Pass-Though Vacuum Chambers for Research and Production

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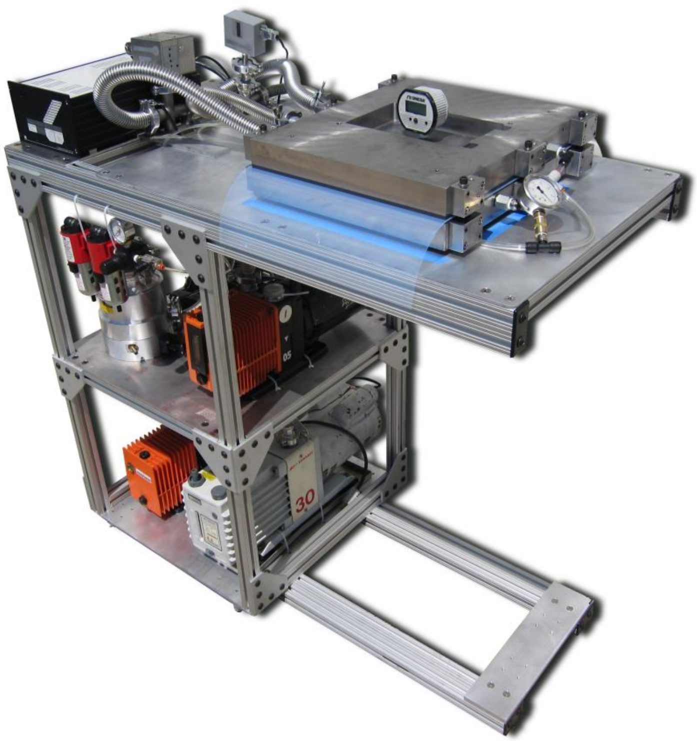


SUMMARY

A “Pass Though” vacuum chamber has been constructed and tested, demonstrating the technical feasibility of using air bearing lands to protect differentially pumped groves from atmospheric flow, creating a very stable non-contact vacuum seal. Because the high and low pressure areas are arrayed symmetrically on both sides of the film, the film sees no stress. This technology allows for small but potentially wide vacuum chambers appropriate for CVD, PVD, ALD or other processes requiring deep vacuum or isolated environment. The big advantage is that continuous processing would be possible as the requirement to put a roll in a vacuum chamber and pump it down for processing would be eliminated. Instead the web would flow though one or more vacuum chambers with other atmospheric processes inserted in between and may do so continuously.

Because they are small and inexpensive these Pass Though Vacuum Chambers would enable many researchers and process developers to avail themselves of the advantages of vacuum processing and easy integration into their current flexible processing line. This would be an enabling technology to accelerate the development of flexible displays, PV, LED lighting and printed batteries by reducing the cost and complexity of traditional vacuum processing equipment. Vacuum assisted deposition achieves the highest quality films and the best barrier performance, a critical component in manufacturing flexible, printed electronics.

HOW IT WORKS

New Way's pass-through vacuum chamber features the company's Porous Media® Technology, which distributes air pressure uniformly across the entire bearing surface, through millions of sub-micron sized holes. This continuous air pressure forces the two halves of the chamber housing apart, with the film stably centered in a 20-micron gap (10 µm on each side) through which the roll-to-roll flexible film flows.

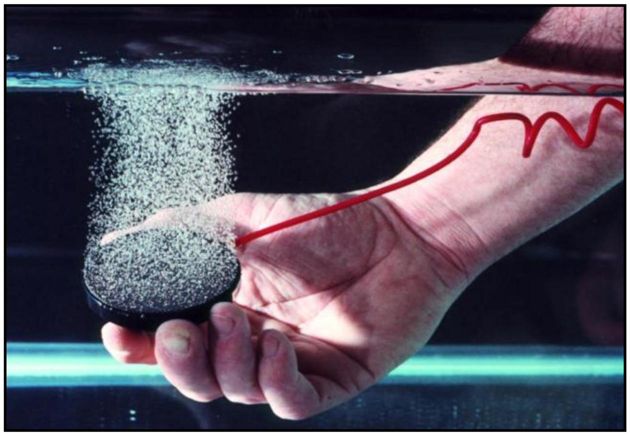


Figure 1

A series of differentially-pumped grooves isolate a vacuum region – though which the flexible web may be passed – from the air bearing sections. The forces from the atmosphere and the air bearings are balanced, so the film always sees the same pressure on both sides.

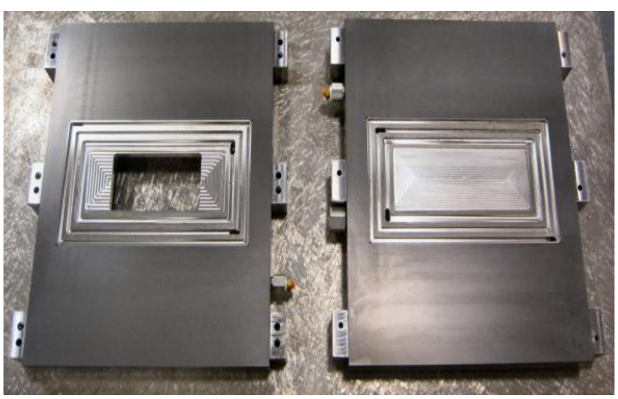
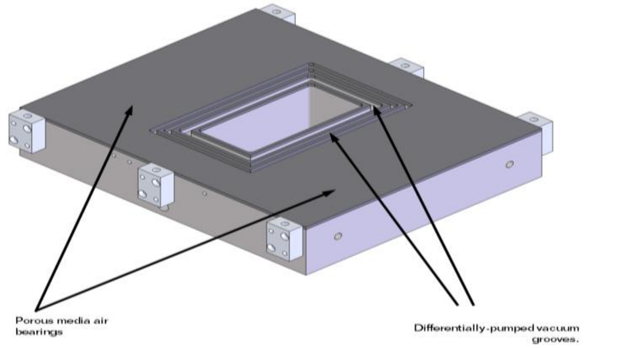
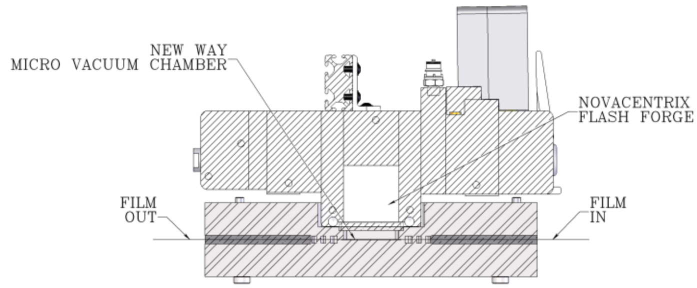


Figure 2





RESULTS

The first test performed on the vacuum chamber was a measurement of distortion in the top of the assembly under vacuum pressure as input pressure was increased. The bottom of the assembly was not tested for distortion.

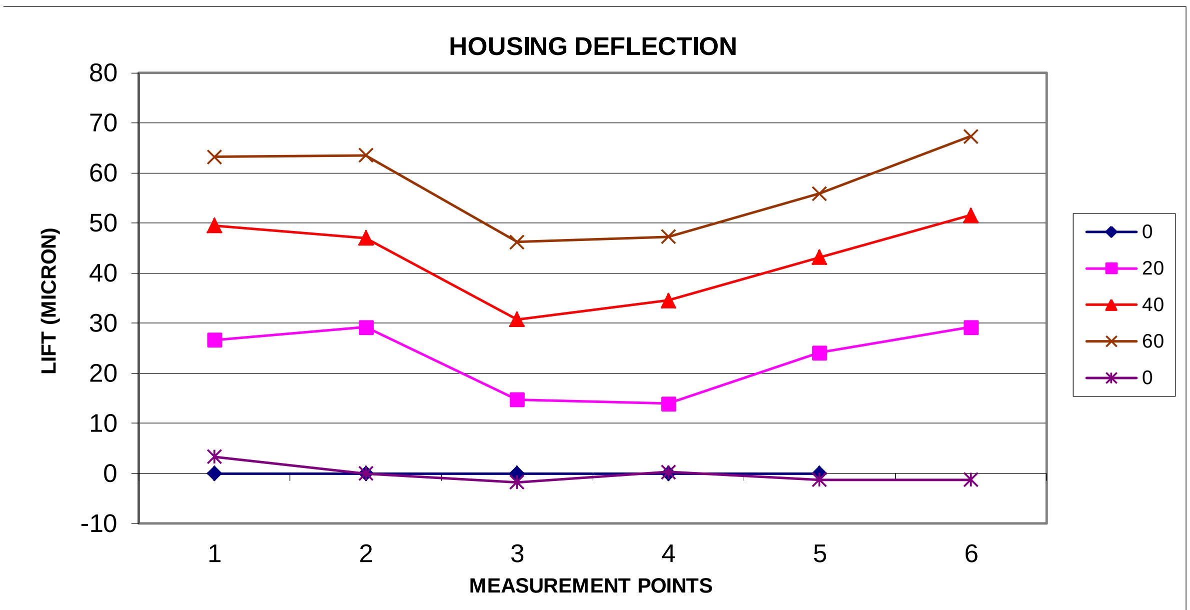
A piece of film was placed in the system with the top of the assembly sitting directly on top of it. A series of (6) dial indicators were positioned around the top of the system. Vacuum pressure was applied and the indicators were set to zero. An input pressure was applied and gradually increased and measurements of the displacement were observed and recorded.

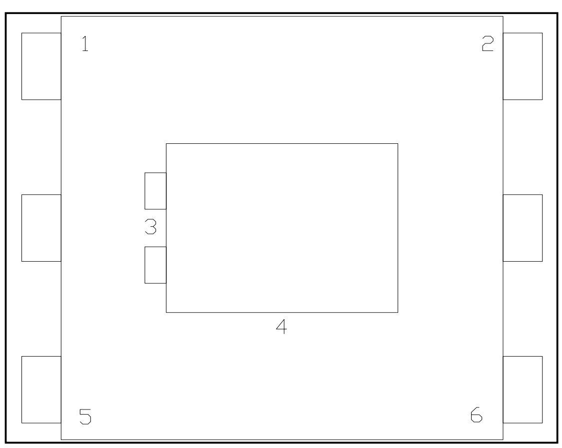
Figure 5

TEST DATA SHEET

DATE: 2/18/10
TESTED BY: JHA
DESCRIPTION: CHECK AMPLITUDE OF HOUSING DEFLECTION UNDER PRESSURE

VACUUM AT CENTER (MM/HG.)	INPUT PRESSURE (PSI)	MEASUREMENT POINTS (MICRONS) 1	2	3	4	5	6
736.6	0	0.0	0.0	0.0	0.0	0.0	0.0
736.6	20	26.7	29.2	14.7	14.0	24.1	29.2
741.7	40	49.5	47.0	30.7	34.5	43.2	51.6
741.7	60	63.2	63.5	46.2	47.2	55.9	67.3
739.1	0	3.3	0.0	-1.8	0.3	-1.3	-1.3





The test results show that the entire assembly lifted relatively evenly as the pressure increased with the indicators near the middle of the housing showing less lift than the edges, indicating some distortion from atmospheric force. The maximum displacement observed was seen at 60 PSI and was less than 15 microns below the average edge measurement.

This test suggests that when possible the micro chambers should be designed so that the atmospheric force loads the structure in a column stiffness relative to the air bearings. In other words in this design the backside of the differentially pumped grooves are exposed atmospheric pressure and since their support is cantilevered from the bearing area there is more deflection and hence a smaller gap.

Vacuum levels of 10^{-4} torr were achieved with the film moving though the vacuum chamber without contact. This achieves the major stated goal of the project. The stretch goal of 10^{-6} torr was not achieved in large part, we believe, because of oil contamination from the many tradeshows the demo unit attended. The difference between 10^{-4} torr and 10^{-6} torr in pressure either on the edge of the film or atmospheric force trying to compress the two halves of the assembly onto the film is negligible as 10^{-4} tour is already in the molecular flow regime. This means that achieving the 10^{-6} goal has more to do with avoiding oil contamination or improving the conductance path then the merit of the technical concept.

DATE: 3/21/11
TESTED BY: JHA
DESCRIPTION: TEST OF SYSTEM PERFORMANCE WHEN ALL PUMPS ARE TURNED ON. TURBO PUMP HAS BEEN REBUILT.

VACUUM PRESSURE DATA					
	GROOVES				
	OUTER	MIDDLE	INNER		
INPUT PRESSURE (PSI)	EDWARDS M30 ROTARY VANE PUMP (MM/HG)	ALCATEL 2004A ROTARY VANE PUMP (TORR)	ALCATEL 2005 ROTARY VANE PUMP (TORR)	W/TURBO PUMP? (Y/N-LED LIGHTS LIT*)	DESCRIPTION OF FILM MOVEMENT
ALL PUMPS ON					
0	688.34	1.3 (-3)	1.0 (-4)	Y	LOCKED IN PLACE
10	679.45	7.4 (-2)	3.0 (-4)	Y	LOCKED IN PLACE
15	670.56	1.9 (-1)	7.9 (-4)	Y	PIVOTS
16.8	668.02	3.0 (-1)	8.0 (-4)	Y	FREE
17.5	665.48	3.5 (-1)	1.3 (-3)	Y	FREE
20	660.40	6.3 (-1)	1.9 (-3)	Y	FREE

ALTERNATIVES CURRENTLY USED

Thin Film Deposition and Laser Processing

The current technology for the vacuum deposition of thin films onto flexible substrates is typically done with in large drum shaped vacuum chambers. These chambers are usually equipped with side chambers that contain a feed roll and he take-up roll. The volume contained in these chambers can easily add up to several cubic meters. Such large vacuum chambers which are typically made from stainless steel have huge atmospheric loads exerted on them and so they must be built to withstand the loads, this makes the chambers very expensive. These chambers also require extensive services and installation requirements. These factors add up to the current process being very expensive. This expense precludes many researchers and developers of flexible circuits from being able to avail themselves of the best films that could be used for the purposes.

Inherent advantages of Pass-Through Vacuum Chambers

- The whole reel is never in vacuum at the same time. Film is only in vacuum when it is being processed.

- Because the payout roll is not in a vacuum there are no issues with internal roll pressures during pump down or external pressures on the take-up roll when opening the chamber.

- There is no out gassing as the role unwinds. A conventional roll coater has tens of square meters of substrate exposed in vacuum and in an unrolled condition. The internal pressure of the film is a major cause of surface defects in the film itself, the longer it's in vacuum the more likely there are to be defects. Almost all films have some moisture content which out gases, changing its width and thickness, the properties of the film and contaminating the chamber.

  To compound this problem the film spends more time hot while it is in the vacuum. The only way for the film to lose its heat is radiation. In the pass through vacuum chamber the film can be heated or cooled rapidly using high pressure, high velocity air flows through the bearing gaps to dramatically improve convective film coefficients (wind chill) just before or just after the vacuum zone.

- Since there may be only a fraction of a square meter exposed that anyone time the possibility for flash or rapid thermal processing exists. This would prevent the entire substrate from getting hot while enabling higher temperatures at the surface during processing. A similar technique has been demonstrated by Novacentrix.

- Versatility in processing; Because of the unit's small weight and footprint, it can be inserted into a number of advanced sequential processes and where necessary.

- Due to the short pump down times and the ability to actually just thread the material through, dramatic time savings are possible over conventional loading and unloading.

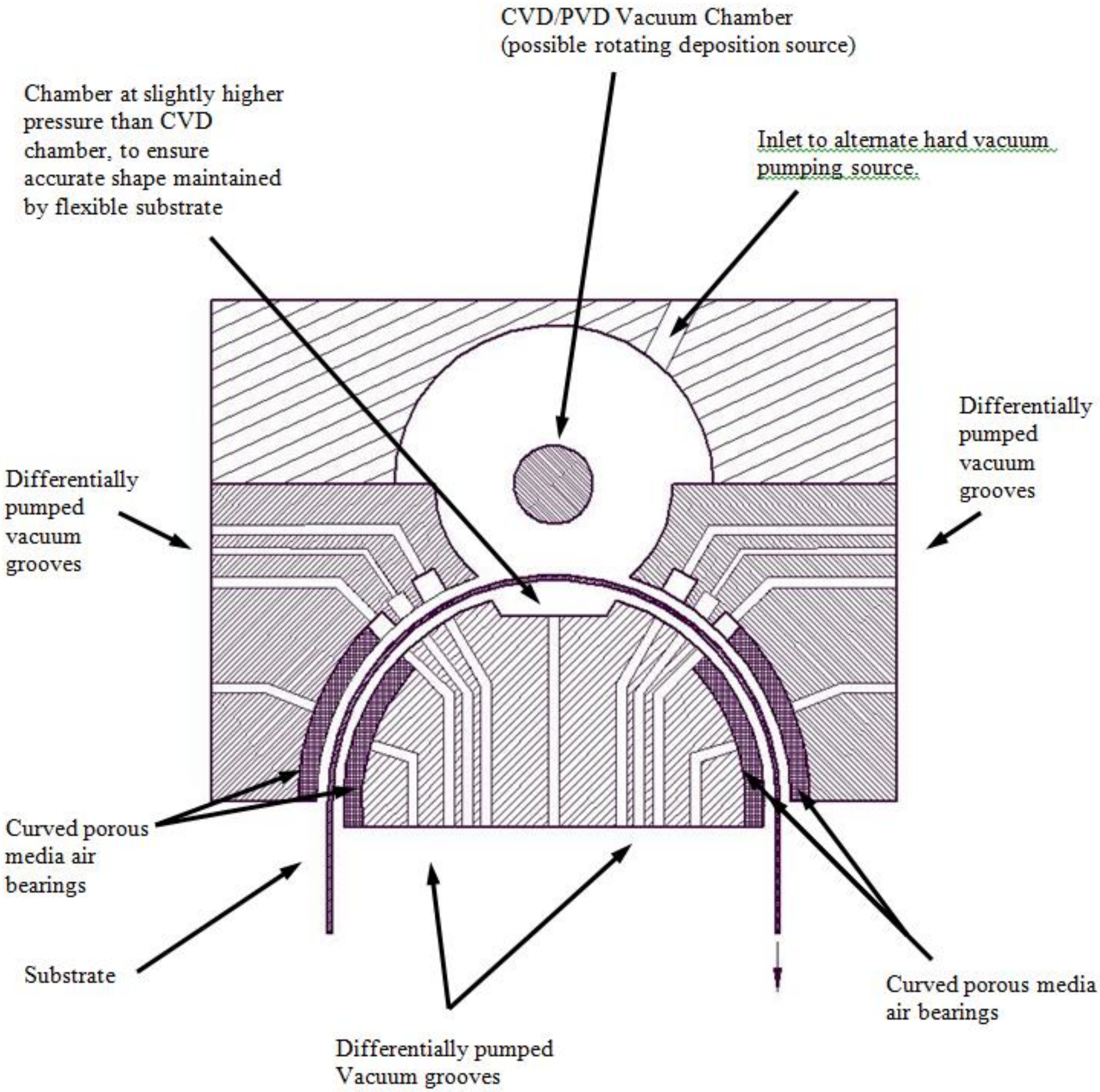
- Cost reduction on runs due to energy saving.

- There is a lower potential to contaminate the vacuum chamber and a quicker path to recovery.

- Slitting is not required before processing, 'standard web guides' can be used; beaded edges are outside the 'vacuum box.'

- Dramatically lower capital cost reduces fixed costs applied to the product, resulting in shorter payback times.

The prototype that was tested was on a plane. Non-contact entry and exit of film would be simplified by radiused air bearing guides as shown below.



Vacuum process coating of a flexible web substrate

CONTRIBUTORS

The Army Research Laboratory through the FlexTech Alliance, which is focused on developing the electronic display and the flexible, printed electronics industry supply chain, funded one half of the cost to develop a non-contact vacuum seal allowing for small, but potentially wide vacuum chambers by New Way Air Bearings (Aston, PA). Novacentrix participated as a commercialization partner.

REFERENCE

Patent publication Number 2007/0031600A1