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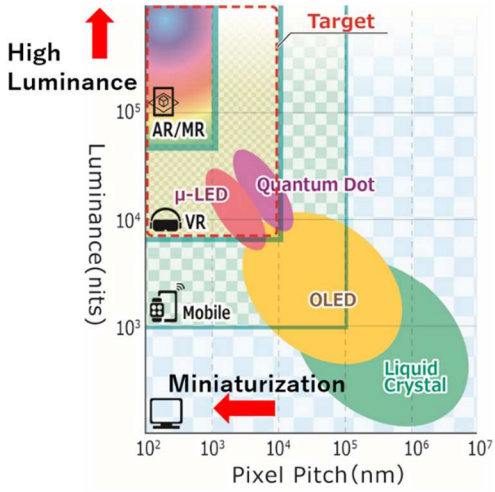
Realizing Highly Realistic and Immersive Displays for the Metaverse
Development of the World's First Monolithic GaInN-Based RGB Full-Color μLED Array via Tunnel Junctions

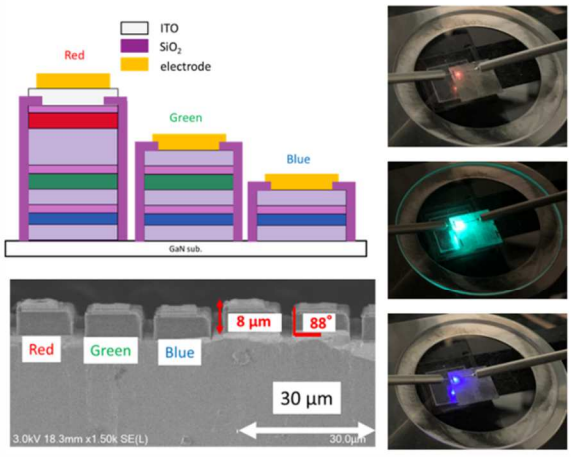
A group led by Professors Motoaki Iwaya, Tetsuya Takeuchi, and Satoshi Kamiyama from the Department of Materials Science and Engineering, Meijo University, in collaboration with Professor Kazuhiro Ohkawa from King Abdullah University of Science and Technology (KAUST), Saudi Arabia, has succeeded in developing the world's first "monolithic GaInN-based RGB full-color μLED arrays via tunnel junctions," which can be used to fabricate displays that embody the Metaverse such as VR/AR/MR with ultra-high definition and ultra-brightness. The results of this research were published on August 17th, 2023 in the international journal of the Institute of Physics, "Applied Physics Express," at DOI: https://doi.org/10.35848/1882-0786/aced7c in August 2023.

【Key Points】

- Development of monolithic full-color μLED arrays on the same substrate by stacking red, green, and blue (RGB) LEDs via tunnel junctions.
- The fabricated μLED arrays successfully emit red, green, and blue light.
- This technology is expected to provide a realistic and immersive visual experience with ultra-high



Display Trends and Targets of This Technology



Demonstrated Device Structure and Luminescence

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definition and high brightness.

【Backgrounds】

In recent years, there has been enthusiastic development of displays that embody Metaverse. Specifically, competition for developing head-mounted displays and smart glasses for VR (virtual reality), AR (augmented reality), and MR (mixed reality) is intensifying worldwide. The Metaverse has shown potential to become a standard display device in the future, with some market forecasts predicting that its market size will reach $1.5 trillion (¥210 trillion) per year by 2030.

In Metaverse, it is essential to provide a realistic and immersive visual experience, so miniaturization, high definition, and high luminance are the most important challenges. It is also said that the maximum viewing angle that humans can distinguish is 0.02 degrees. Based on this viewing angle, research and development is progressing with the goal of developing a one-pixel size of several to several tens of micrometers. As specific targets, for VR, which is supposed to be used by blocking out external light, the pixel size should be less than 10 μm square and the luminance should be more than 3000 nits, while for AR and MR, which are supposed to include external light, the pixel size should be less than several hundred nm square and the luminance should be more than several tens of thousands of nits. Recently, Apple Vision Pro and other products have been announced as display devices for VR. This display uses an OLED with a color filter system, but there are challenges in achieving both high definition and high luminance, and further improvement in performance is desired. In addition to OLED, several other technologies have been proposed, including liquid crystal and quantum dot, but there are still issues in achieving high luminance and high definition.

To solve these technological issues, the research group has been studying the application of GaInN, the material used in blue LEDs by the late Nobel laureate Professor Isamu Akasaki, which can realize RGB with a single material by controlling its chemical composition. GaInN also offers higher luminance than other technologies such as OLEDs, and can be miniaturized. This material has been expected to be used for Metaverse displays that can achieve both high luminance and high definition. However, there have been issues such as the method of connecting elements, the difficulty of fabricating red LEDs with high luminance, and the difficulty of monolithic (integrated) production.

【Research Achievements】

The group used a technique used in quantum mechanics called tunnel junctions to fabricate devices on the same substrate. The Meijo University group had been developing GaN-based tunnel junctions for many years and had been working on technological development. The KAUST group has been developing high-brightness red LEDs for many years, and their efficiency is among the highest in the world. These two groups have jointly fabricated wafers with blue, green, and red LEDs stacked via tunnel junctions on the same substrate, and by processing them into μLEDs, they have succeeded in developing the world's first "monolithic RGB full-color GaInN-based μLED array stacked via tunnel junctions".

【Future Development】

Since the luminance of μLEDs can exceed tens of thousands of nits, it is expected that ultra-high definition and ultra-bright displays for VR/AR/MR can be fabricated by miniaturizing this device. The realization of these displays is expected to lead to the realization for Metaverse displays with a high realism and immersive experience as in the real world.

【Terminology】

1) Metaverse: A virtual digital space, a virtual world where social and business activities take place that are different from those in the real world.
2) Tunnel junction: A quantum phenomenon in which electrons tunnel through a nanoscale barrier to achieve high electrical conductivity.
3) GaInN: A compound semiconductor mainly composed of gallium nitride and indium nitride, used in LED and laser devices that emit blue to green light. Recently, red LEDs are also becoming available.
4) μLEDs: LEDs with device sizes ranging from a few micrometers to several tens of micrometers.
5) Monolithic: Refers to an integrated system or device. In semiconductor devices, it often refers to integration.
6) Full-color display: A display refers to a color display technology that can reproduce a wide range of colors by combining the three colors (the three primary colors of light): red, green, and blue (RGB).

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