May 15th, 10:00 AM - 2:00 PM

The development of a spin coater for under $100

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ABSTRACT

This project was created to address the need of an inexpensive spin coater. The chosen solution included the use of an Arduino UNO to control a computer cooling fan, the creation of a solvent resistant housing to contain excess solvent during a spin coating cycle, a suitable housing for the Arduino and its supporting electronics, build instructions to create additional units and operation instructions.

Overview

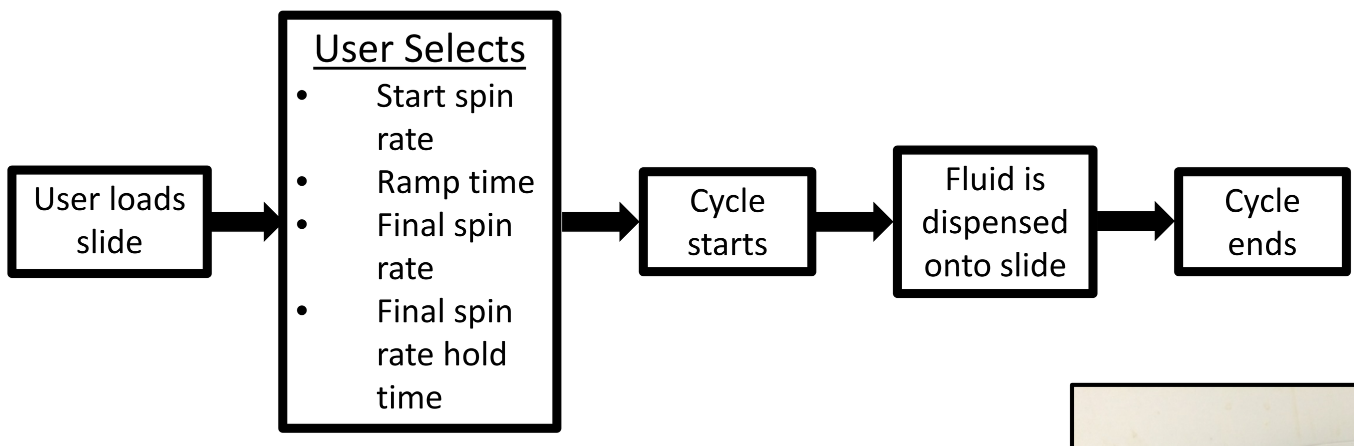
WWU's Advanced Materials Science & Engineering Center currently has one spin coater. This limits the spin coaters availability to independent researchers as well as its use in educational labs. AMSEC has voiced a need for additional spin coaters, however because commercial units cost several thousand dollars each, purchasing these is not a viable option. Instead an inexpensive solution needs to be created and qualified for its ability to create high quality thin films.

Solution

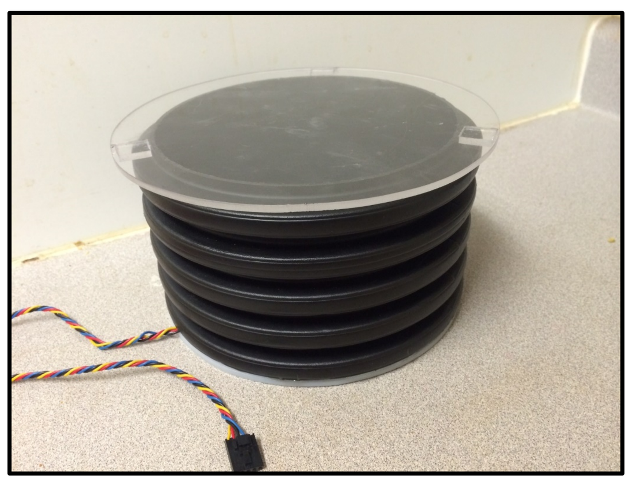
The implementation of this project continued to develop and refine the design originally proposed during definition. The objectives, functions and constraints of this project along with an initial design were laid out

Electronics

An Arduino Uno will be used to control a four wire computer fan motor and allow for a controlled cycle.

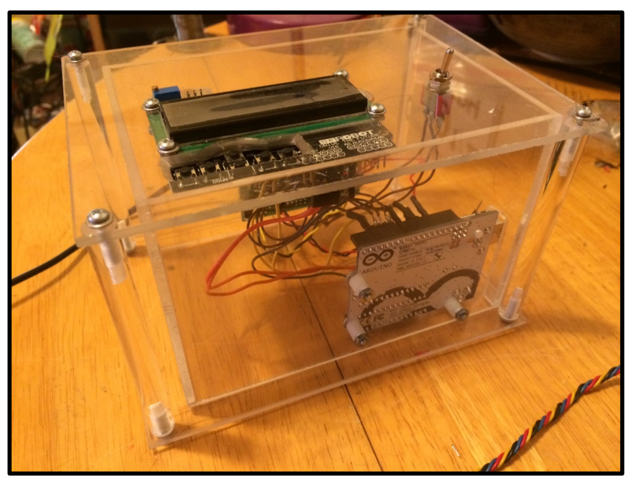


Motor Housing



- HDPE housing provides resistance to many solvents
  - 6" diameter, corrugated drainage pipe
  - 1/8" thick HDPE bottom
- Acrylic top allows users to view sample during cycle

Control Box



- Custom acrylic case houses electronic control box
- Inner box
  - Solvent welded at corners (Acetone)
  - Top & bottom sheet clamp inner box in place
- Provides easy visual inspection and disassembly
  - Great for continuous development and debugging
- Provides easy access to Arduino's USB port
  - Debugging, programming, experimentation

Testing

RPM Evaluation

Evaluation of the spin coater's ability to maintain the users' set spin rate was conducted by comparing the set spin rate to actual spin rate of the spin coater. The spin coat software allows these variables to be sent to a computer, via USB in a CSV type format. This makes evaluation in excel practical and easy.

Stress & Thermal Testing

Testing was conducted on the prototype spin coater's ability to run a longer than usual cycle of ten minutes in both HIGH and LOW spin rate mode to ensure no problems would occur, whether it be a software problem or hardware failure. In addition, thermal testing was conducted during the ten minute test by placing a thermocouple in the control box and recording the temperature every thirty seconds.

Film Thickness Evaluation

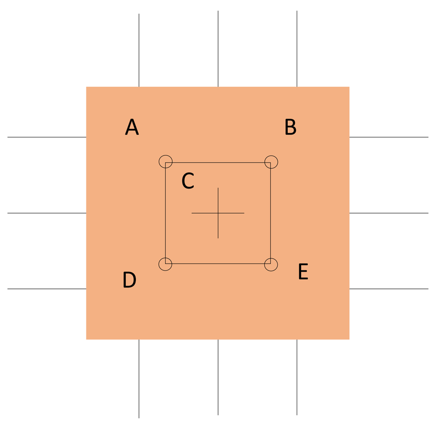
A 2^2 factorial, using three replicates and three center points was used. Furthermore each sample was measured in five locations to determine the factors involved in predicting a thin films thickness as well as the variation within and between samples.

To measure the film's thickness, UV/Vis spectroscopy was used between a 300 and 800 nm wavelength. The absorbance plots of the thin films showed evidence of interference patterns. The films thickness was then measured by using the equations below.

$$thickness = \frac{\lambda_1 \lambda_2}{2(\lambda_1 n_2 - \lambda_2 n_1)}$$

$$refractiveIndex = n = 1 + \frac{E_d \cdot E_0}{E_0^2 - E_{photon}^2}$$

$$refractiveIndex = n = 1 + \frac{E_d \cdot E_0}{E_0^2 - (h \cdot c/\lambda)^2}$$

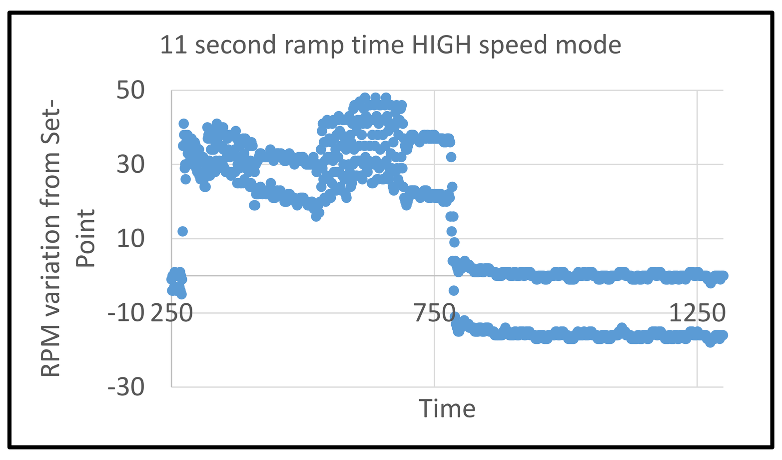


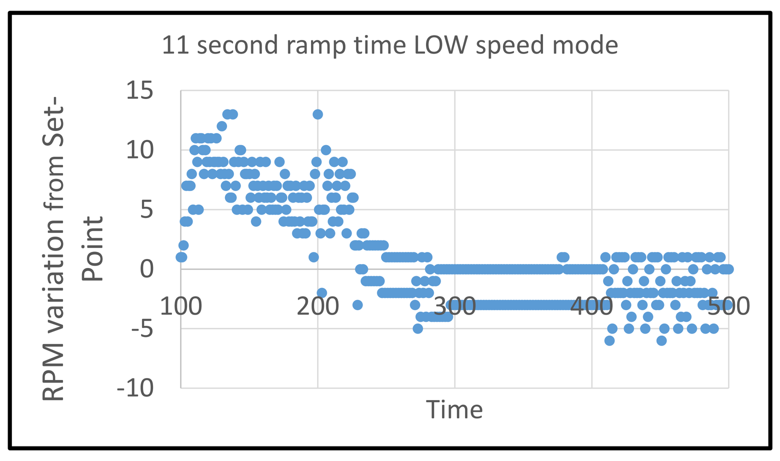
Sample measurement locations

Results

RPM Evaluation

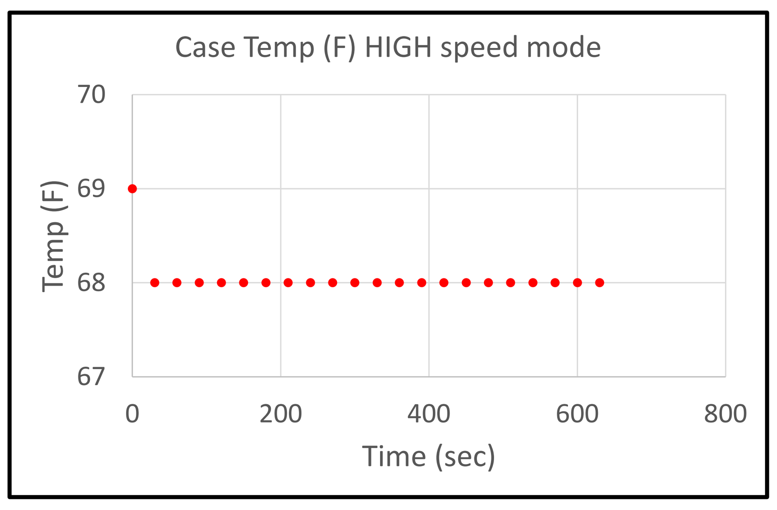
Several iteration of software were required to allow the motor to maintain a set speed. A spin rate variation within 50 RPM of the set rate was achieved. On HIGH speed mode a variation during acceleration of 48 RPM and a variation of 19 RPM during a set hold speed cycle was seen. LOW speed mode showed a variation of 13 RPM during acceleration and 7 RPM during a hold cycle.

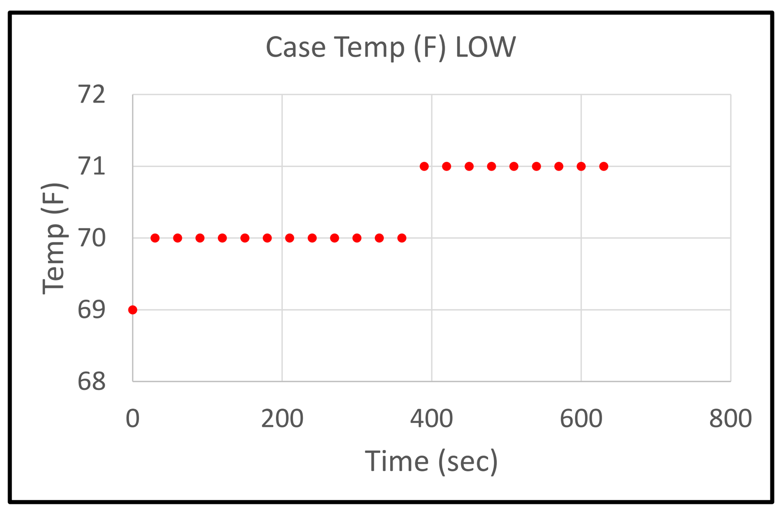




Stress testing

Stress testing showed that the prototype spin coater could run a cycle of at least ten minutes on both LOW and HIGH speed mode. On LOW speed mode, case temperatures increased two degrees Fahrenheit over the course of the test. High speed mode showed no increase in temperature during another ten minute test.





Film Thickness Evaluation

A regression of the results show spin rate (RPM), solution concentration, as well as an interaction between the two factors and curvature were significant.

Regression Statistics	
Multiple R	0.99376264
R Square	0.987564184
Adjusted R Square	0.982589857
Standard Error	0.049507993
Observations	15

ANOVA

	df	SS	F	Significance F
Regression	4	1.946442951	198.5322396	1.76603E-09
Residual	10	0.024510414		
Total	14	1.970953365		

	Coefficients	Standard Error	P-value
Intercept	0.544009	0.028583453	3.48314E-09
Spin Rate (RPM)	-0.130451951	0.014291727	3.6447E-06
PS concentration (%)	0.367534538	0.014291727	1.81589E-10
A*B	-0.065288522	0.014291727	0.001028982
A^2	0.170904069	0.031957272	0.000324576

Thickness variation

Analysis of the variation of film thickness shows an average variation of 3.57% within samples and an average variation of 18.18% between samples.

This did not meet the target goal of 10% variation however it leaves room for improvement.

Thickness variation within individual films

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
95% CI	13.31	13.71	80.58	46.19	21.09	7.7	27.43	47.07	24.11	4.35	17.53	29.47	19.35	5.5	11.04	Average
% of avg thickness	3.39	4.34	6.57	4.75	5.1	2.83	2.1	5.85	5.74	1.66	1.35	3.33	3.19	1	2.31	3.57

Thickness Variation between replicates

	(-1,-1) replicates	(1,-1) replicates	(-1,1) replicates	(1,1) replicates	(0,0) replicates	Average
95% CI	41.17	68.33	81.35	185.33	160.77	
% of avg thickness	9.98	24.21	6.36	20.81	29.55	18.18

Conclusion & Future Work

The project was successful and resulted in a usable prototype spin coater. Most of the project goals were met with the exception of implementation time and building a successful chuck, where double sided tape was used instead. Several solutions exist for future development of a chuck. The cost of materials for the prototype spin coater is within the budget at a cost of $93.78.

Proposed future work includes further refinement of the spin coaters software and further refinement of the housing. Other opportunities for future work are the development of a high school or college level lab that involves the use of thin film polymers. An MSA should be conducted to further evaluate the machine and measurement system's capabilities.