

Think Positive, Pulse Positive

HiPIMS with positive reverse pulsing.

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### Bipolar Pulsing Technology and/or Reverse Pulsing for Magnetron Sputtering

Classically, bipolar pulsing technology is in most cases referred to dual magnetron applications. Positive Reverse Pulsing should not be mixed with this. It can be applied to single and to dual magnetron applications. The expression bipolar pulsing or bipolar technology in magnetron sputtering needs to be explained a bit more. There are symmetrical and asymmetrical bipolar pulses.

#### Let's look a bit closer:

Asymmetrical bipolar pulses have been used in DC-pulsing for decades already. These pulses are, among other benefits, doing a great job to discharge the target in reactive processing to avoid poisoning. Lately more and more companies, mainly for HiPIMS are actively promoting this asymmetrical bipolar pulsing technology. Yet for a different technical purpose. The negative or cathode voltage pulse, let's call it the "work pulse" is doing the deposition. Analog to it, we can call the asymmetrical bipolar pulse, inverse or positive reverse pulse, the enhancement cycle or enhancement pulse. It occurs right after the negative work pulse. This enhancement cycle pulse employs additional advantages and opens supplementary playroom for process improvements. It has been implemented mainly on single magnetron applications. Of course, for dual magnetron applications the reverse pulsing technology offer's the same advantages. It just adds a bit more technology to the PS design.

#### A historical look at positive reverse pulsing for HiPIMS

Checking the older HiPIMS literature we do not find a lot about the positive reverse pulse. Prior to the recognition of the advantages of this positive reverse plus, let's say before 2015, a positive overshoot voltage after the work pulse has of course been noted already. Documented on many older oscilloscope graphs of the HiPIMS impuls. These at the time considered as undesirable and uncontrollable pulses were accepted as an annoying side effect, probably induced by the high peak currents in power transmission lines from the PS to the magnetron, or whatever. For sure it has been improving the depositions, yet unrecognized.

One of the first publishing's about active positive reverse HiPIMS pulse was mentioned and explained in a conference poster in 2012. Here the pos. pulse was "more or less" hidden. Yet, experts could see that it was used as the main ingredient of an ultra-fast arc-handling technology. At the time, the most sophisticated arc-management for HiPIMS-PS. Similar arc handling circuitries were later applied to other state-of-the-art HiPIMS-PS.

At research work on arc sensitive processing, it was discovered that the more arcs had to be suppressed by this positive voltage pulse, the better the film properties turned out to be. It took a bit of guess work and of course a deep knowledge of processing to find out the true reason why these coatings were of higher quality. This was actually the birth of implementing the positive reverse pulsing for HiPIMS to improve the quality of thin film coatings. Now, in all state-of-the-art HiPIMS-PS this positive reverse pulse is available, either proportionally self-adjusting or as a fully adjustable and regulated option.

#### How should this reverse positive voltage pulse be called?

As most of the HiPIMS (high-power impulse magnetron sputtering) and/or HPPMS (high-power pulsed magnetron sputtering) technologists remember, the terms HiPIMS or HPPMS have been used in parallel for many years. And this, for the same thing. Confusing to many, because in numerous cases it was thought of and communicated as a different technology.

So how should this reverse voltage pulse be called? Well, if we check the most recent HiPIMS publications we find hiPlus or V+, some call it bipolar pulsing (which is true but may be misleading), some call it voltage boost, some kick or whatever..... Whatever it is called, it is doing a great job. If applied correctly it is a beneficial tool for boosting the quality of the coated thin film.

If ever a common name for this asymmetrically bipolar positive reverse pulse for high-power impulse magnetron sputtering or high-power pulsed magnetron sputtering will be found ? Time will tell.