

Virtual Project on the History of ALD in perspective: past, present, and final steps

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Atomic layer deposition (ALD), a materials growth technique based on repeated separate self-terminating reactions, has become an enabler for semiconductor technology and is currently being investigated for a growing range of other applications.

ALD has two historical roots. The international community is in general aware of the invention of ALD under the name atomic layer epitaxy (ALE) in Finland in 1974 [1,2]. The community is significantly less aware of developments under the name molecular layering in USSR/Russia since the 1960s [3,4]. For example, the world's most cited review on ALD only cites the early Finnish developments [5]. Another review article (written by several leading authors in the field) to describe the history of ALD (and its relation to AVS) [6] recently had to be corrected with respect to its description of the USSR-Russian developments [7,8].

Why the molecular layering works have remained poorly known and cited, is not known. An explanation has repeatedly been offered in the literature that the works were published in Russian [9,10]. This statement is not quite correct. While there have been many publications in Russian only, there have also been plenty of publications in English, typically published in journals published in Russian, which automatically receive an English translation. Two such references are given here as examples [11,12]. Also, the first international symposium on ALE (i.e., ALD) in Espoo, Finland in 1990 received participants from the USSR/Russian ALD community [13,14].

The seeds for the Virtual Project on the History of ALD (VPHA, <http://vph-ald.com>) were sown already almost twenty years ago, when the article in Solid State Technology called "Early work on atomic layer deposition cited" by Malygin et al. was published in 2002 [15]. This article (response to an earlier article in the same journal) triggered the interest of R.L.P. while a postdoc at IMEC, Belgium. R.L.P. contacted the lead author (Malygin) with a request to get copies of some of the early works. Copies were soon provided, and the work to find facts about early ALD developments under the name molecular layering (and sometimes, other names) started. The results of the research were published in a review article (Table 1 of it) in 2005 [16]. To our knowledge, this review was the first review in English (after the contribution of Aarik in 1990 [17]), to clearly acknowledge the independent invention of ALD in the USSR/Russia. The author hoped that this article would change the way the scientific community sees the history of ALD, and would trigger others to find out about the history, too. While some advances were booked, leading mainstream works continued to acknowledge only the atomic layer epitaxy origin of ALD.

VPHA was launched in July 2013 with the following statement [18] "VPHA is an open collaborative effort, whose goal is to clarify open questions related to the early history of the ALD thin film deposition technique. VPHA is based on voluntary efforts, and anyone interested in the history of ALD is welcome to join. All VPHA activities are made in an atmosphere of openness, respect and trust."

The core activity of VPHA is to collect together, and collectively read, and write short comments (in English) on early ALD works, which are then openly shared. Such work forms the factual basis to form a common understanding on the early works of ALD; common understanding of the facts related to early ALD developments has been clearly missing. Outcomes presenting the progress of VPHA have been presented at various conferences [19], and VPHA has directly or indirectly resulted in four scientific journal articles [1,3,20,21]. The authors understand that the

VPHA has also contributed to awarding the Millennium Technology Prize 2018 to the Finnish inventor of ALD, Tuomo Suntola [22].

Although VPHA has already booked significant progress, the work is not completed yet. Setting as the target that each early ALD publication should receive comments from at least three persons to be shared in the collective “ALD-history-evolving-file” document, the reading work is about half completed. Of the ~170 articles still missing one to two comments, ~140 are available only in Russian. So far, 79 contributors from over 20 countries have participated in the reading activity. To complete the reading effort, it is essential to have a significant number of researchers from the Russian ALD community, too, to actively participate in the reading effort.

With this abstract at the ALD Russia 2021 conference — chaired by the first author of the “Early work on atomic layer deposition cited” letter [15] — the final stage of VPHA is launched. The purpose is to finalize the reading and commenting work, and optionally to write a review article on the history of ALD on the basis of the information collected and findings made. **We invite all researchers worldwide, interested in ALD and ALD’s early roots, to volunteer to work together in VPHA, to build together fact-based understanding of the early ALD works.** Especially we invite Russian-speaking ALD researchers to volunteer: thorough understanding of both the technique and the technical language used to describe ALD both in Russian and English will give the best result when writing brief comments on Russian-only articles in English. To join, please contact us via info@vph-ald.com.

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