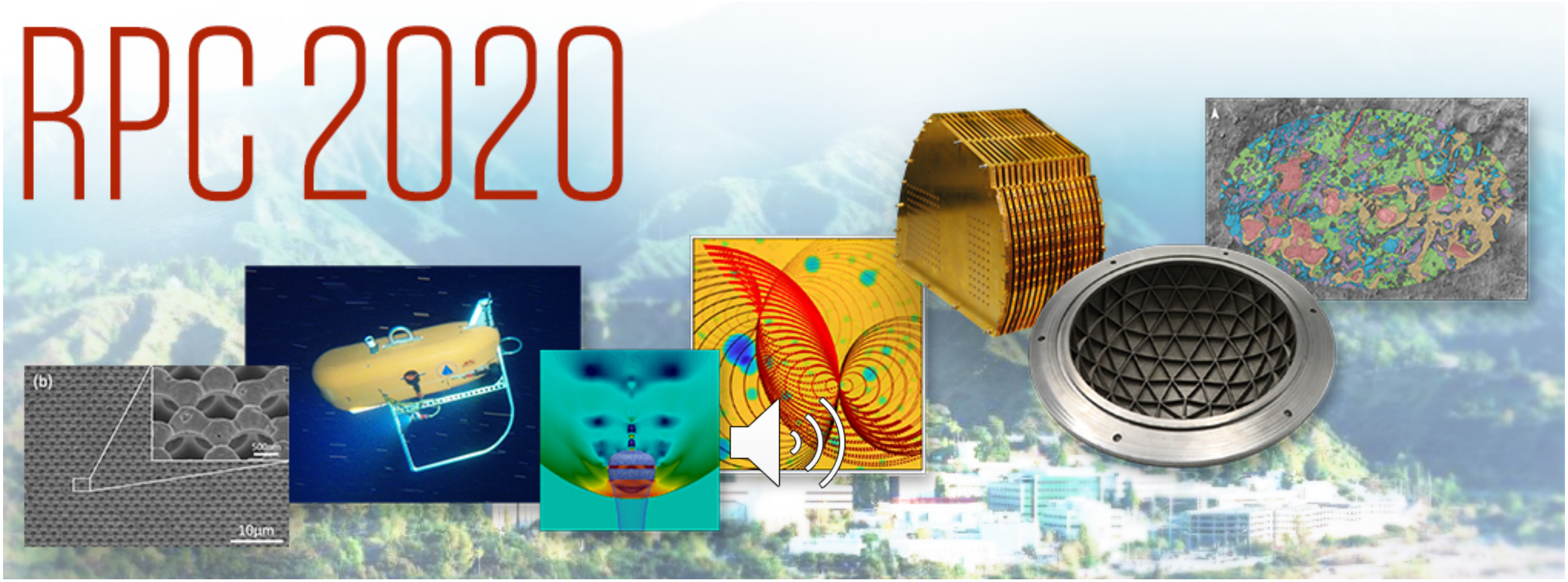

Virtual Research Presentation Conference

TRL Advancement & Qualification for UV & UV/Vis Photon Counting & Scientific Si Detector Arrays

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Program: (Strategic Initiative)

Assigned Presentation # RPC-205

Jet Propulsion Laboratory
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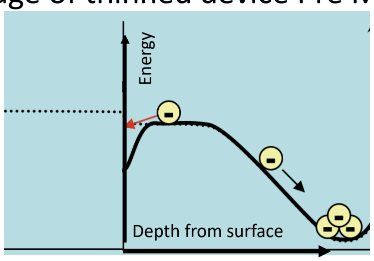
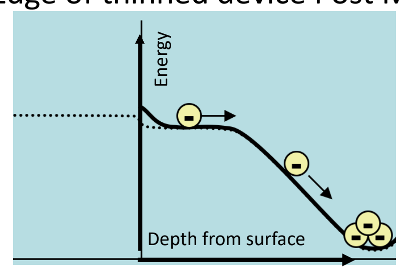
Tutorial Introduction

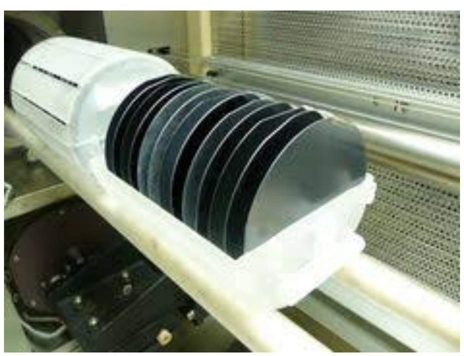
Abstract Under this Strategic R&TD task and in collaboration with Teledyne-e2v, we create, characterize, and environmentally test a statistically significant number of high efficiency ultraviolet scientific detectors in order to develop optimized processes for scientific ultraviolet detectors, establish a high-fidelity yield of our end-to-end detector fabrication processes, and advance the TRL of high-performance UV and UV/Optical large format scientific charge-coupled devices (CCDs) and electron-multiplying CCDs (EMCCDs). JPL applies unique surface nanoengineering processes to two Teledyne-e2v wafer batches, comprising 10 each of the standard CCDs similar to the flight-qualified detectors for the Euclid Space Telescope, and EMCCDs similar to the detectors currently being qualified for the Roman Space Telescope.

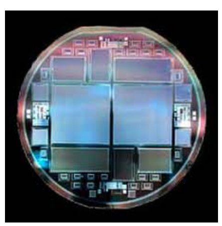
Edge of thinned device Pre MBE

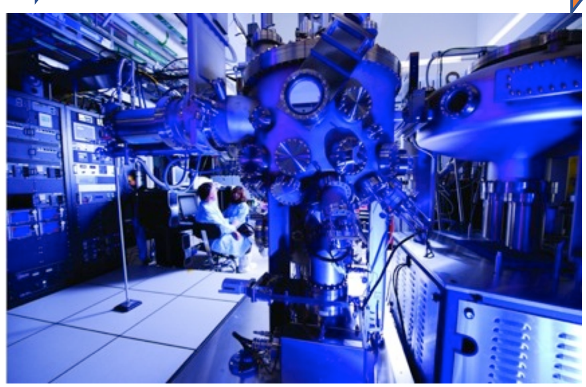


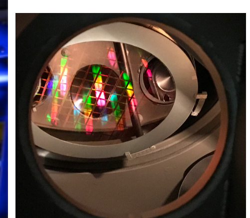
Edge of thinned device Post MBE

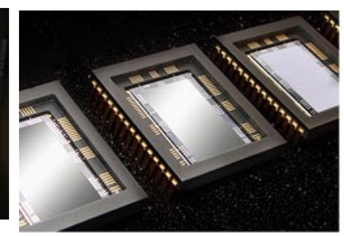












Problem Description

a) With the surge of ideas for ultraviolet mission and with interest in having high efficiency detectors, it is important to advance the readiness of detector technologies that can deliver mission enabling performance. JPL's 2D doping encompassing delta doping and superlattice doping combined with custom coatings developed at JPL show great mission enabling promise in high QE, highly stable and uniform response.

b) By teaming with Teledyne-e2v, a leading manufacturer of scientific CCDs for spaceflight, we advance and certify the end-to-end processes required for producing ultraviolet and ultraviolet/visible CCDs with unique performance and capabilities for future NASA missions. Teledyne-e2v will be performing environmental and endurance tests silimiar to their lot acceptance tests (LAT) for qualifying a lot of wafers for a flight project thereby advancing the TRL of the ened to end process.

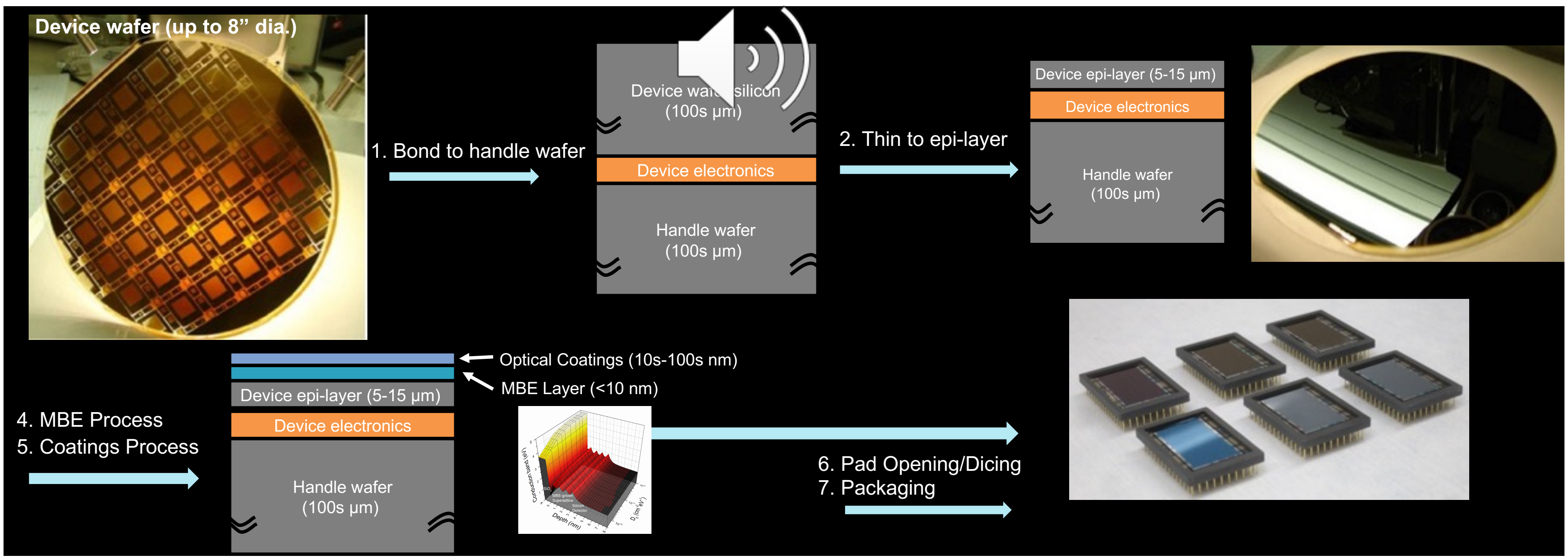
c) Most previous ultraviolet missions have used image tube based detector technology, i.e., microchannel plates or MCPs. While they have worked well, they have lower quantum efficiency (QE) and they require high voltage. Comparison with SOA standard processing of CCDs or CMOS arrays shows a factor of 2 better QE in the near UV range. WFC's CCD have shown hysteresis while these devices do not.

d) Relevance to NASA and JPL (Impact on current or future programs). JPL's delta doped and optimally coated CCDs and CMOS arrays are baselined for a number of Explorer mission concepts including a number of MIDEX concepts for the recent MIDEX-AO as well as for SMEX-Dorado which is in phase A and Step 2 proposal with concept study report due in March 2021. Delta doped arrays are baselined in flagship concepts of Large Ultraviolet/Optical/Infrared survey mission (LUVOIR) and Habitable exoplanet characterization mission (HabEx). In addition to astrophysics missions, there are planetary mission concepts that will benefit from this detector technology maturation.

Methodology

a) JPL's post fabrication back illumination process modifies CCDs, CMOS detector arrays, or other Si detector arrays into high efficiency detectors with response from soft x rays to near infrared using 2D doping technology. Coatings tailors the response of device to narrowband UV , broadband, solar blind, etc. The steps of the post fabrication process are shown below (starting from left and following arrows) where a device wafer comes out of the foundry, it is then bonded to a handle wafer, thinned down to 5-15 μm, 2D doped using MBE, diced packaged and custom coated for specific spectral response

b) The advancement through this effort is to work with Teledyne-e2v, produce devices by processing 10 wafers each of scientific conventional read CCDs (CCD 272, and scientific EMCCDs, and characterize their performance and environmental response



Results

a) Accomplishments versus goals

a) Teledyne-e2v completed the fabrication of two half lot runs of the large format scientific CCDs (10 wafers, 4kx4k, 12 µm pixels CCD272) and EMCCDs (10 wafers, 2kx1k, 13 µm pixelCCD201). The first batch of 5 CCD wafers includes one nonfunctional wafer for calibration. and the second batch of 6 wafers completes the processing.

b) Worked with both partners (Teledyne-e2v and Nhanced) to optimize processes on the first batch of CCD272s in order to improve yield and also establish yield measurements. Process optimization for bonding showed marked improvements in preventing bonded wafer survival through the steps of the process.

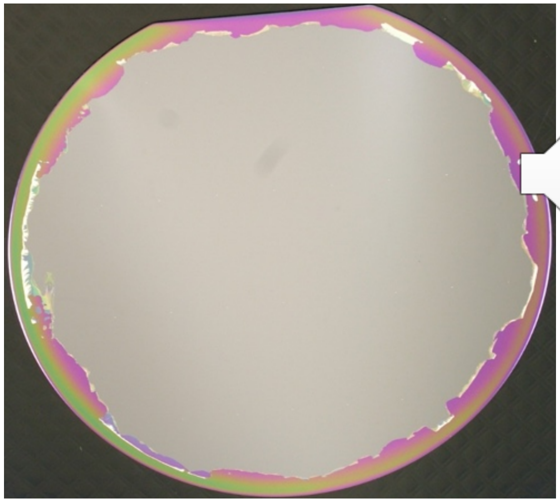
c) First batch of CCD272s are in the steps of final thinning and surface preparation at JPL. The first batch of CCD201s are at Nhanced and about to be bonded and coarse thinned.

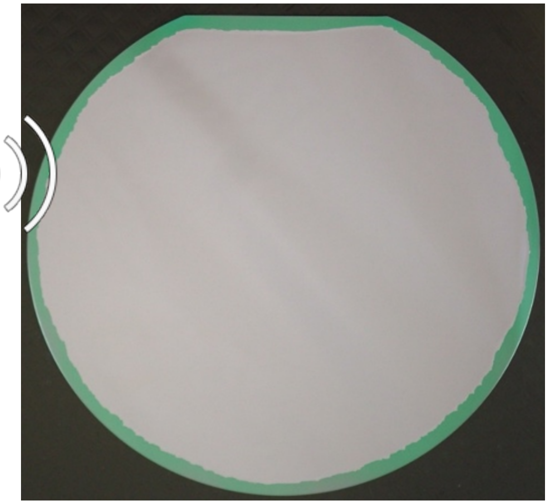
Significance: High performance, high efficiency UV/Optical CCDs that are mature and reliable in fabrication increases the chance of success in future mission proposals and missions. Large scale processes done under this task produces devices as high fidelity prototype for virtually all of delta doped Teledyne-e2v CCDs that are in the process of being baselined for a variety of Explorer mission concepts and missions. Optimization could lead to higher yield processes.

Next Steps: Complete the processing of first batch of 4 wafers of large format CCDs; ship to Teledyne for packaging and testing; process the batch of 4 EMCCD wafers. Incorporate feedback from Teledyne-e2v tests into processing last batches.

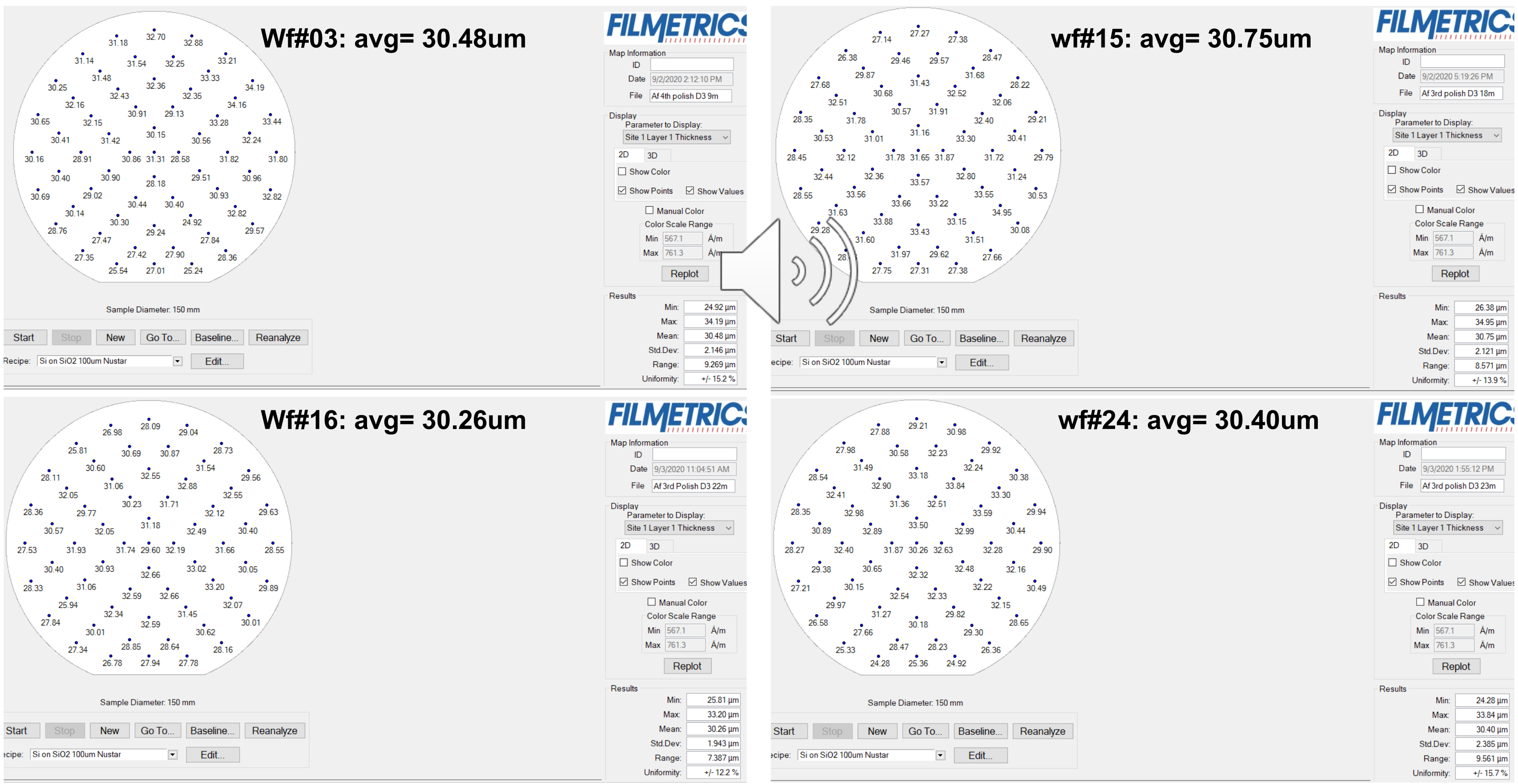
Optimization of Processes—

Bonding Integrity, bonding progress

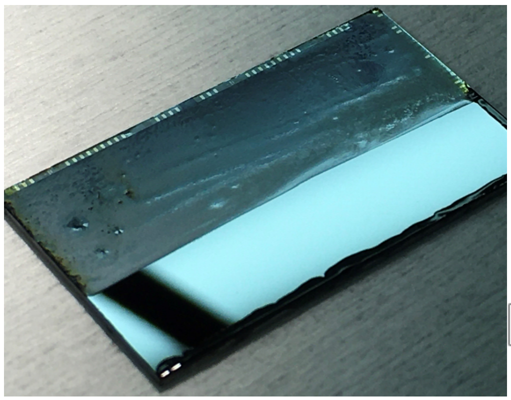


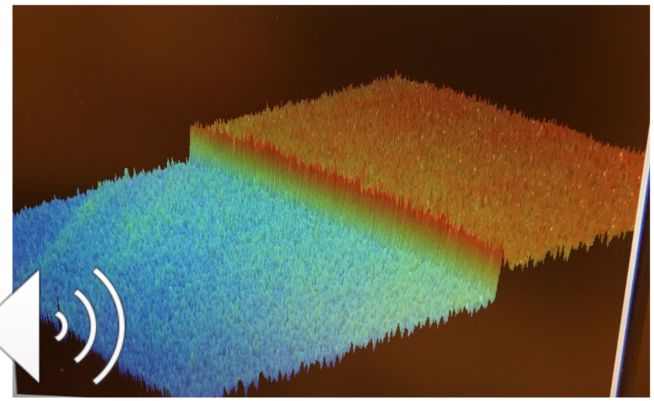


Results—Thinning the first batch of large format CCD wafers



Pre MBE (2D doping) Surface Preparation





Surface preparation for atomically clean and smooth surface is key for MBE growth of crystalline surface and 2D doping. Additional consideration in our processing of live devices is that it should be compatible with safe processing, i.e., not causing delamination or damage the live devices.

The image on the left shows a test device that was used for developing an improved cleaning and pre-MBE surface preparation process to reduce the risk of delamination in bonded and thinned wafers.

Device was patterned prior to etching the surface, approximately ~20 nm of silicon was removed from half of the detector in order to mitigate residual damage and contaminants left over from the backside thinning process.

This alternative cleaning process is gentler than the standard silicon cleaning process and significantly reduces the risk of delamination. Verification via device testing is underway.