Alternative Plasma Gas Chemistries for Plasma Enhanced ALD

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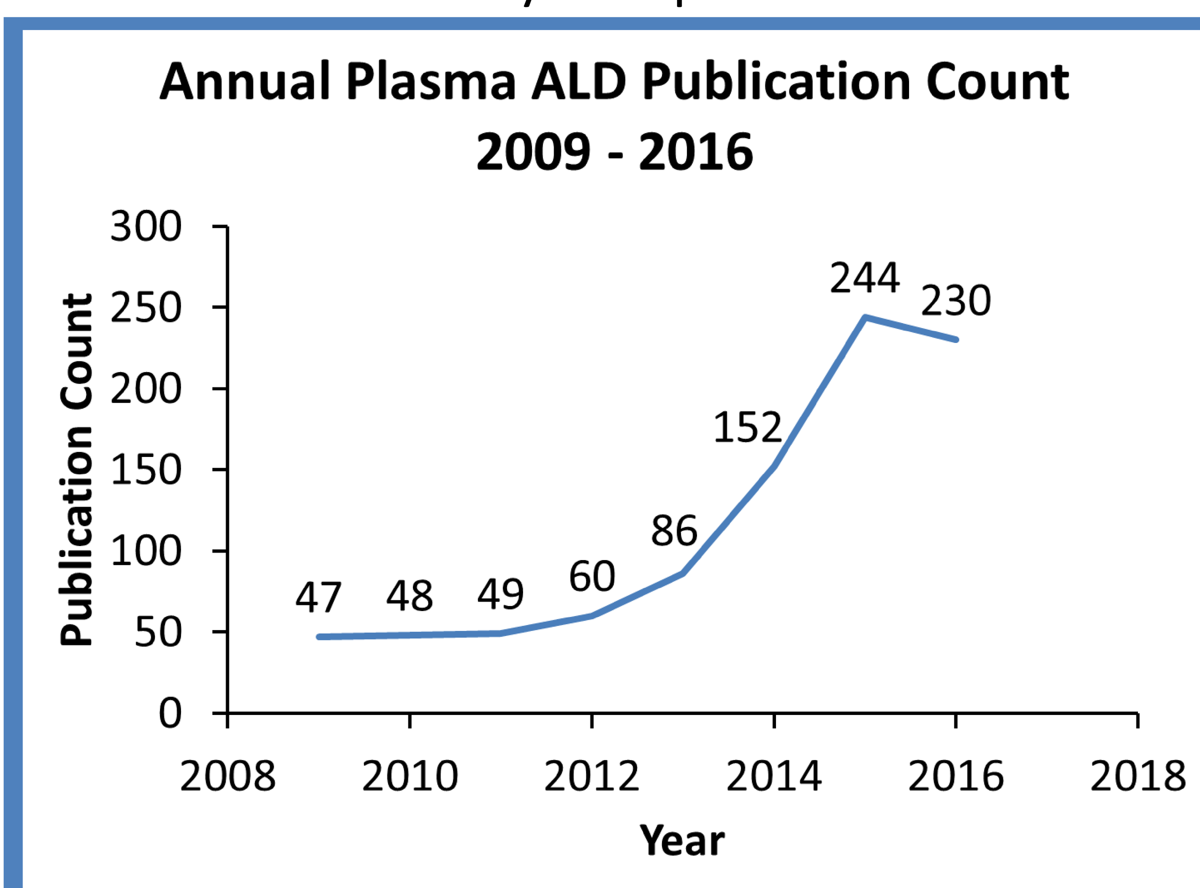
- In Plasma Enhanced ALD (PEALD), thermal ALD molecular co-reactants are replaced with highly reactive plasma generated species offering multiple potential advantages in film selection, film properties, and processing requirements.
- Most PEALD studies utilize a relatively small set of plasma gases including Ar, O_2, N_2, NH_3, and H_2.
- In the table below, less common plasma ALD gases are listed with a brief description of their applications.
- Visit the publication database at plasma-ald.com to learn more about these alternative plasma gas chemistries.

Plasma Gas	Comments
H_2O	Yamagata University has demonstrated room temperature deposition of HfO_2, ZrO_2, and Al_2O_3 with humidified argon plasma
N_2O	Al_2O_3, TiO_2, $AlTiO_x$, HfO_2, ZrO_2, and ZnO have been deposited with N_2O plasma with little to no nitrogen incorporation
CO_2	Al_2O_3, TiO_2 have been deposited with CO_2 plasma with little to no carbon incorporation
D_2	Substituting D_2 plasma has helped elucidate the surface mechanism of Cu deposition from $Cu(hfac)_2$ + H_2 plasma
He	Adding He to the plasma can change plasma density and electron temperature impacting film growth rate and properties
CH_4	Methane plasma admixing has been studied for introduction of carbon to produce TaCN, TiCN, and WCN
CO	Carbon monoxide plasma has been investigated for introduction of carbon to SiO_2
PH_3	GaP has been deposited with trimethyl gallium and phosphine plasma
TMP	Trimethyl phosphate plasma has been studied for Al, Fe, Li, Ti, and Zn phosphate materials
H_2S	Hydrogen sulfide plasma has been studied for the deposition of ZnS, MoS_2, In_2S_3
CH_3NH_2	SiC_xN_y Using Si_2Cl_6 (R. A. Ovanesyan et al. Chem. Matls. 29(15) 2017.)

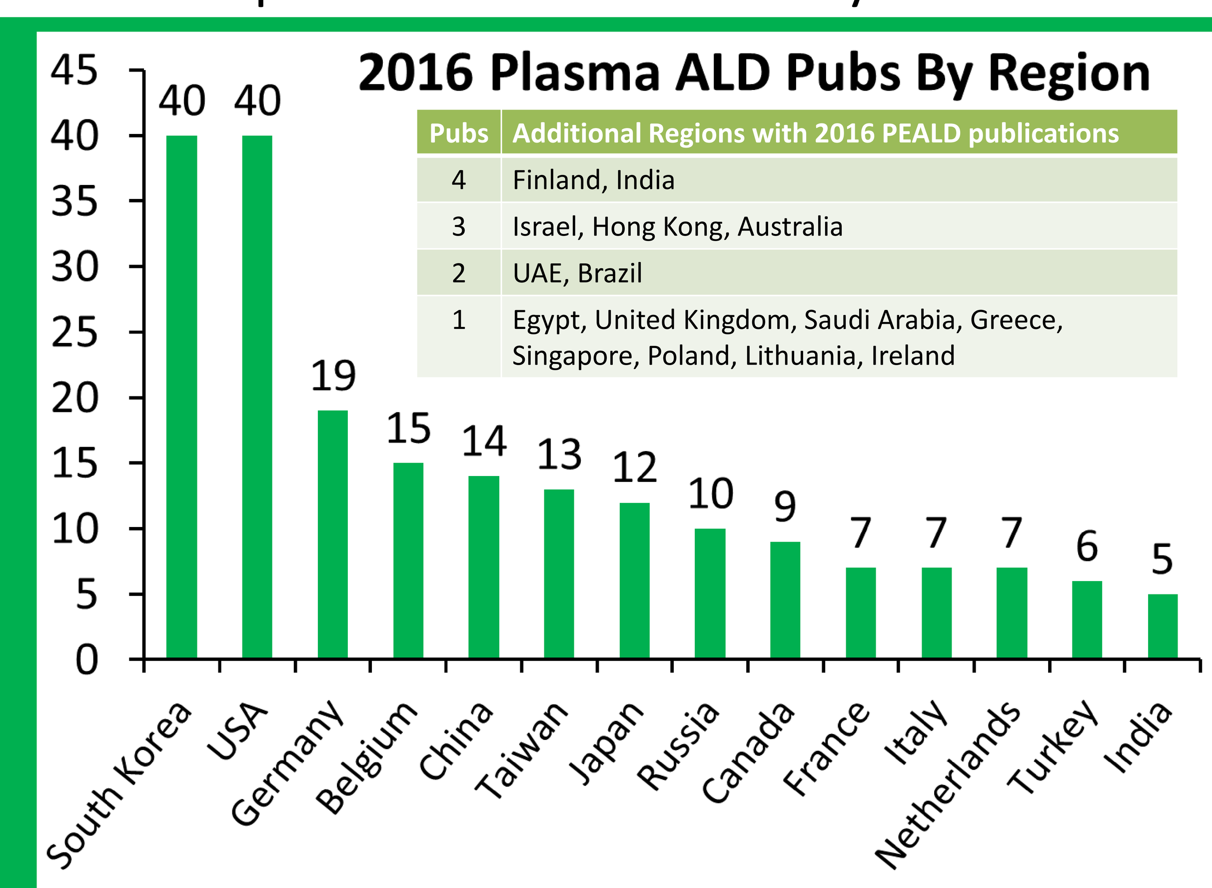
2016 Plasma ALD Year in Review

- Plasma-ald.com hosts a freely accessible, highly searchable database of plasma ALD publications currently with 982 entries.
- Plasma ALD publications can be searched by any combination of: film; substrate; precursor and plasma chemistry; deposition hardware; author name and affiliation; film and plasma characteristic, analysis method, and diagnostic equipment; and deposition temperature range.
- After each new year's publications have been entered, a summary review is released to provide an overall picture of the community activities.

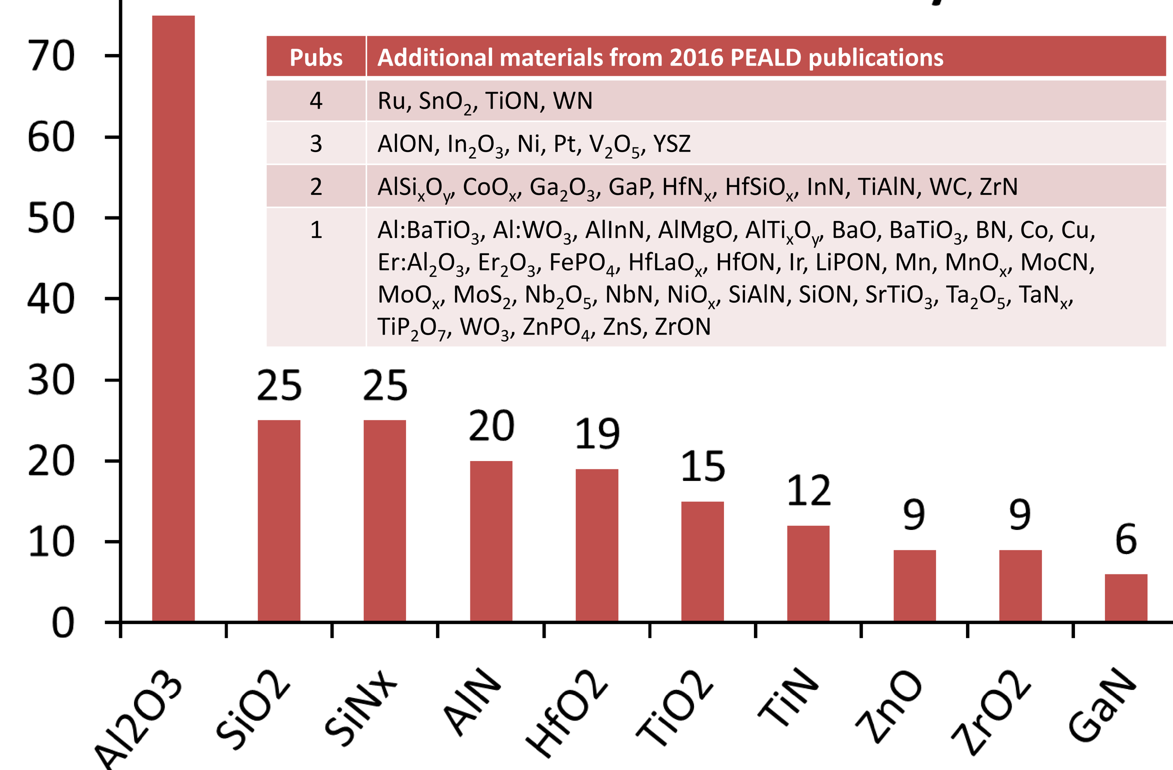


- Strong growth has been seen through 2015 but 2016 did not continue the trend.
- Inclusion in the database has become slightly more selective. Journal publications and conference proceedings are included, but I no longer include conference talks based purely on an abstract.
- The number of ignored conference abstracts not included in this years tally that might have been previously included to number in the 10-20 range. Just enough to make 2016 pretty much in-line with the 2015 numbers. Acceptance date is used for determining the date of a publication.

- As in 2015, South Korea and the USA led the way with Germany in third place.



2009-2016 PEALD Publications	Top 31 PEALD Publication Authors 2009-2016
67	Erwin Kessels
34	Necmi Biyikli
30	Richard van de Sanden
29	Çagla Özgit-Akgun
27	Hyungjun Kim
20	Christophe Detavernier
19	Ken Cadien, Hyeongtag Jeon, Miin-Jang Chen
17	Harm C. M. Knoops, İnci Dönmez
15	Gijs Dingemans, Kensaku Kanomata
14	Fred Roozeboom
13	Ali Kemal Okyay, Han-Bo-Ram Lee
12	Bashir Ahmmad, Fumihiko Hirose, Sang-Hee Ko Park, Ali Haider, Shigeru Kubota
11	Mustafa Alevli, Soo-Hyun Kim, Douglas W. Barlage
10	Fritz B. Prinz, Jolien Dendooven, J Provine, Hassan Gargouri, Marcel A. Verheijen, Heeyoung Jeon, Jolien Dendooven
The database includes 3061 other authors.	



- 144 PEALD film materials are listed in the database.
- Al_2O_3 continues to be the most popular material.
- SiO_2 rose from 6th to 2nd.
- SiN_x went from 3rd to tied for 2nd.
- AlN rose from 5th to 4th.
- TiO_2 dropped from 2nd to 6th.
- HfO_2 dropped from 4th to 5th.

Deposition Hardware

- Deposition hardware for 2/3 of the 2016 PEALD films have been identified.
- 13% of the papers utilized custom, homemade hardware.
- 24 different commercial deposition systems were used for the remaining 53% of films including: Aixtron Genus Strategem 200; Altatech AltaCVD; Applied Materials Producer GTTM, P-5000 Mark II, and TxZ chamber; ASM Eagle XP8 and EmerALD; Atomic Premium CN1; Beneq TFS-200 and TFS-500; Cambridge NanoTech Fiji; Ensure LabNano PE; Kemicro PEALD-150; Kurt J. Lesker ALD-150LX; NCD Lucida MP-100; Oxford Instruments FlexAL, OpAL, and Plasmalab 100; Jiaxing Kemicro Microelectronic PEALD-200A; Picosun R200 and SUNALE R-150B; Quros Plus 150 and 200; and SENTECH
- The database includes publications from 23 other deposition systems as well.

Plasma-enhanced atomic layer deposition is an exciting, growing field that is becoming more recognized as an indispensable tool to researchers outside the ALD community. The free, on-line database at www.plasma-ald.com can help you quickly find PEALD publications that will help you with your research interests.

If you have any questions or comments, please send me an email: plasma-ald-guy@plasma-ald.com