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Broadband image sensor array based on graphene–CMOS integration

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		Gr-QD CMOS Modulation-type read-out		Gr-QD CMOS Broadband read–out		Silicon CMOS	High performance InGaAs non-CMOS	Typical InGaAs non-CMOS	Extended InGaAs non-CMOS
Parameter	Units	standard substrate, uncooled, small pixel	optimized substrate, uncooled, small pixel	standard substrate, uncooled, small pixel	optimized substrate, uncooled, small pixel	Uncooled, Small pixel pitch, smartphone type	Cooled, Sensors unlimited Micro SWIR 640CSX,	Uncooled, large pixel size	4 stage thermo-electric cooler, large pixel size
Wavelength range	*nm*	300-2500				300-1100	700-1700	700-1700	1000-2500
Pixel pitch	*μm*	<3				<3	12.5	12.5	30
Power consumption	*[mW]*	t.b.d. (for the current 100k Pixel ROIC it was 211 mW)				400 [7]	325[8] (uncooled)-2500(packaged and cooled)[9]		$85 \cdot 10^3$
Pixel fall time	*ms*	<1				<1E-4	<1E-4	<1E-4	<1E-4
Quantum efficiency	*%*	>50				>50	>65	>65	>65
Dynamic Range	*dB*	>80				<80	68	68	68
NEI*	W/cm^2	$3 \cdot 10^{-10}$	$<2 \cdot 10^{-11}$	$2 \cdot 10^{-9}$	$<4 \cdot 10^{-10}$	$6 \cdot 10^{-10}$	$2.1 \cdot 10^{-10}$	$6 \cdot 10^{-9}$	$6.2 \cdot 10^{-9}$
Detectivity	*Jones*	$1 \cdot 10^{13}$ *	$>5 \cdot 10^{13}$ *	$6 \cdot 10^{11}$ *	$>9 \cdot 10^{12}$ *	$4 \cdot 10^{13}$	$2.8 \cdot 10^{13}$	$4 \cdot 10^{12}$	$6 \cdot 10^{10}$

Table S2 *Performance projection for an optimized Graphene quantum dot CMOS image sensor. The specific wavelength for which the values are given is 1550nm except for the silicon CMOS . We compared the performance to a state of the art Si CMOS image sensor that can be found in smartphones[10], to a non-ITAR SWIR camera that is manufactured by Sensors Unlimited[9] and to non-cooled InGaAs and cooled extended InGaAs camera pixels (Xenics Xeva 2.5). *detectivity and NEI at 60 fps, for photoconductive detectors the NEP is determined by the built-in time constant of the detectors.*

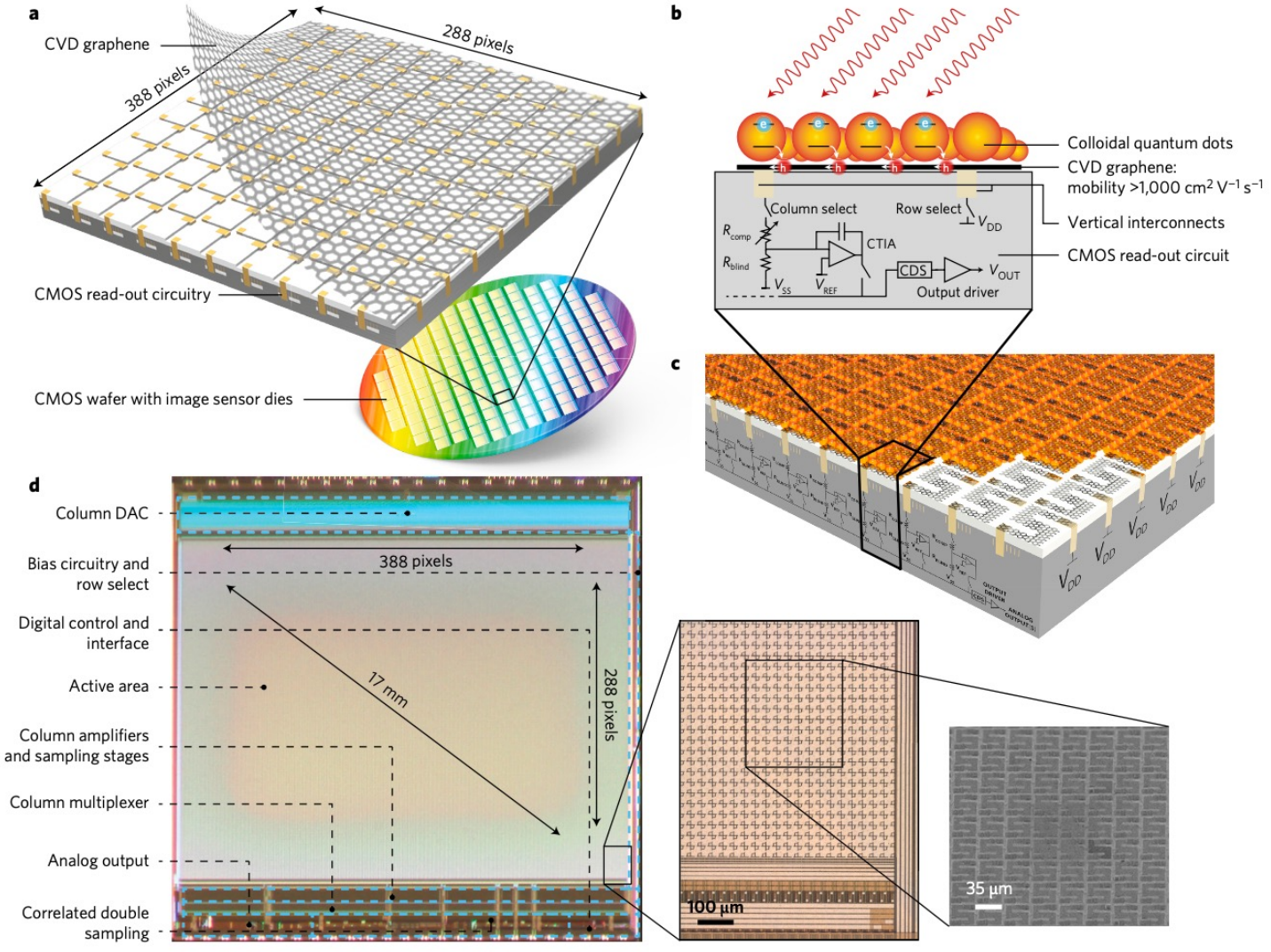

Figure 1 | Back-end-of-line CMOS integration of CVD graphene with 388 × 288 pixel image sensor read-out circuit. a, Computer-rendered impression of the CVD graphene transfer process on a single die (real dimensions 15.1 mm height, 14.3 mm width) containing an image sensor read-out circuit that consists of 388 × 288 pixels. **b**, Side view explaining the graphene photoconductor and the underlying read-out circuit. The graphene channels are sensitized to ultraviolet, visible, near-infrared and short-wave infrared light with PbS CQDs: on light absorption, an electron–hole pair is generated, due to the built-in electric field, the hole transfers to the graphene while the electron remains trapped in the CQDs. The schematic represents the CTIA-based balanced read-out scheme per column and global correlated double sampling (CDS) stage and output driver. V_{DD}, drain voltage; V_{SS}, source voltage; V_{REF}, reference voltage. **c**, 3D impression of the monolithic image sensor displaying the top level with graphene carved into S-shaped channels sensitized with a layer of quantum dots, vertical interconnects and underlying CMOS read-out circuitry. **d**, Photograph of the image sensor indicating the functionality for each area. To enhance contrast for different regions the photograph was taken before the CQDs were deposited. DAC, digital-to-analog converter. Middle: microscope image of the lower right corner of the active area of the ROIC. Right: scanning electron micrograph of the active area of the image sensor displaying the S-shaped graphene channels. Both images were taken before the CQDs were deposited.

Emberion VS20 CL | Emberion VS20 GigE | Emberion VS20 Compact

Emberion VS20 VIS-SWIR imagers of VGA resolution provide superior responsivity with very low noise over a broad spectral range from visible (400 nm) to short-wave infrared (SWIR, 2000 nm) wavelengths in room temperature operation. The dynamic range of the detectors is very large, owing to the low noise and a response that does not saturate. The Camera works at 100 fps with CL interface.

Wide, tunable spectral range covered with a single sensor array , from visible 400 nm (VIS) light to short-wave infrared 2000 nm (SWIR).

Large inherent dynamic operation range, enabling **High-Dynamic-Range (HDR)** imaging.

Cost-efficient sensor manufacturing process, providing affordable camera solutions for a wide range of imaging applications.

In house designed CMOS ROIC supporting low noise.

EMBERION CAMERA EVALUATION KIT MEETS THE FOLLOWING SPECIFICATIONS:

- Wavelength: 400 – 2000 nm
- VGA resolution: 640 x 512 pixels
- Pixel size: 20 x 20 µm
- Max Frame Rate: 100 fps
- TEC: thermo-electric temperature control
- Lens Mount type: C-mount
- +12 Vdc (power source included)
- Camera Link, one cable, SDR
- Dimension of the camera: 169 x 101 x 110 mm
- Weight of the camera: 1.5 kg
- Software: graphical PC user software
- Capable of firmware updates
- Lens can be recommended *

ARTICLE Open Access

Gold-patched graphene nano-stripes for high-responsivity and ultrafast photodetection from the visible to infrared regime

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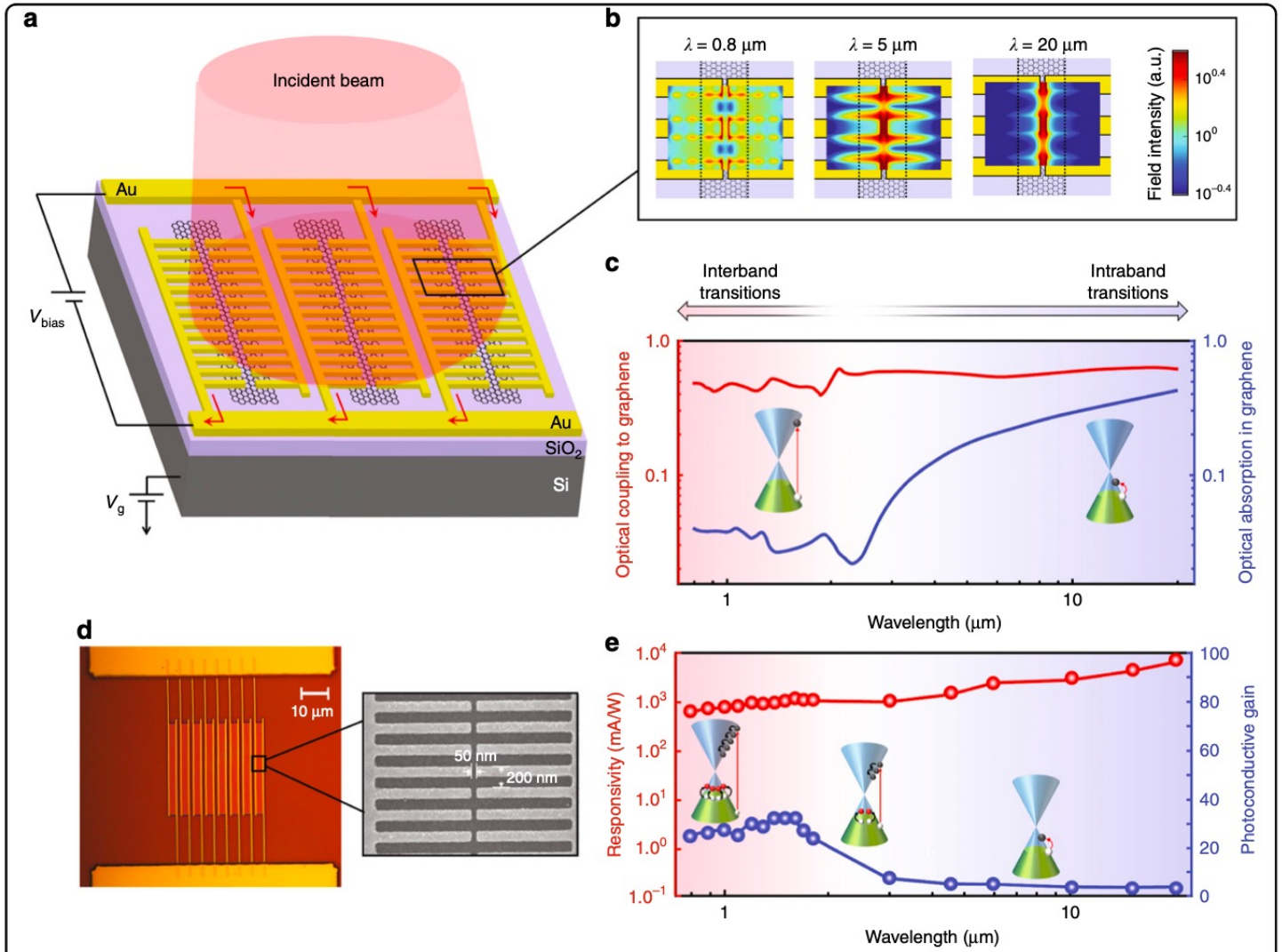

Fig. 1 High-responsivity and broadband photodetection via gold-patched graphene nano-stripes. a Schematic of a photodetector based on gold-patched graphene nano-stripes. The photodetector is fabricated on a high-resistivity Si substrate coated with a 130-nm-thick SiO_2 layer. The gate voltage applied to the Si substrate, V_g, controls the Fermi energy level of the graphene nano-stripes. The gold patches have a width of 100 nm, periodicity of 200 nm, height of 50 nm, length of 1 μm, and a tip-to-tip gap size of 50 nm. **b** Color plot of the transmitted optical field, polarized normal to the graphene nano-stripes, through the gold patches at 0.8, 5, and 20 μm, indicating highly efficient and broadband optical coupling to the graphene nano-stripes. **c** Numerical estimates for the optical coupling (red curve) and optical absorption (blue curve) in the graphene nano-stripes as a function of wavelength. **d** Optical microscope and scanning electron microscopy (SEM) images for a fabricated photodetector based on gold-patched graphene nano-stripes. **e** The measured responsivity (red data) and photoconductive gain (blue data) of the fabricated photodetector at an optical power of 2.5 μW, gate voltage of 22 V, and bias voltage of 20 mV