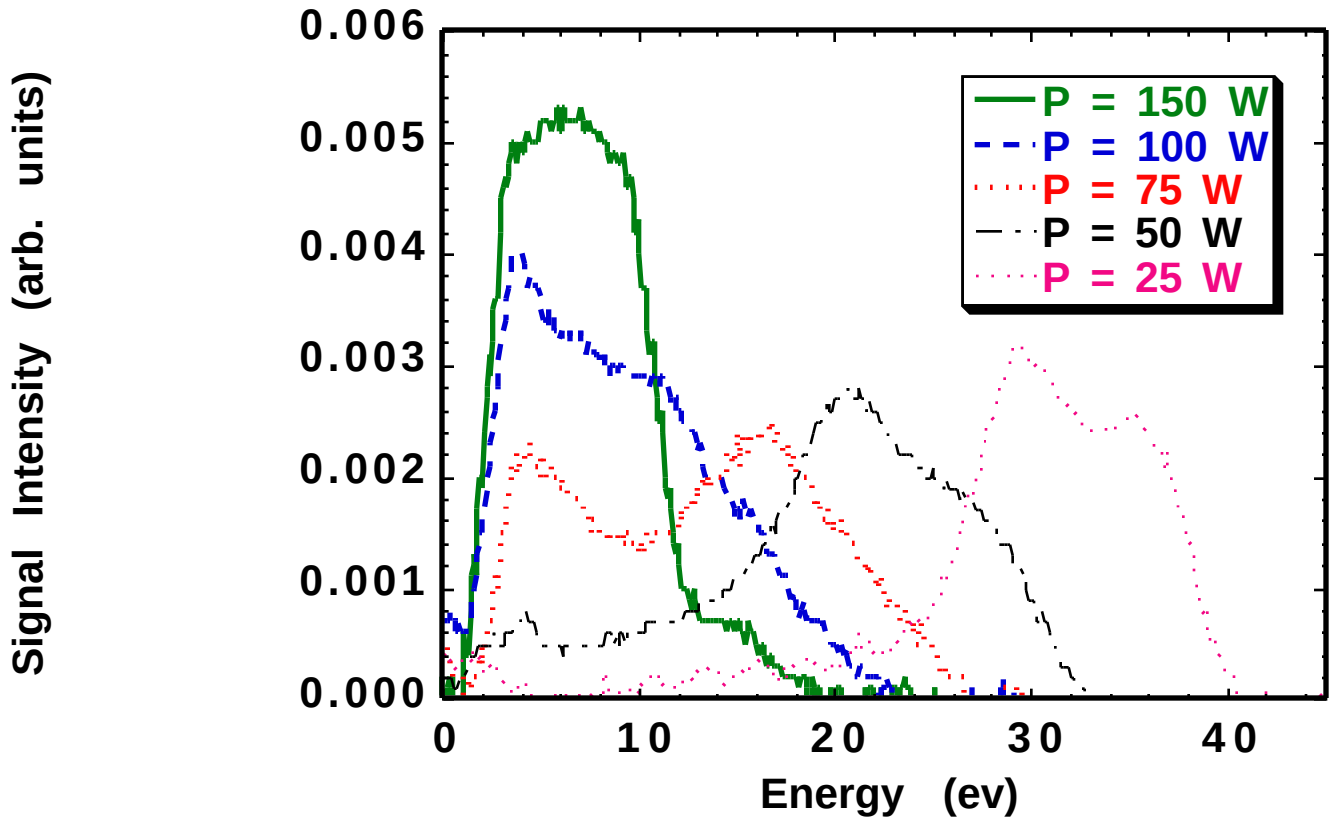
The power coupling changes from capacitive to inductive as the input power increases



- Good inductive coupling is needed for high densities of ion and atomic species (the transition region is pressure and gas dependent)
- Deposition rate increases with inductive coupling and density

The ion energy distribution shifts to lower energies as the power increases



Argon Plasma
10 mTorr

- The ion energies hitting the surface (from sheath acceleration) are lower as the discharge shifts from capacitive to inductive coupling
- Increased power means increased density, but not energy

Typical run conditions and results

Pressure (mTorr)	H2 flow (sccm)	SiH4 flow (sccm)	RF Power (W)	Dep rate (nm/min)
200	100	10	1000	27
50	100	10	1000	80
50	50	10	1000	75
50	150	10	1000	60
50	150	5	1000	58
50	150	2.5	1000	46
50	150	5	1250	45

- Best deposition rates for a 10:1 hydrogen/silane ratio at an input power of 1000 W
- Conductivity for this sample was < 2 x 10^{-7} S/cm: implies low oxygen impurity content

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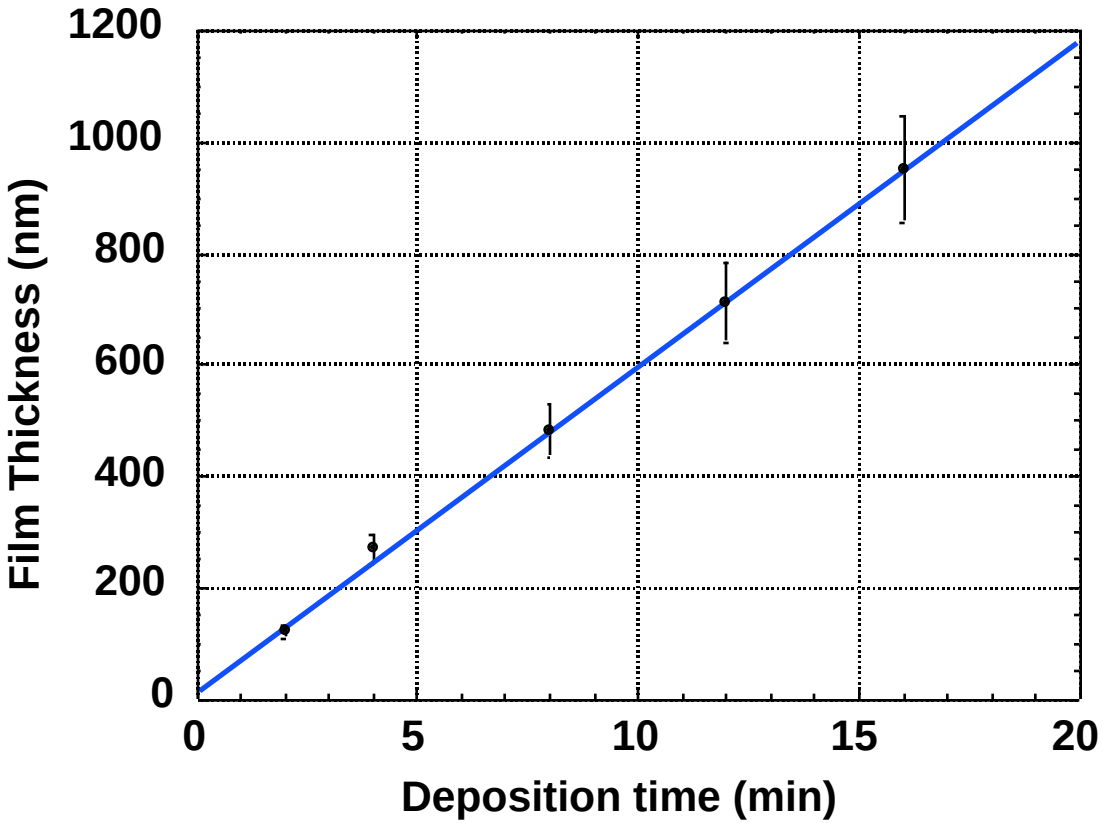
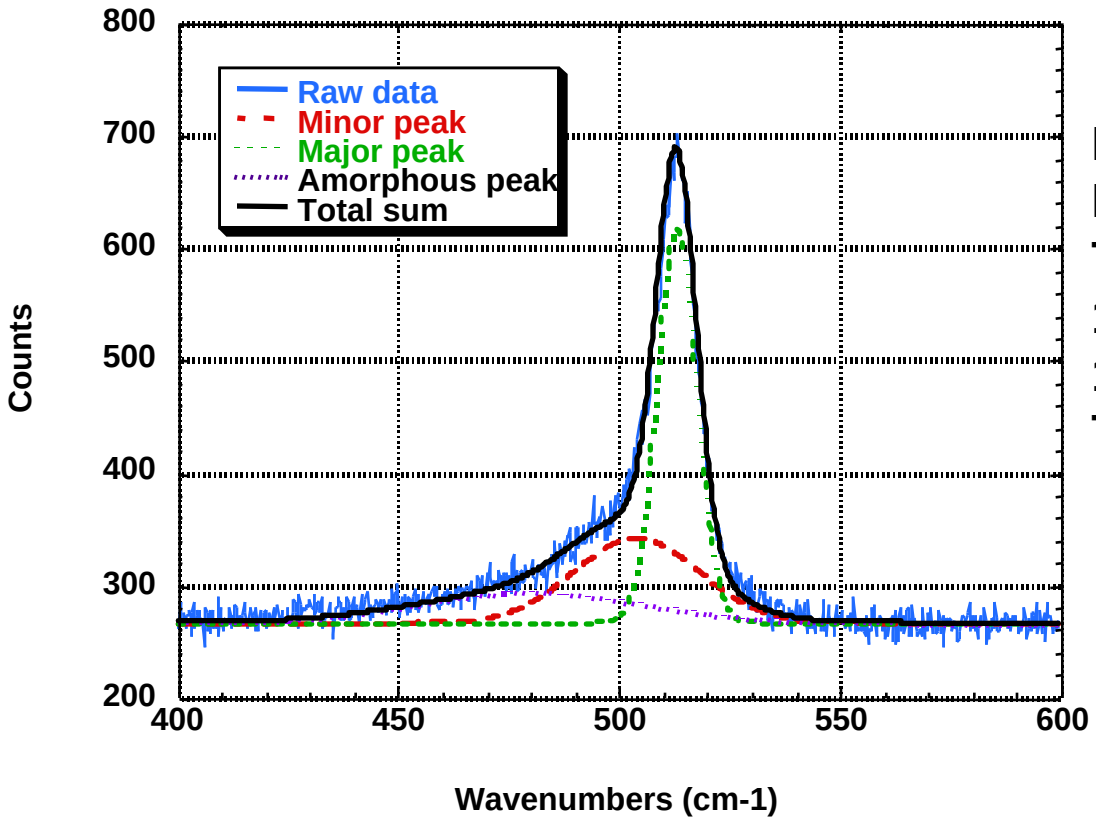
The deposition rate increases linearly with time



- **Conditions: 50 mTorr, 1 kW rf power, 150 sccm H2, 10 sccm silane**

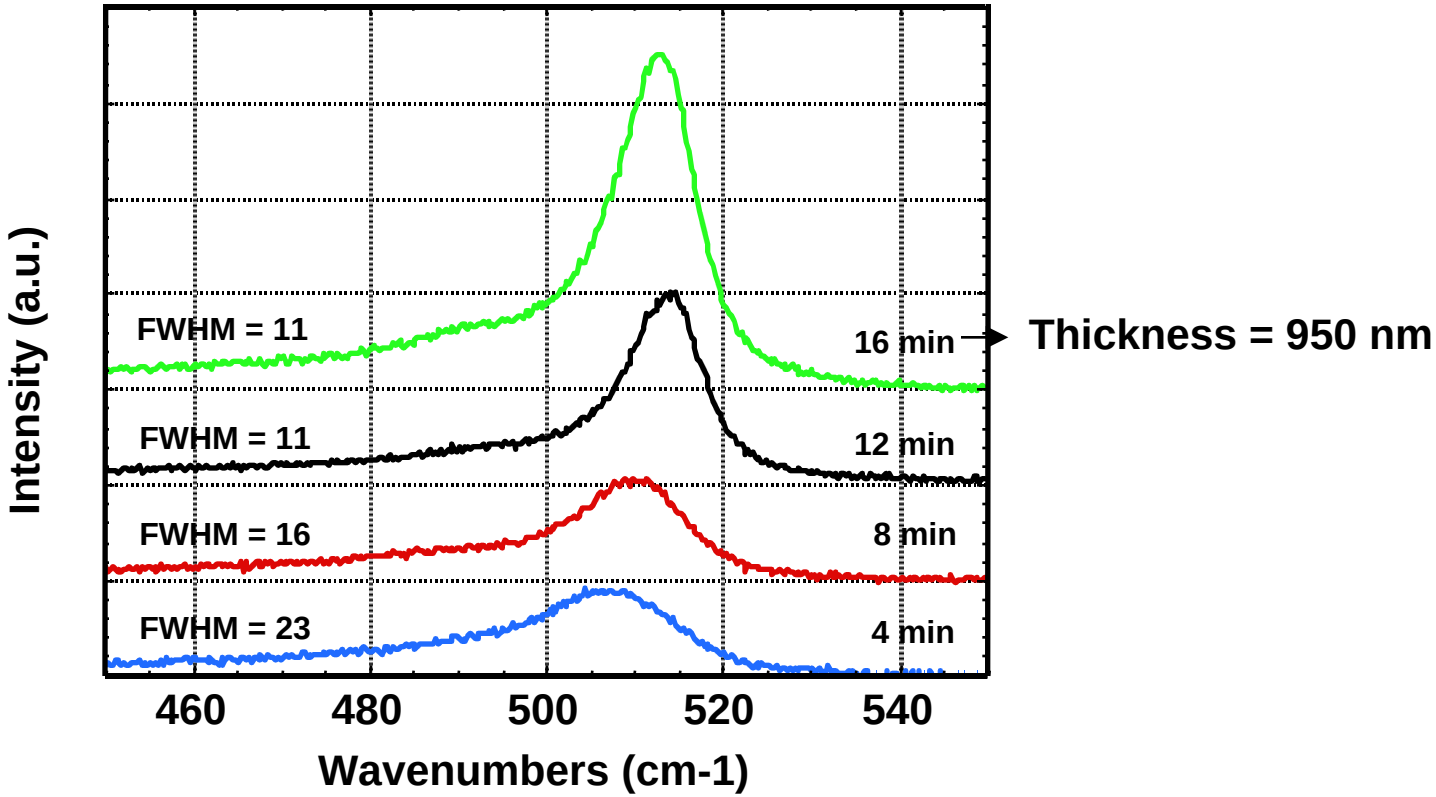
Crystallinity is estimated to be >80%



Prf = 1000 W
Press = 50 mTorr
Tsub = 370 ºC
150 sccm H2
10 sccm silane
Thickness = 60 nm

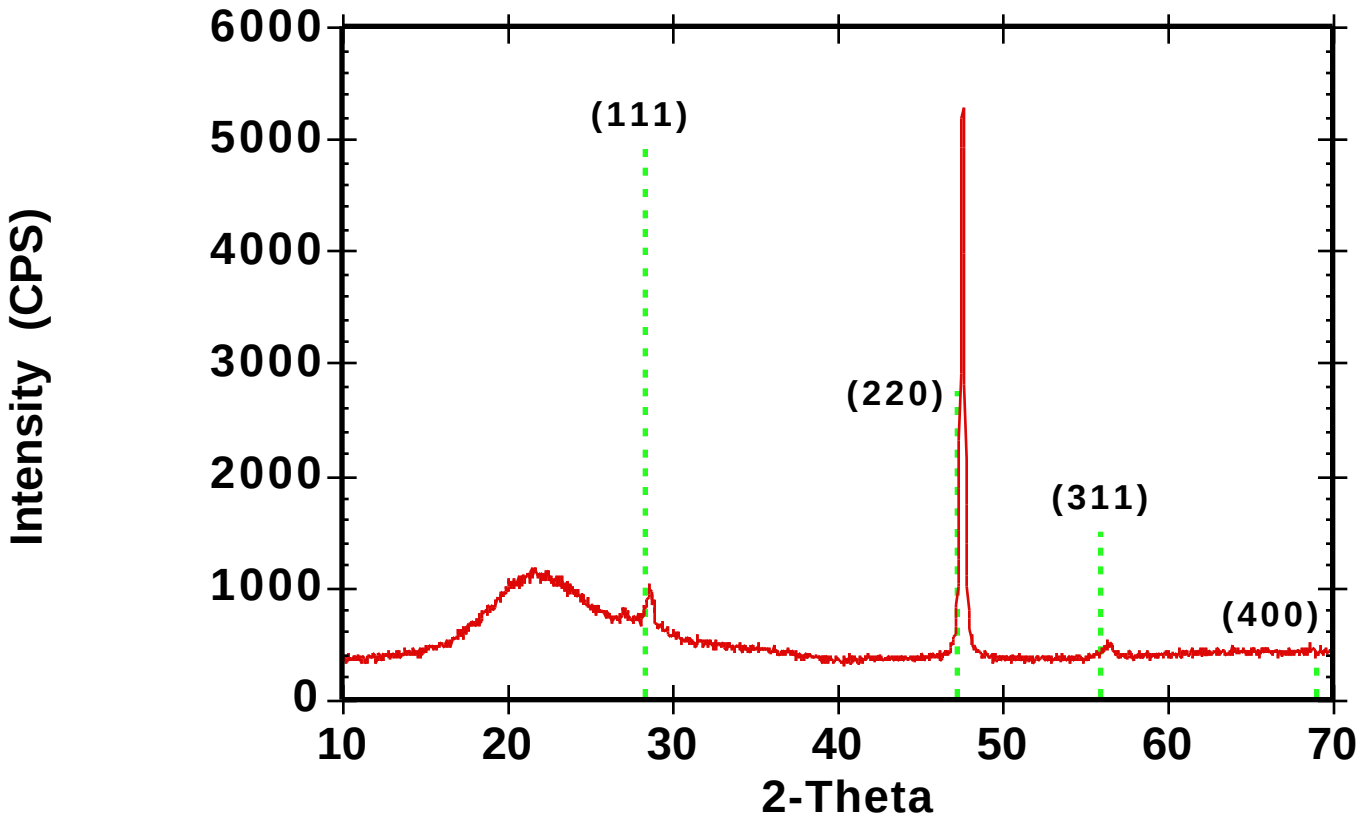
- **Best fit to the data is for three Gaussian peaks**
- **Crystalline peaks for wavenumbers of 514 and 503 cm-1, amorphous at 480 cm-1**
- **Volume fraction estimated to be >80% for this example**
- **FWHM = 12.3**

The crystallinity increases as the film thickness increases



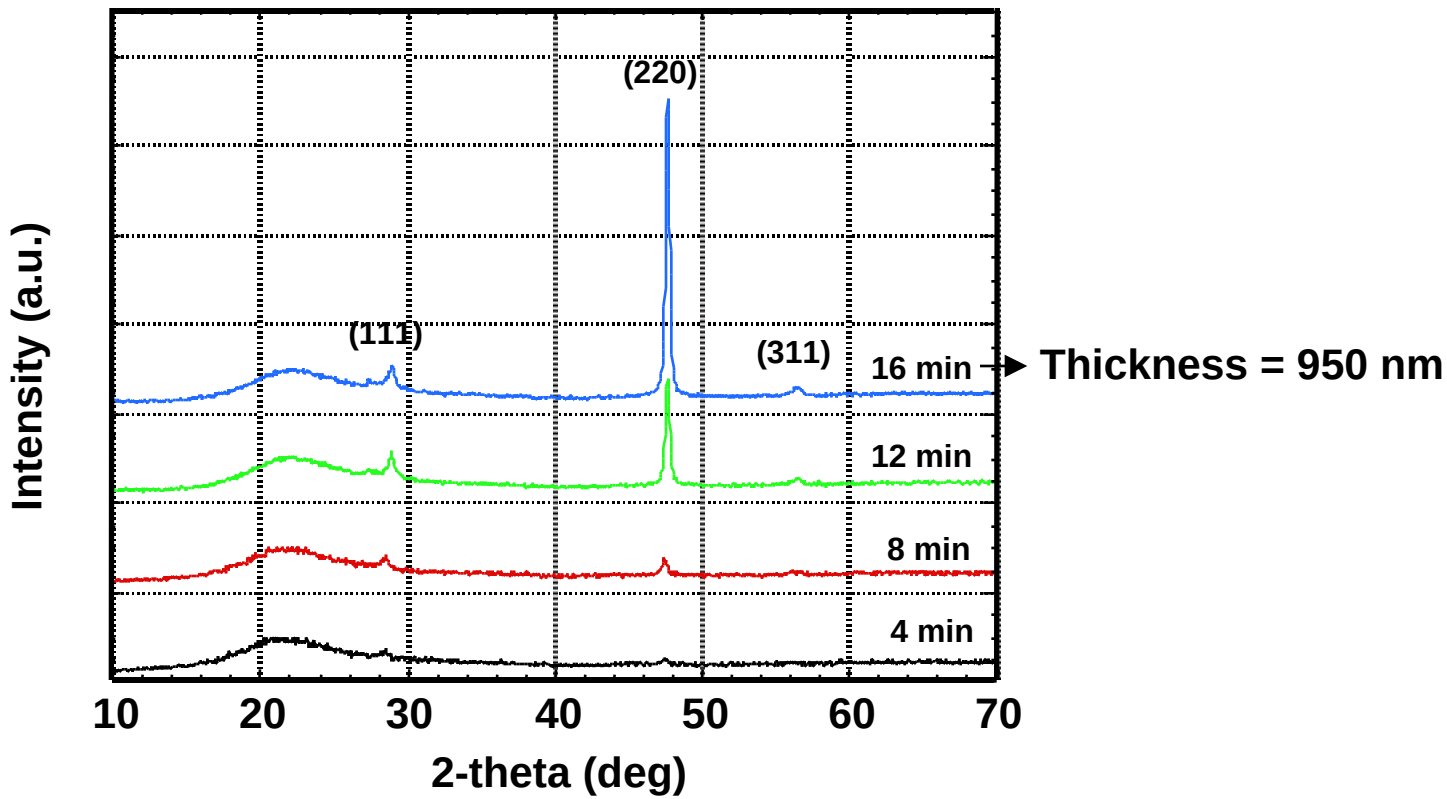
- Spectrum narrows as the film gets thicker
- We will get some TEM work done soon to determine change in film morphology vs. thickness

The films have a preferred orientation



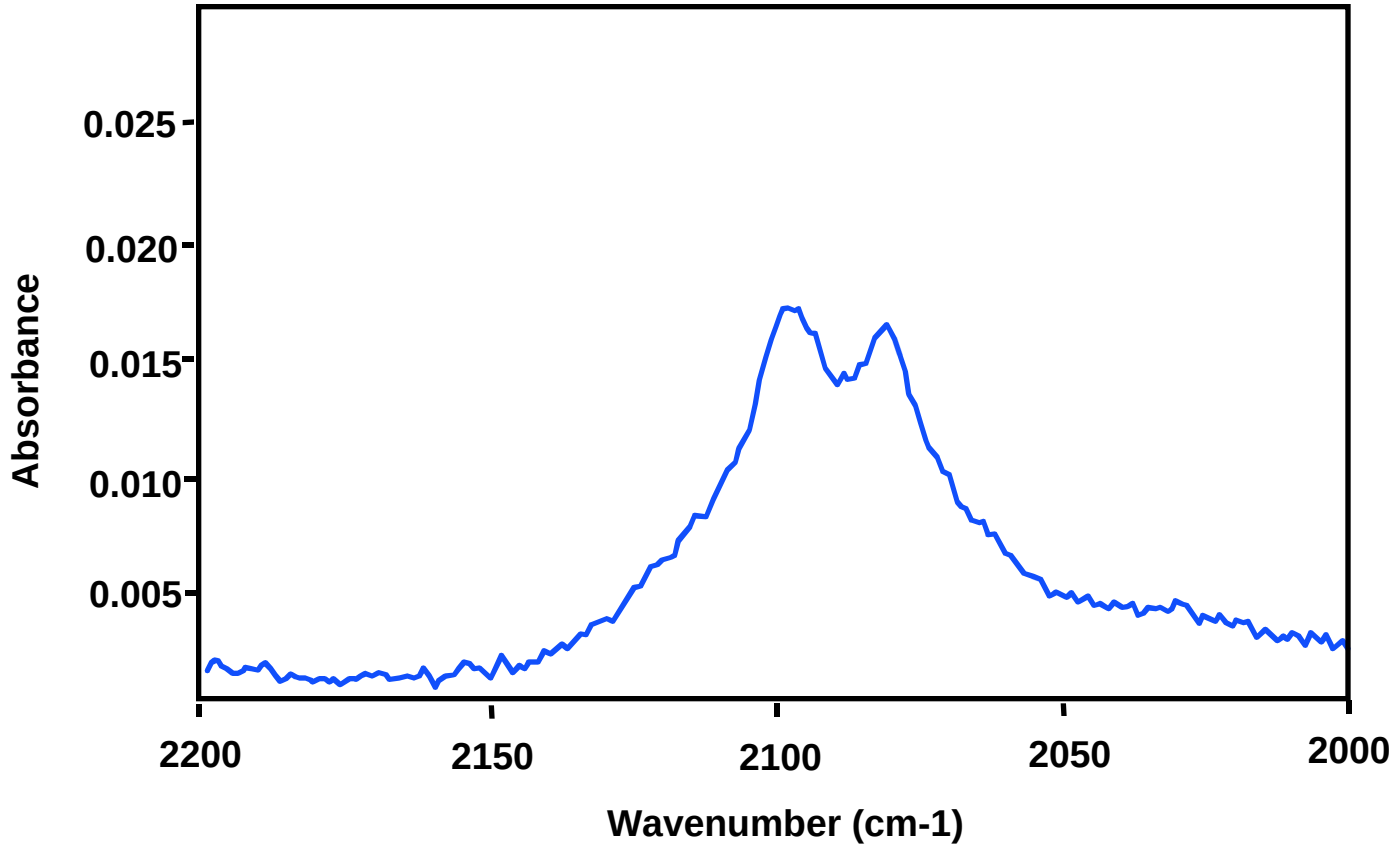
- X-ray diffraction shows preferred orientation in the <110> plane
- It has been speculated that this effect is a function of preferred nucleation and preferred etching of weak bonds

The 220 peak increases with film thickness



- Increase in (220) intensity is consistent with improved RAMAN spectrum
- Broad peak at 22 cm-1 is due to quartz substrate

FTIR absorbance measurement shows hydrogen percent in film at < 2%



- Difference in absorbance measured on single crystal silicon sample before and after polysilicon deposition
- Si-H stretching mode used to determine H content
- Estimated to be less than 2% H content

Summary

- The use of a high density inductively coupled plasma source for polysilicon deposition has been demonstrated
- Power coupling regime makes a difference in film properties
- Deposition rates can be as high as 80 nm/min (reactor geometry and conditions still not optimized)
- Conductivity of the films is low (impurity content low)
- Crystallinity of the films seems to be high (80%)
- XRD data shows preferred orientation of the films (<110>)
- FTIR measurements indicate low hydrogen content (< 2%)

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