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Progress in High Throughput Processing of Long Length, High Quality and Low Cost IBAD MgO Buffer Tape at SuperPower

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Challenges in the commercialization of 2G HTS wire

- Three challenges for 2G HTS wire to become commercially viable are long length, high quality and low cost
- Long length production of high quality 2G wire presents a challenge because the yield decreases exponentially with tape length
- High throughput processing is a must for cost reduction and increasing production capacity to meet market needs
- Development of process control techniques based on a deep understanding of the process and details is the key to success
- Identification, evaluation, and selection of a high yield, robust process for production plan is critical important.
  - Of numerous processes, some are good for lab demonstrations or of scientific interest, but need further process yield-throughput study and process control technique development to determine if it can be a high yield and robust production process

Previous processes, thickness and speeds of IBAD buffer layers

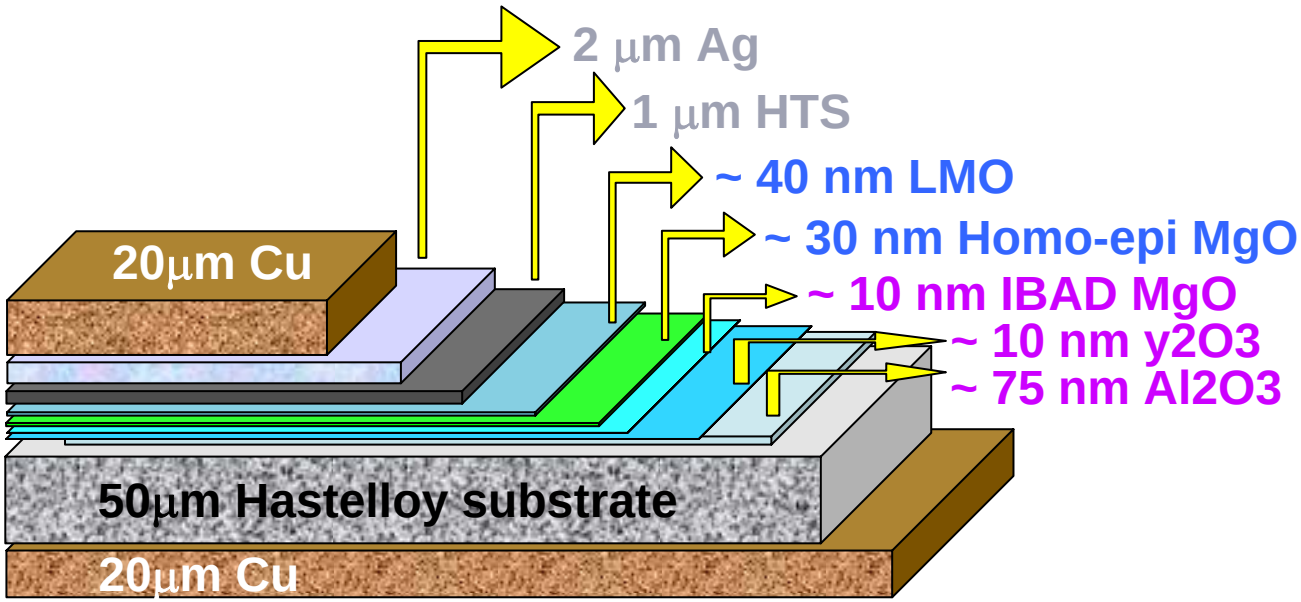
Al2O3 --- reactive ion beam sputtering, ~75nm, speed=120 m/h*.

Y2O3 --- ion beam sputtering, ~10nm, process speed=360m/h

IBAD MgO --- IBAD and ion beam sputtering on oxide target, ~10nm,speed=195m/h

Homo-epi MgO --- reactive magnetron sputtering, ~30nm, speed=120m/h

LMO --- RF magnetron sputtering on ceramic target, ~40nm, speed=120m/h



* All speeds in this presentation are equivalent speed of 4mm tape

Breakthrough in Al2O3/Y2O3 process - 1

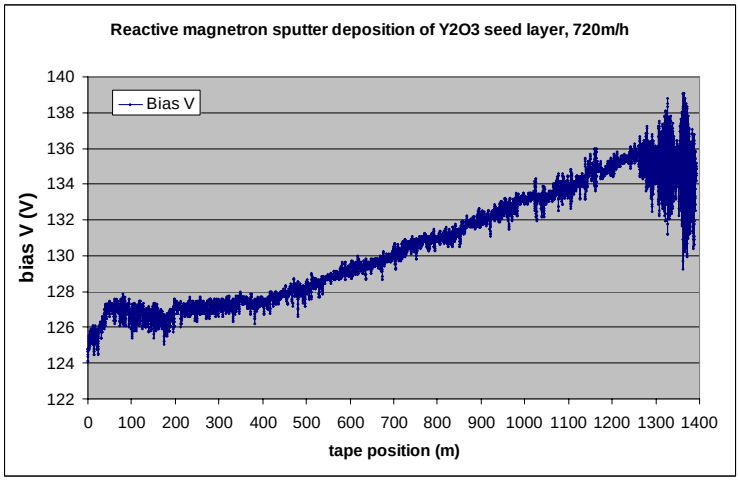
- Al2O3 process is bottleneck in buffer stack througput.
- Al2O3 speed was first increased to 195m/h
  - enlarging deposition zone from 42cm to 60cm
  - fine tuning reactive process to get higher deposition rate
- Still bottleneck after our IBAD MgO process speed increased to 360m/h with reactive ion beam sputtering of Mg target
- Reactive magnetron sputtering at transition mode => 3000m/h Al2O3 process speed.
  - Why not use magnetron sputtering early? LANL tried to use magnetron sputtering to prepare Al2O3 for IBAD MgO, but results were not as good (rougher film surface) and discontinued work. Our attempt succeeded, possibly due to good process control
  - we demonstrated that the magnetron sputtered Al2O3 has no issue as IBAD MgO barrier layer, obtain same texture and Ic as ion beam sputtered Al2O3 layer, even IBAD MgO process condition needs no tuning with magnetron sputtered Al2O3
  - Working at transition mode of reactive sputtering to get speed up to 3000m/h with our Pilot Buffer system. Right now at 750m/h due to tape driving limit
  - Now used as standard Al2O3 layer production, 38 long tapes have been produced

Breakthrough in Al2O3/Y2O3 process - 2

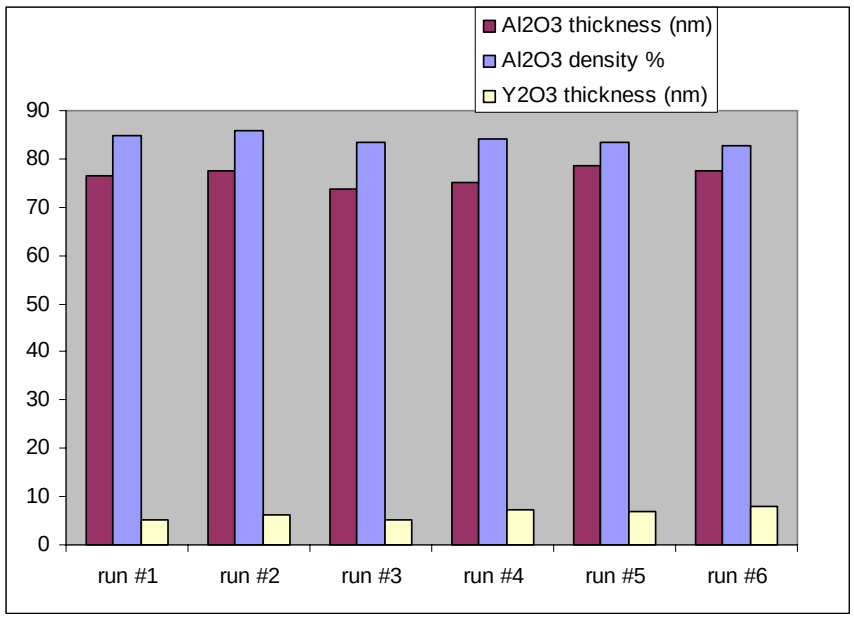
- Magnetron-sputtered Y2O3 is also suitable for IBAD MgO seed layer
  - No one used magnetron sputtered Y2O3 as seed layer before. We show that magnetron sputtered Y2O3 has no issue as seed layer. Same texture and Ic as ion beam sputtered Y2O3, even no need to change IBAD MgO condition with magnetron sputtered Y2O3
  - Work at transition mode of reactive magnetron sputtering to get speed up to > 10,000m/h, but present routine run at 750m/h due to tape driving limit
  - Now used as standard Y2O3 layer production, total 35 long tapes were produced
- Combined two Al2O3 and Y2O3 process steps into one Al2O3-Y2O3 process step to further double throughput
  - Deposit Al2O3 and Y2O3 simultaneously in our Pilot Buffer system at speed of 750m/h
  - Significantly cut down setup/pumpdown time. Setup/pumpdown time is longer than process time, right now the main limiting factor for throughput

Stable Al2O3-Y2O3 reactive sputtering process

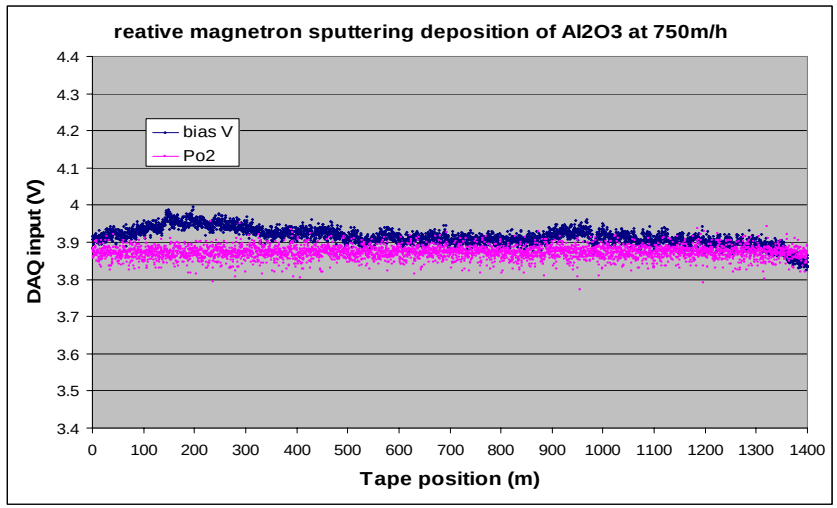
Reactive sputtering has high throughput, but very delicate, feedback control on single parameter, in most cases, is not enough to get stable process over long time and from run to run. Stable reactive processes for long length production were developed at SuperPower with MPML (multi-parameters/multi-loops) feedback control.



Bias voltages run away in Y2O3 run. single feedback control on O2 partial pressure



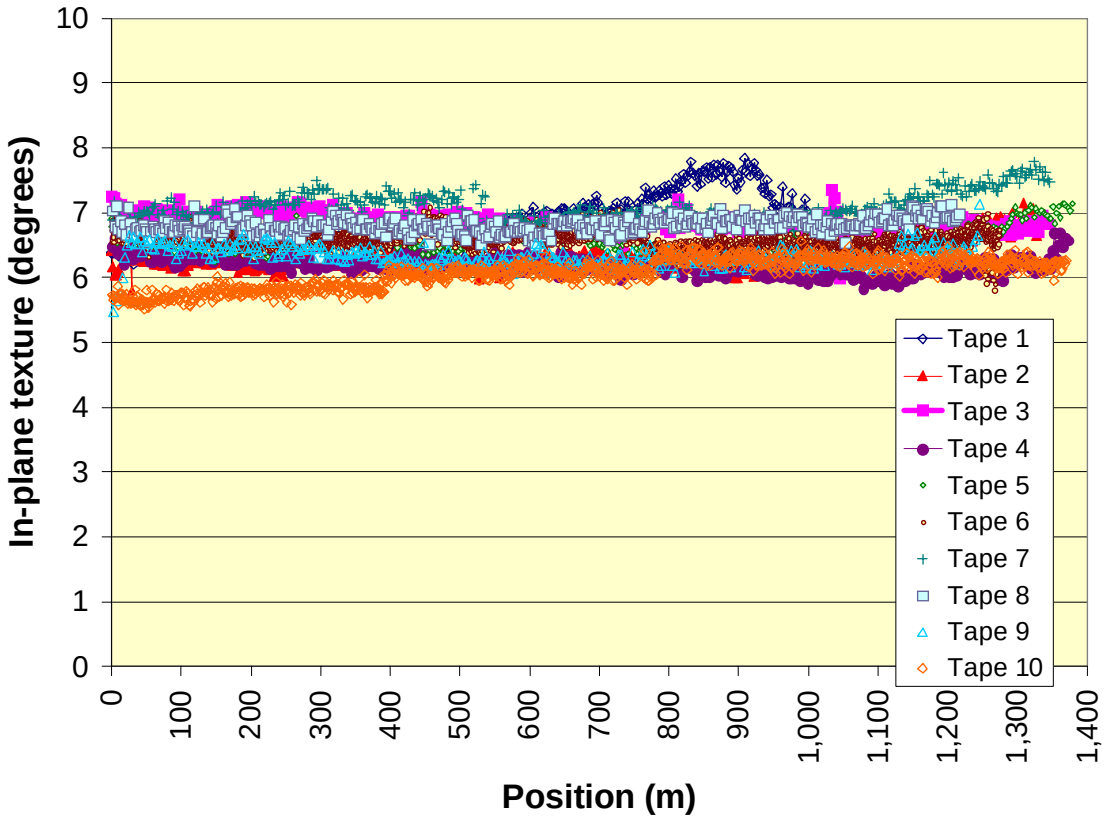
Good stability from run to run



Good stability during run. MPML feedback control

IBAD MgO process speed increased to 360m/h

- Using reactive ion beam sputtering with Mg metal target to get higher deposition rate
- But reactive process is delicate, easy run away during the long run and from run to run
- Feedback control was developed to achieve long time stability.

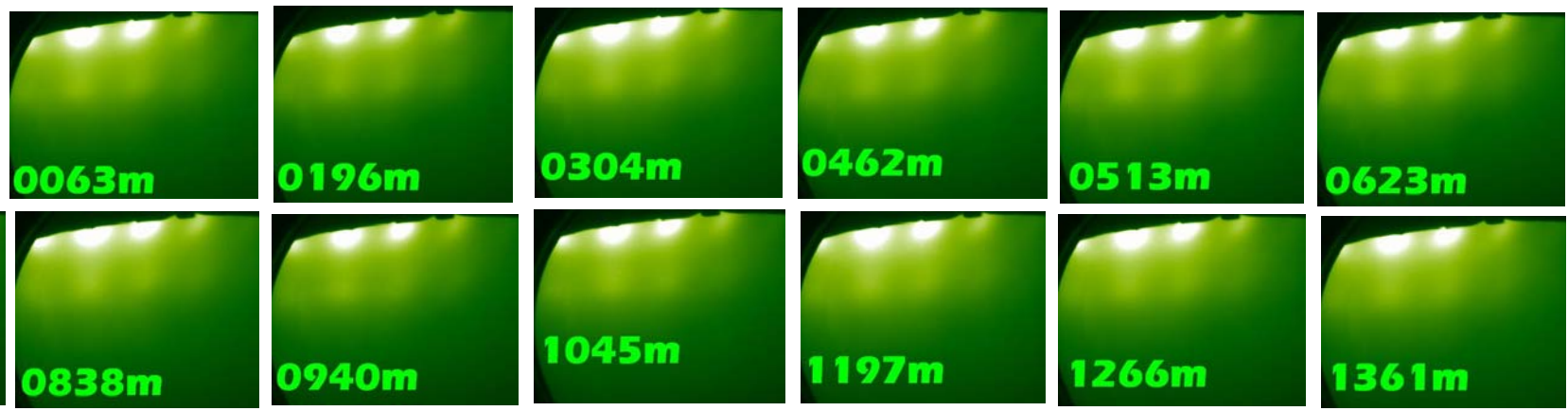


Tape	Length (m)	In-plane texture (°)			Uniformity
		Average	Min	Max	
1	1,001	6.79	6.20	7.84	6.2%
2	1,343	6.33	5.80	7.16	3.3%
3	1,346	6.85	6.00	7.35	2.1%
4	1,372	6.20	5.83	6.68	2.2%
5	1,375	6.58	6.23	7.14	2.5%
6	1,277	6.59	5.80	7.09	2.1%
7	1,346	7.09	6.66	7.79	2.9%
8	1,265	6.81	6.30	7.12	1.7%
9	1,246	6.33	5.47	7.13	2.4%
10	1,369	6.18	5.95	6.26	1.2%

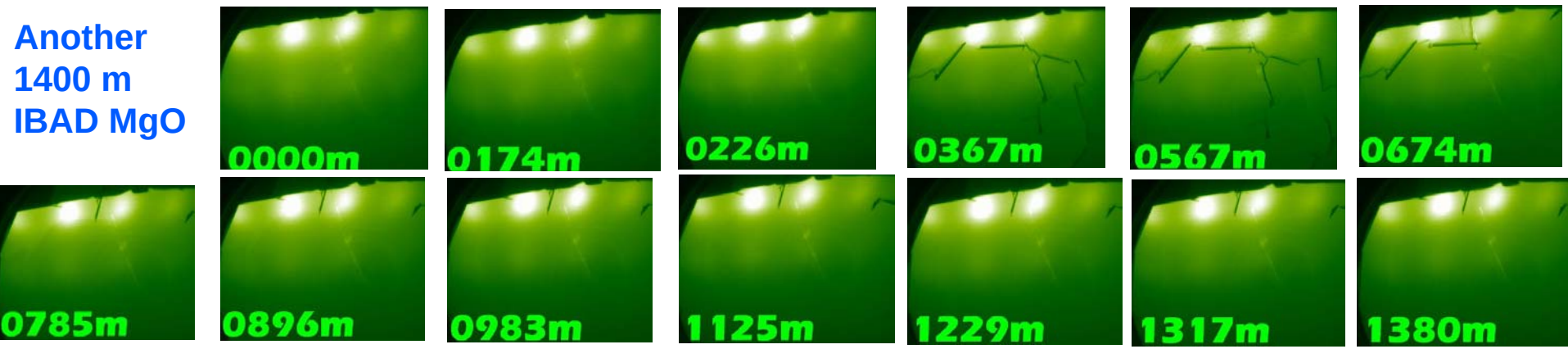
Routine manufacture of high quality, ~ 1.4 km IBAD MgO templates with excellent uniformity

Online RHEED shows stable 1.4km long IBAD MgO production, 360 m/h

1400 m long IBAD MgO



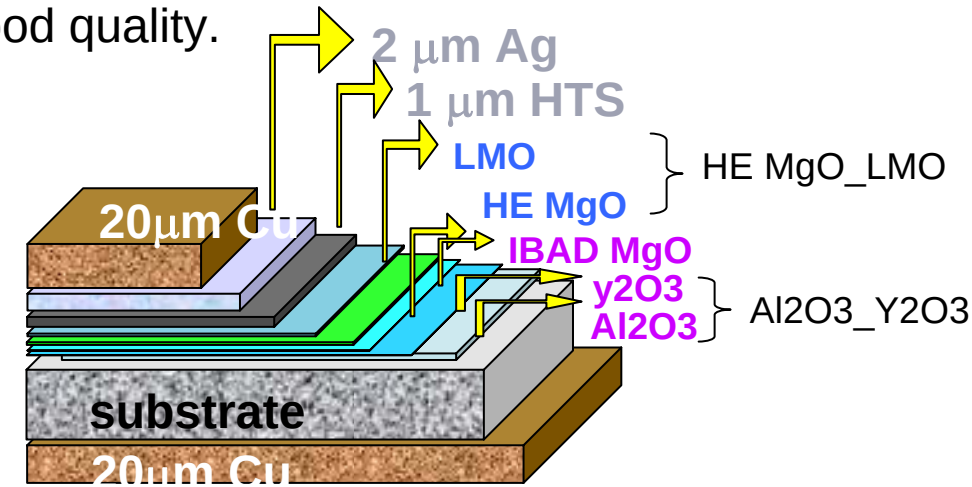
Another 1400 m IBAD MgO



Progress in Homo-Epi MgO and LMO Processes

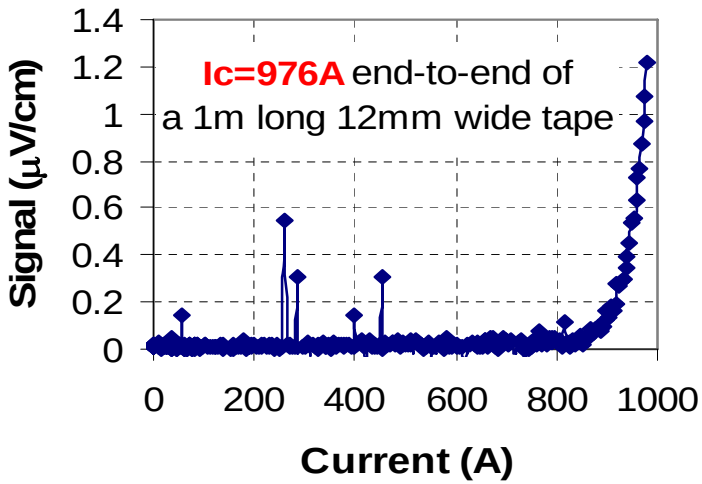
- Tape driving helix in Pilot Buffer system was upgraded from 6 wraps to 11 wraps, almost double the process speeds of both HE MgO and LMO
- HE MgO process speed was further increased by developing stable process at higher plasma power (close to limit of cathode equipped). Now routinely produce HE MgO tape at speed of 360m/h
- LMO process speed was further increased by using La-Mn alloy target which allow higher plasma power and higher deposition rate. several long tape were produce with speed of 450m/h with good quality.

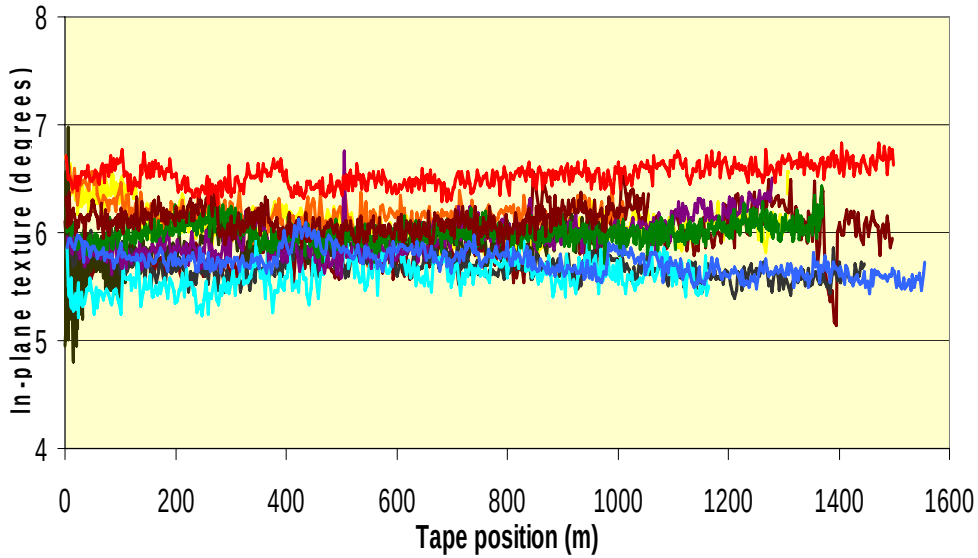
- Combined HE MgO and LMO process into one step process --- simultaneous run of both HE MgO and LMO --- reduce setup time and double the throughput. Now routinely produce HE MgO_LMO tape at 360m/h. ~40 long tapes were produced with combined HE MgO_LMO process



5-step process reduced to 3-step process

Routine high throughput manufacturing of kilometer lengths of high quality, low cost IBAD buffered tape

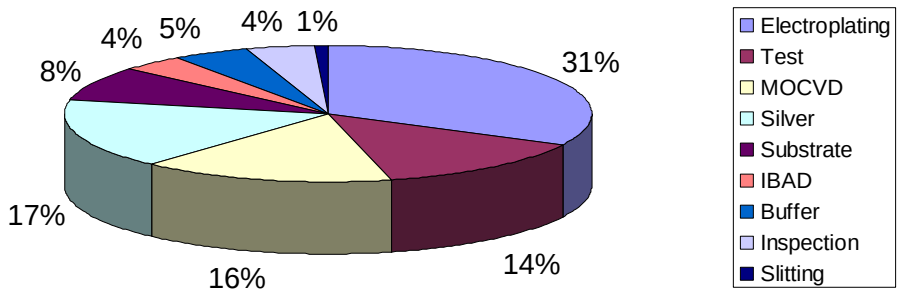




Buffer production capacity:

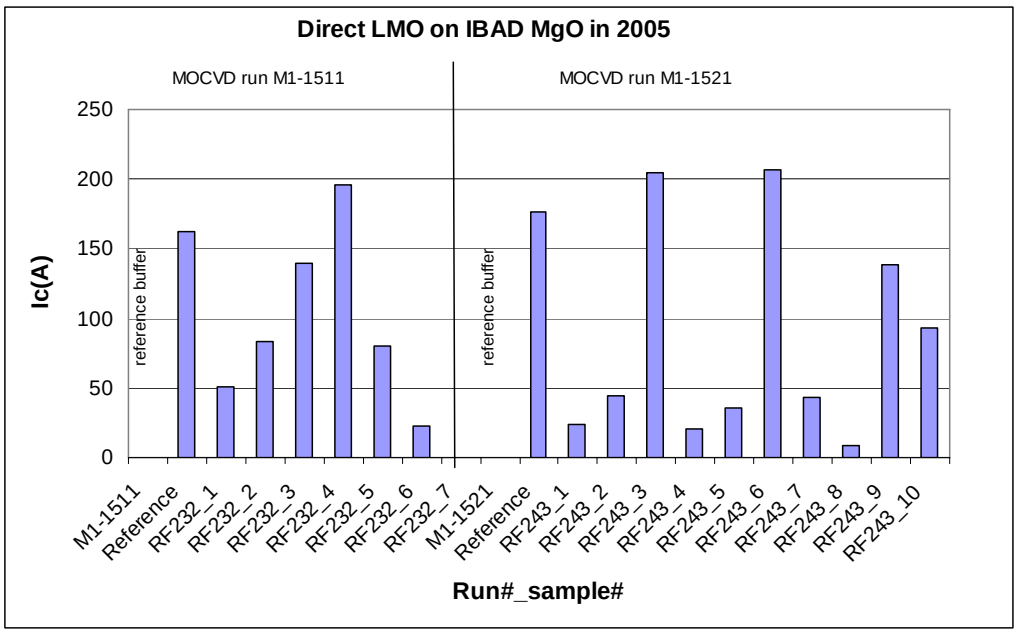
~ 1400 km/year

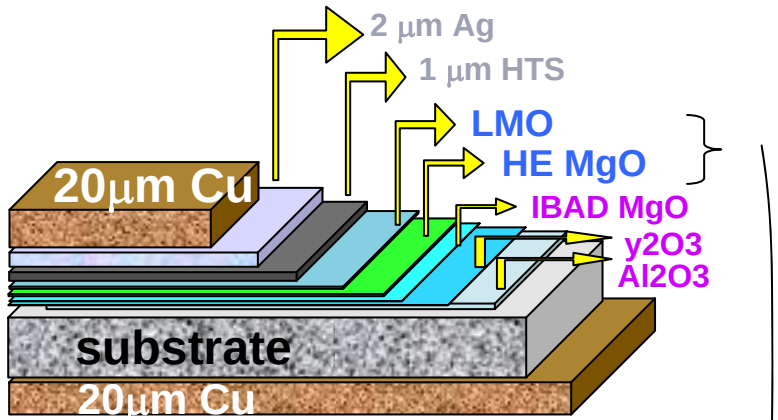
(assuming 45% run time and 90% yield)

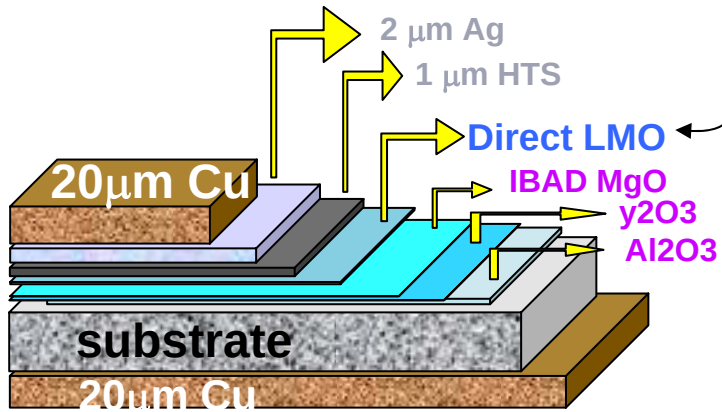


Progress in Direct LMO without HE MgO

- In July 2005, SuperPower successfully deposited LMO directly on IBAD MgO without HE MgO. Ic can be the same or better than the reference sample. But results were not consistent, yield was too poor to be a manufacturing process.







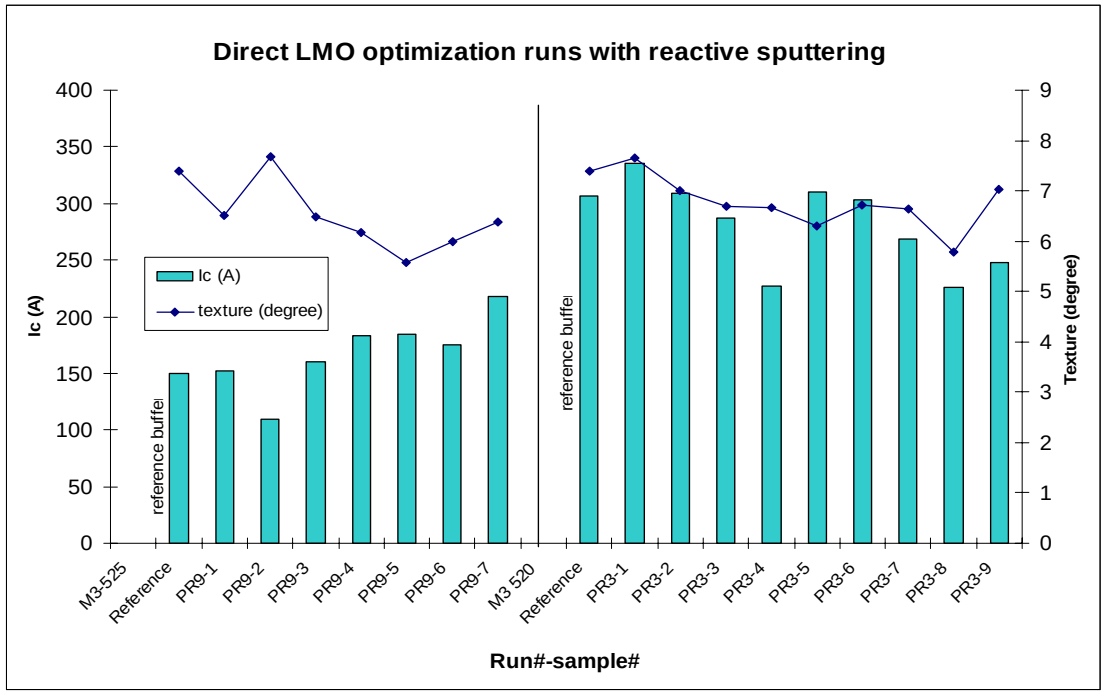
High yield Direct LMO process with 2x throughput is on the way to manufacture

Recently, we revisited the work on the Direct LMO process

High rate reactive magnetron sputtering at transition mode to deposit Direct LMO. Good feedback control on O2 partial pressure enables us to achieve much more reliable process control within process window required by Direct LMO growth without forming gas.

•Yield is greatly improved together with high rate Direct LMO process.

•Is working on further improve yield



- Once development and transfer to our Pilot Buffer system is completed, the expected process speed can be doubled from the present 360 m/h to 720 m/h.