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: t~600ps at 220nm
This is accompanied by a much larger slow component: t~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)

Preliminary characterization of first prototypes (1x1 mm$^2$):
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$_2$O$_3$.
Al is deposited by electron beam (e-beam) evaporation and Al$_2$O$_3$ 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.

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.

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