A large area SiPM for efficient detection of the fast scintillation component of BaF_2

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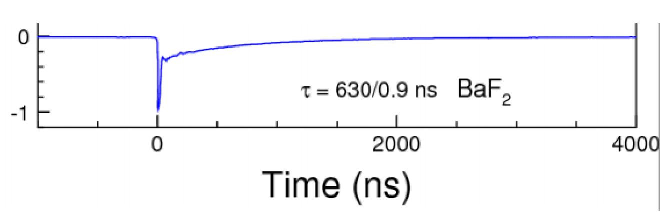
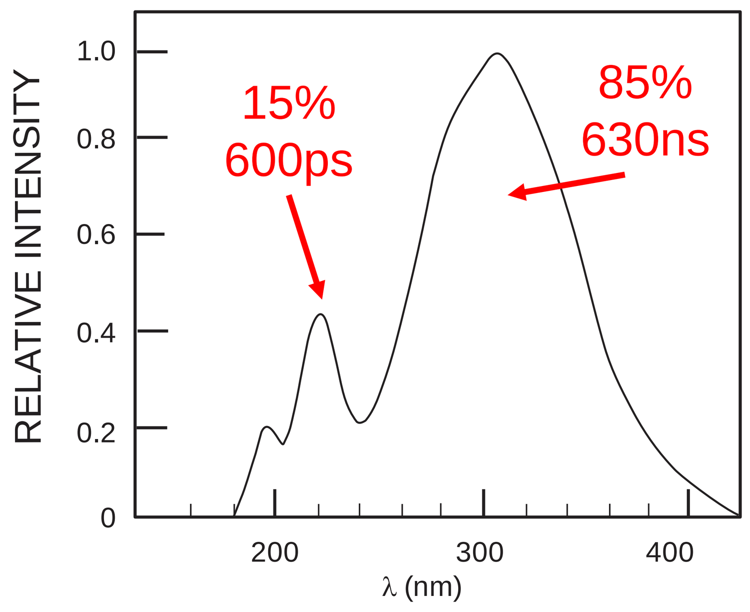
Barium Fluoride scintillation

BaF_2 has the fastest decay time of any inorganic scintillator: τ~600ps at 220nm
This is accompanied by a much larger slow component: τ~630ns at 300nm





In order to fully exploit the fast decay time of the 220nm component for good time resolution and high rate capability, we must suppress the 300 nm component. This can be done using Yt or La doping, by filtering, or both.

A solar-blind SiPM

An integrated antireflectance/interference filter can provide substantially higher efficiency at 220nm than an external filter, as well as excellent extinction at 300nm.

We are realizing this concept with an FBK NUV-HD SiPM having a thin optical entrance window on which we deposit a multilayer metal/dielectric filter (MDF) for the band pass of interest.

The normal SIPM optical entrance window must be redesigned in order to be

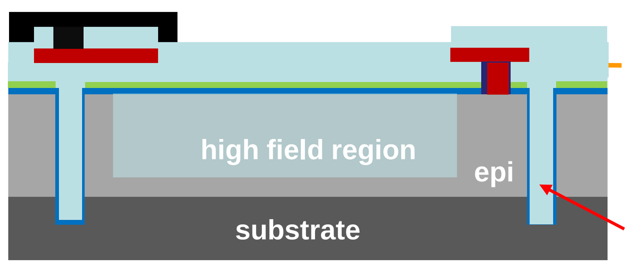
- ultra-thin: less than 30 nm, made of a single dielectric film (SiN or SiO_2)
- extremely uniform at wafer level (few nanometers)

In addition, we must preserve the SiPM performance in terms of noise and quantum efficiency

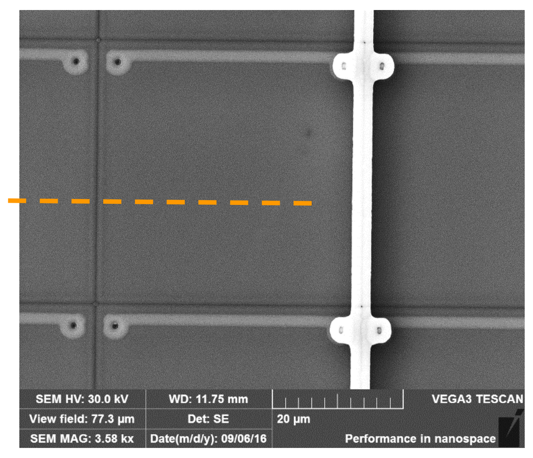
Prototype structure

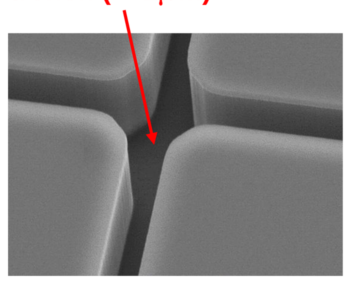
FBK **NUV-HD design** produces devices with small cell pitch (from 40µm down to 12µm) with a high fill factor (82% for 40µm cell pitch)

Standard SiPM NUV-HD
standard optical window is a 2 µm multilayer stack

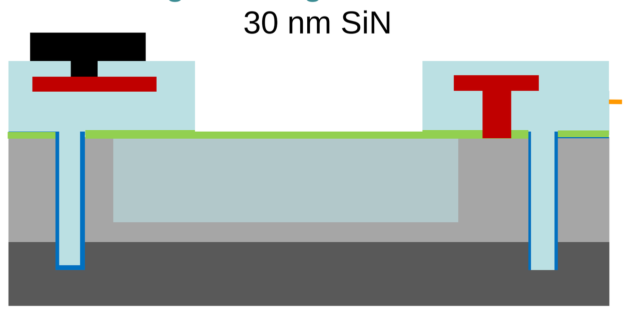


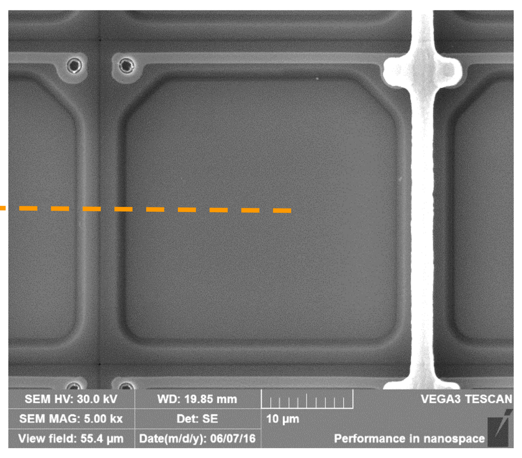
trench (< 1µm)

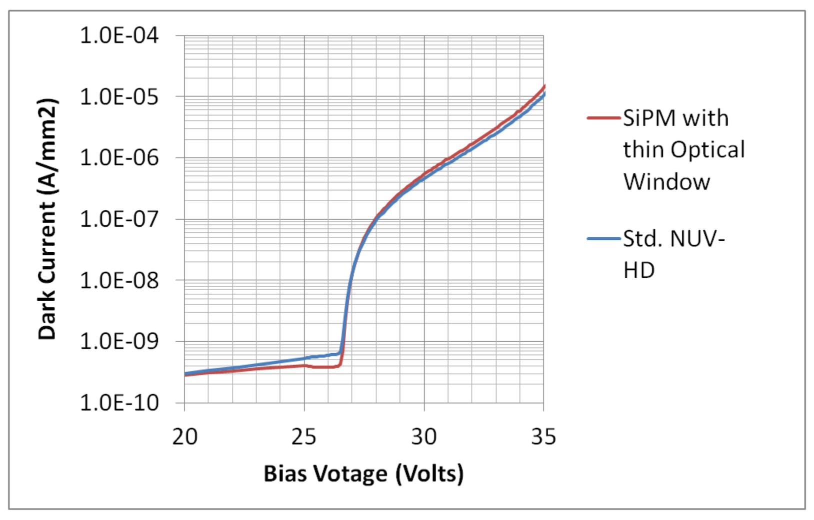




SiPM with thin entrance window and guard ring structure
30 nm SiN







Preliminary characterization of first prototypes (1x1 mm²):

First samples with thin optical window (30nm SiN) work properly

Dark current is comparable to that of a standard NUV-HD, indicating that the thin entrance window does not affect the electrical performance of the device.

The next step is to introduce the MDF filter

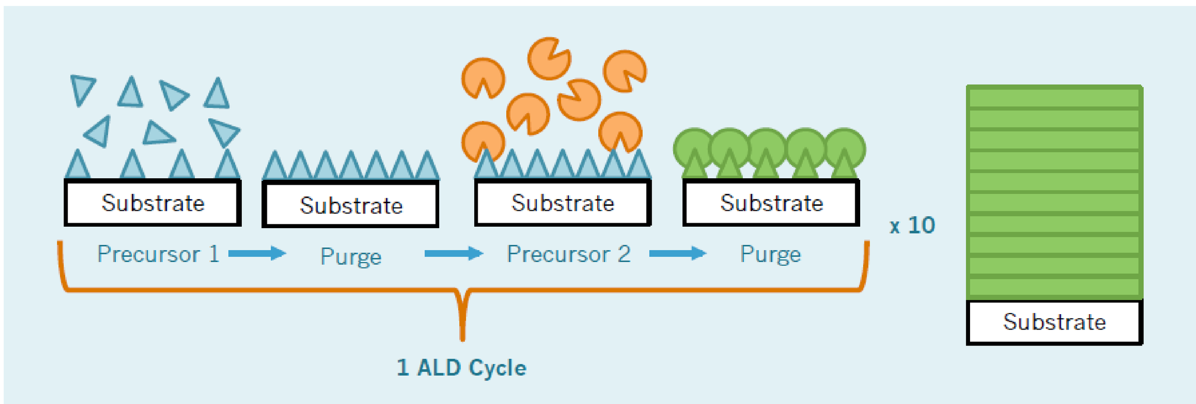
Filter fabrication

The MDF is based on alternating thin layers of Al and Al_2O_3.

Al is deposited by electron beam (*e*-beam) evaporation and Al_2O_3 is deposited by atomic layer deposition (ALD).

ALD allows for extremely fine control over film stoichiometry, thickness, and interface characteristics.

This results in well-controlled band pass selection capabilities.

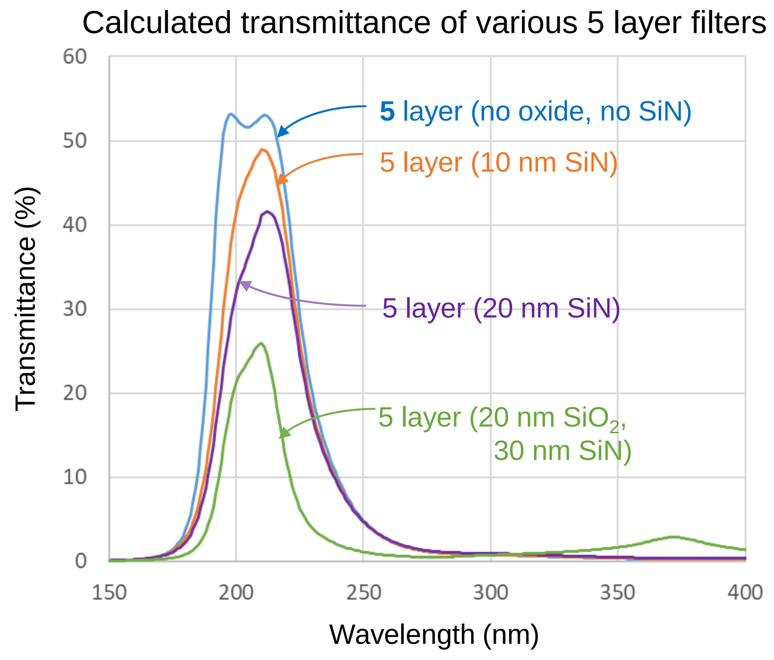


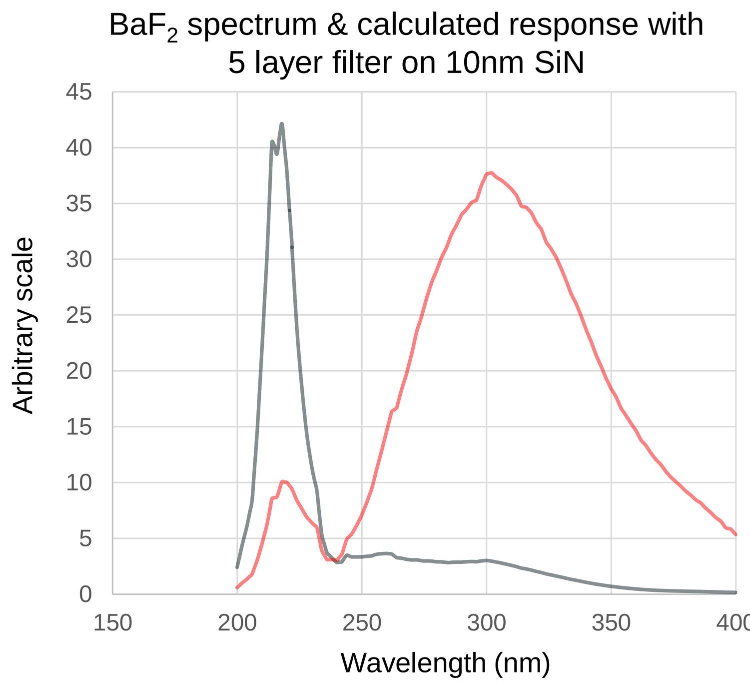
Five Layer MDF

Filter design

MDF is efficient at 220 nm and provides strong extinction at 300 nm.

MDF characteristics (i.e., number and thickness of layers) can be adjusted to trade throughput for degree of 300 nm extinction



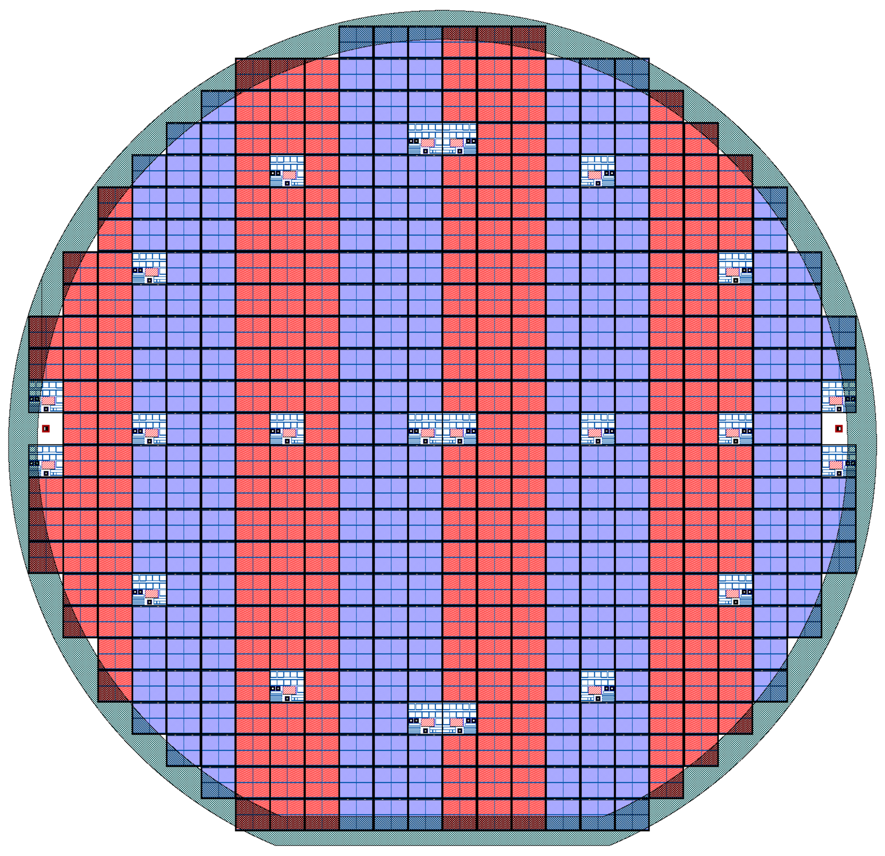


Status

MDF will be added to FBK-produced SiPM wafers by JPL in the next month.

Wafers will then be diced and individual chips tested for efficiency.

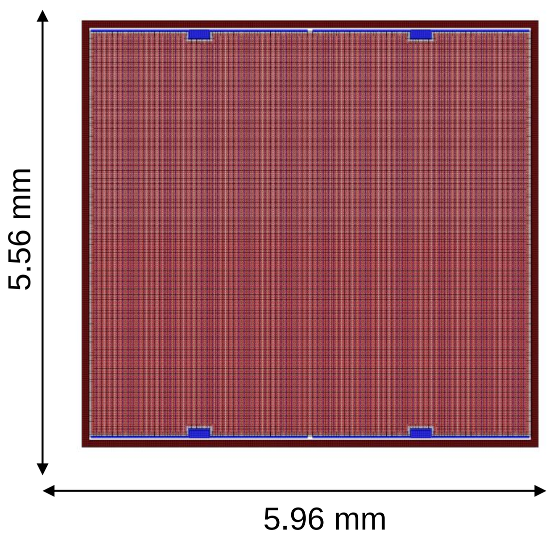
The next development stage will be the introduction of a delta-doping layer to improve rise time and further increase quantum efficiency.



Optical window Splits
10nm SiN
20nm SiN
30nm SiN
20nm SiO2
Bare Si

Technology NUV-HD
Geometry quad 3x3 mm²
Cell Size 40 µm

6x6 mm² quad



Two different SiPM Layouts have been designed: standard and metal/poly guard ring. The latter provides a ring around the cell acting as field plate and controlling the E field at the SPAD border