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# FROM CRYSTAL STRUCTURE TO PHOTORESPONSE IN CuO-BASED VISIBLE-LIGHT PHOTODETECTORS: HETEROJUNCTION DESIGN, PERFORMANCE METRICS, AND REPORTING CHALLENGES

**By**

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***Abstract***

*Copper(II) oxide (CuO) is an attractive p-type component for visible-light photodetectors, yet heterojunction performance is frequently reported under non-equivalent optical and electrical conditions. This critical narrative review examines selected experimental studies of CuO-containing devices and assesses the comparability of published responsivity, external quantum efficiency (EQE), and specific detectivity. A focused literature consultation, with source verification completed on 15 October 2026, examined seven experimental publications from 2020 to 2026 and one associated author correction. The selected architectures comprise CuO-ZnO single nanowires, interconnected arrays and decorated nanorods; $MoS_2$/CuO and $MoS_2$/CuO/Si junctions; CuO/reduced graphene oxide hybrids; and CuO-$TiO_2$/Si structures. Device geometry, excitation wavelength, applied bias and source-reported performance were compared descriptively. Published responsivity-EQE pairs were checked using their conventional physical relationship. The studies demonstrate visible or broadband photoresponse but differ substantially in test conditions. Numerical discrepancies between responsivity and EQE in two CuO-ZnO papers, and between detectivity values within another publication, require qualified interpretation. The findings support context-dependent comparisons rather than a universal performance ranking. Reproducible benchmarking requires explicit reporting of wavelength, irradiance, bias, active area, noise model and response-time criteria.*

***Keywords***: *copper(II) oxide; visible-light photodetectors; heterojunctions; responsivity; detectivity.*

## 1. Introduction

Photodetectors convert optical excitation into measurable electrical signals and are relevant to imaging, optical communication, instrumentation, and distributed sensing. Their performance is usually discussed in terms of responsivity (R), specific detectivity (D*), external quantum efficiency (EQE), dark current, photocurrent-to-dark-current ratio, and rise or recovery time. These indices are complementary rather than interchangeable: responsivity characterizes electrical signal per unit incident optical power, whereas detectivity also depends on noise assumptions and temporal response reflects carrier and device dynamics (Costas *et al*., 2020; Kumawat *et al*., 2022).

Copper(II) oxide (CuO) is generally a p-type semiconductor with a relatively narrow optical bandgap and absorption extending into the visible region. Combining CuO with n-type ZnO, layered $MoS_2$, $TiO_2$, silicon, or electrically conductive reduced graphene oxide (rGO) can modify carrier collection and recombination pathways. However, nominal composition is insufficient to establish device behavior: phase purity, junction geometry, electrode material, interfacial states, illumination conditions, and applied voltage may decisively influence observed photocurrent (Costas *et al*., 2020, 2022b; Giang *et al*., 2023; Ngo *et al*., 2024).

An isolated radial CuO-ZnO nanowire, a self-connected array contacted by interdigitated electrodes, and CuO nanoparticles decorating ZnO nanorods are not equivalent measurement systems. Even within one nominal material combination, differences in illuminated area, contact resistance, and collection distances can alter reported figures of merit. Likewise, a zero-bias response must be distinguished from enhanced photocurrent obtained under reverse or forward

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applied voltage (Costas *et al*., 2020, 2022b; Giang *et al*., 2023; Kumawat *et al*., 2022).

A further challenge is the numerical comparability of independently published results. Metrics are often extracted at different wavelengths, irradiances, and biases, and detectivity can be derived from idealized noise models rather than direct spectral-noise measurements. Published pairs of responsivity and EQE can be checked against the same physical relation, but a mismatch identifies a reporting or definitional discrepancy rather than independently invalidating an experimental trace. Mixed copper oxide phases (CuO *versus* $Cu_2O$) present an additional attribution problem (Costas *et al*., 2020, 2022b; Giang *et al*., 2023).

The objective of this review is therefore to organize source-traceable experimental evidence on CuO-containing visible-light or broadband photodetectors, describe the conditions underlying reported performance, independently check selected numerical relationships, and propose a minimum reporting framework. The review deliberately favors depth of interpretation over comprehensive bibliometric coverage or a pooled numerical ranking.

## 2. METHODOLOGY

### 2.1 Study design and research question

This study was conducted as a critical narrative literature review, combining qualitative synthesis of experimental photodetector architectures with descriptive comparison of published figures of merit. Its guiding question was: how do CuO-containing heterojunction designs and measurement conditions influence the interpretation of visible-light photoresponse? The narrative approach was appropriate because the studies employ different semiconductor partners, geometries, preparation routes, illumination regimes and electrical configurations. The review was intended to explain selected, traceable cases and their methodological implications; it was not designed to estimate the prevalence of devices across the literature or to calculate a pooled effect.

### 2.2 Information sources, consultation date and search terms

A targeted literature consultation and bibliographic verification were completed on 15 October 2026. The sources consisted of publicly available journal records and articles hosted by Scientific Reports/Nature Portfolio, RSC Publishing, Beilstein Journal of Nanotechnology and Nano Materials Science/ScienceDirect, supplemented by accessible full-text repositories when required to confirm numerical passages. Article titles and digital object identifiers (DOIs) were cross-checked against the corresponding publisher pages. This consultation was aimed at validating a focused group of experimental studies and refining the scientific comparison, rather than documenting comprehensive coverage of every CuO photodetector publication.

English-language combinations of “CuO” or “copper(II) oxide” with “photodetector”, “photodetection”, “photoresponse”, “ZnO core–shell”, “nanowire”, “nanorod”, “$MoS_2$”, “reduced graphene oxide”, “rGO” and “$TiO_2$” guided the consultation. Searches by known article title or DOI were also used to retrieve the primary texts, and the published correction to Costas *et al*. (2022b) was examined separately. The selected experimental articles appeared in journal volumes dated 2020-2026; this interval describes the temporal coverage of the articles discussed, not an exhaustive survey of the entire interval.

### 2.3 Criteria for selecting and discussing studies

Papers were prioritized when they (i) presented an experimentally fabricated CuO-containing photodetector; (ii) described an identifiable interface, heterostructure or hybrid-device geometry; (iii) evaluated photoresponse in the visible range (defined here as 400-700 nm) or over a broadband spectrum that included visible wavelengths; and (iv) reported operating conditions and at least one experimentally linked performance indicator. Measurements at 395 nm were retained solely as explicitly identified near-boundary examples and were not described as strictly visible-wavelength measurements.

Studies centered exclusively on $Cu_2O$, theoretical predictions without fabricated devices, photocatalytic responses without photodetector characterization, or reports without sufficiently identifiable operating conditions were not used in the device-level comparison. Seven experimental publications were selected intentionally to represent CuO-ZnO, $MoS_2$/CuO, CuO/rGO and CuO-$TiO_2$/Si architectures; one author correction was treated as a supporting document. Selection was relevance-based and did not yield a representative sample of all publications in the field.

### 2.4 Information extraction and narrative synthesis

Information was organized in a study-comparison matrix covering author/year, semiconductor combination, device geometry, illumination wavelength or spectral interval, applied bias, available irradiance, responsivity (R), specific detectivity (D*), external quantum efficiency (EQE), reported temporal response, and interpretive limitations. Values were drawn from the articles’ text, abstracts or published tables and accompanied by the conditions provided in those sources. When a value could not be associated unambiguously with one wavelength, device or measurement condition, that limitation was explicitly stated rather than resolved through assumptions.

The synthesis distinguished (a) results measured or reported by the original authors, (b) algebraic checks of published numerical relationships, and (c) interpretations of plausible carrier-generation and transport mechanisms. Comparisons focused on what each architecture demonstrated and which differences in electrical bias, illumination and calculation conventions limited direct benchmarking. Proposed mechanisms were described as hypotheses unless the cited work provided experimental evidence that discriminated among them (Costas *et al*., 2020; Giang *et al*., 2023; Kumawat *et al*., 2022).

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### 2.5 Numerical consistency checks and scope of analysis

For reports giving responsivity R and external quantum efficiency at the same stated wavelength, dimensional consistency was assessed using EQE = R hc/(qλ), where h is Planck's constant, c is the speed of light, q is the elementary charge, and λ is the illumination wavelength in metres. For R expressed in A $W^{-1}$ and λ in nm, the corresponding percentage is EQE (%) ≈ 124000 × R/λ. This calculation tests the mutual consistency of reported metrics under the conventional definition; it does not reproduce laboratory calibration, light-power estimation, spatial uniformity, or current traces. EQE above 100% is physically possible in detectors with internal gain and is not, by itself, evidence of error.

Specific detectivity was not recalculated across different publications because the necessary current-noise spectra, effective area, frequency bandwidth or noise assumptions were not consistently available. The shot-noise-limited expression D* = R√A/√(2qI_dark), with A representing device area and I_dark its dark current, is included only to clarify the source of some calculated detectivity estimates; it should not be confused with experimentally measured noise-equivalent power. The synthesis used no new laboratory data, statistical pooling, curve digitization or unreported measurement reconstruction. Its numerical analyses are limited to transparent unit conversions and consistency checks based on published quantities.

## 3. RESULTS AND DISCUSSION

### 3.1 Characteristics of the selected evidence

Seven experimental studies were examined, with publication years spanning 2020-2026. Three addressed CuO-ZnO configurations (a single radial nanowire, self-connected nanowire arrays and CuO-decorated ZnO nanorods), two investigated $MoS_2$/CuO-containing junctions, one assessed a two-dimensional CuO/rGO hybrid, and one described a CuO-$TiO_2$/$TiO_2$/Si architecture. An accompanying 2022 author correction was considered to clarify the status of one selected article. These groupings describe the scope of the present narrative comparison, not the distribution of architectures in the wider research literature (Costas *et al*., 2020, 2022b, 2022a; Giang *et al*., 2023; Kumawat *et al*., 2022; Ngo *et al*., 2024; Ghosh *et al*., 2024; Fayad *et al*., 2026).

### 3.2 CuO–ZnO: single nanowires, arrays, and decorated nanorods

Costas *et al*. (2020) investigated individual CuO-ZnO core-shell nanowires contacted as radial p–n junctions. Their devices responded to excitation at 405 and 520 nm. For a selected diode, the paper reports responsivities of 8.74 A $W^{-1}$ at 405 nm and 4.84 A $W^{-1}$ at 520 nm, together with EQE values of 26.56% and 11.59%, respectively. This single-element geometry helps localize the measured response to a contacted heterostructure rather than a statistical ensemble, but its active area, contacts, and current paths differ from array-scale devices.

Costas *et al*. (2022b) subsequently reported self-connected CuO-ZnO radial arrays directly integrated on interdigitated Ti/Pt electrodes. Two device configurations were associated with responsivities of 12.3 and 26.3 A $W^{-1}$ and calculated detectivities of 5.34 x $10^{13}$ and 5.85 x $10^{13}$ Jones, respectively. The authors reported EQE values of 13.34% and 38.75% at 400 nm and described optical-bandgap estimates around 1.5-1.6 eV. Their 2022 author correction revised the Acknowledgements and did not state a change to the device-performance data (Costas *et al*., 2022b, 2022a).

Giang *et al*. (2023) presented CuO nanoparticles decorating ZnO nanorods and described photoresponse at 395, 464, 532, and 640 nm. At 395 nm and an applied bias of 2 V, the study reported R = 1.38 A $W^{-1}$ and D* = 2.58 x $10^{11}$ Jones in its abstract and discussion. The same paper's comparison table instead lists D* = 4.58 x $10^{11}$ Jones for the 395 nm condition. As a result, the two published detectivity values were recorded as discordant rather than collapsed into a single corrected estimate.

### 3.3 $MoS_2$/CuO and $MoS_2$/CuO/Si junctions

Kumawat *et al*. (2022) studied a layered n-type $MoS_2$/p-type CuO junction with measurable zero-bias photoresponse. At an illumination intensity of 12.5 μW $cm^{-2}$, the article reports maximum zero-bias responsivity of 45.67 mA $W^{-1}$ (0.04567 A $W^{-1}$) and detectivity of 9.71 x $10^{11}$ Jones. Under −1 V reverse bias, the reported figures increase to 10.03 A $W^{-1}$ and 1.8 x $10^{14}$ Jones. The two operating modes are directly comparable as settings within that study but should not be merged into one bias-independent device-performance figure.

Fayad *et al*. (2026) compared n-$MoS_2$/p-CuO/n-Si and p-CuO/n-Si designs. For the dual-junction configuration at zero bias, the reported values at 625 nm were R = 21.04 mA $W^{-1}$ and D* = 1.0 x $10^{14}$ Jones; at 720 nm, the authors reported R = 30.50 mA $W^{-1}$ and D* = 1.5 x $10^{14}$ Jones. The 720 nm condition belongs to the near-infrared region rather than the 400-700 nm visible interval adopted here. At 3 V, the two respective architectures exhibited reported responsivities of 0.144 and 0.124 A $W^{-1}$, illustrating the need to retain both device identity and applied-bias condition when transferring values into a review (Fayad *et al*., 2026).

### 3.4 CuO/rGO and CuO–$TiO_2$/Si hybrid systems

Ngo *et al*. (2024) investigated a solution-processed two-dimensional CuO/rGO photodetector over 395-945 nm. The authors attributed light absorption to CuO and interelectrode carrier transport to rGO. The paper describes responsivity of approximately 8 mA $W^{-1}$ at 395 nm in its main presentation, with a maximum value of 8.8 mA $W^{-1}$ given in the conclusion. These are source-specific figures for a near-boundary excitation and do not justify ranking the hybrid against devices tested at different irradiances or biases.

Ghosh *et al*. (2024) described a CuO-$TiO_2$/$TiO_2$/p-Si(100) architecture showing a zero-bias photoresponse across approximately 300-1100 nm. The published spectral span includes ultraviolet, visible, and near-infrared light, and the source identifies the maximum response at 300 nm. Thus, the demonstrated broadband detection includes the visible interval but its peak cannot properly be described as a visible-wavelength maximum. The report is useful for illustrating

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how multiple oxide/semiconductor interfaces may support bias-free operation while requiring wavelength-resolved interpretation.

### 3.5 Comparison of source-reported figures of merit

Table 1 retains the operating conditions and principal numerical limitations of all seven primary reports. Figures extracted from different operating voltages and wavelengths are shown as separate conditional observations rather than as a pooled dataset. The 2022 correction is referenced in the row corresponding to the original CuO-ZnO array study.

**Table 1 -** Experimental CuO-containing photodetector studies included in the narrative comparison and reporting qualifications.

| Study and device | Illumination / bias | Source-reported observations | Interpretive constraint |
|---|---|---|---|
| Costas *et al*. (2020) Single CuO-ZnO nanowire | 405 and 520 nm; single radial diode | R = 8.74 A $W^{-1}$ (405 nm); 4.84 A $W^{-1}$ (520 nm). EQE = 26.56%; 11.59%, respectively. | R–EQE pairs are inconsistent under the conventional same-wavelength relation. |
| Costas *et al*. (2022b) CuO-ZnO nanowire arrays | 400 nm; self-connected arrays on interdigitated electrodes | R = 12.3 / 26.3 A $W^{-1}$; D* = 5.34 x $10^{13}$ / 5.85 x $10^{13}$ Jones; EQE = 13.34 / 38.75%. | R–EQE mismatch; linked correction (2022a) amended Acknowledgements only. |
| Giang *et al*. (2023) CuO NPs/ZnO nanorods | 395 nm; 2 V; additional tests at 464, 532, 640 nm | R = 1.38 A $W^{-1}$; D* = 2.58 x $10^{11}$ Jones (text); 4.58 x $10^{11}$ Jones (comparison table). | Two source-internal D* values; 395 nm is outside the adopted visible interval. |
| Kumawat *et al*. (2022) $MoS_2$/CuO p–n junction | Broadband; 0 V and −1 V; 12.5 μW $cm^{-2}$ | 0 V: R = 0.04567 A $W^{-1}$, D* = 9.71 x $10^{11}$ Jones. −1 V: R = 10.03 A $W^{-1}$, D* = 1.8 x $10^{14}$ Jones. | Strong voltage dependence; reported maxima are not wavelength-normalized across studies. |
| Fayad *et al*. (2026) $MoS_2$/CuO/Si | 625 nm; 0 V (dual junction); 720 nm is near-infrared | 625 nm: R = 0.02104 A $W^{-1}$, D* = 1.0 x $10^{14}$ Jones. 720 nm: R = 0.03050 A $W^{-1}$, D* = 1.5 x $10^{14}$ Jones. | Keep device identity and bias explicit; do not combine visible/NIR figures. |
| Ngo *et al*. (2024) Two-dimensional CuO/rGO | 395–945 nm; optical conditions vary by wavelength | R approximately 0.008 A $W^{-1}$ at 395 nm; maximum 0.0088 A $W^{-1}$ stated in conclusion. | 395 nm is a boundary example; source values and illumination conditions need context. |
| Ghosh *et al*. (2024) CuO-$TiO_2$/$TiO_2$/p-Si | 300–1100 nm; 0 V | Broadband zero-bias photoresponse; maximum reported at 300 nm. | Maximum occurs in the UV; no single normalized visible-range R estimate used here. |

Source: Prepared from the cited studies; reported values and methodological qualifications are retained. Abbreviations: R, responsivity; D*, specific detectivity; EQE, external quantum efficiency; NPs, nanoparticles; rGO, reduced graphene oxide. Values are presented as stated in the corresponding publications, except unit conversion from mA $W^{-1}$ to A $W^{-1}$. No rankings or pooled estimates are implied.

### 3.6 Verification of internal numerical consistency

Two separate CuO-ZnO publications reported responsivity-EQE pairs that do not agree numerically with the conventional relation at the specified wavelengths. For Costas *et al*. (2020), R = 8.74 A $W^{-1}$ at 405 nm implies EQE ≈ 2,676%, compared with the published 26.56%; R = 4.84 A $W^{-1}$ at 520 nm implies EQE ≈ 1,154%, compared with 11.59%. For Costas *et al*. (2022b), the stated R = 12.3 and 26.3 A $W^{-1}$ at 400 nm implies EQE ≈ 3,813% and 8,153%, compared with the published 13.34% and 38.75%. These are arithmetic checks of paired statements; they do not identify whether the discrepancy arose from reporting units, area or power normalization, wavelength correspondence, or another convention. The corresponding figures of merit were therefore excluded from unqualified performance rankings.

A different source-level inconsistency was found in the detectivity reported by Giang *et al*. (2023): D* = 2.58 x $10^{11}$ Jones appears in the abstract, main text and conclusion for the 395 nm measurement, whereas the article's comparative Table 1 gives 4.58 x $10^{11}$ Jones. Because the underlying current/noise calculation was not independently reproducible from the information assembled for this review, no one value was designated correct. The author correction to Costas *et al*. (2022b) did not resolve the R-EQE issue, because its stated amendment concerned the Acknowledgements (Costas *et al*., 2022a).

### 3.7 Heterojunction design and plausible charge-collection pathways

The selected reports collectively show that the role of CuO cannot be separated from the interface in which it is incorporated. Radial CuO-ZnO structures place a p-n interface around a nanowire core and may shorten some charge-separation distances, but single-wire, electrode-connected

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array, and nanoparticle-decorated geometries also differ in contact quality, network connectivity, interface coverage, and illuminated area. A greater nominal interface area does not establish superior device performance if surface traps, recombination, or series resistance are introduced (Costas *et al*., 2020, 2022b; Giang *et al*., 2023).

$MoS_2$/CuO combines a layered semiconductor with p-type CuO, offering a possible combination of depletion-region fields and planar transport. CuO/rGO places greater emphasis on a conductive carbon-assisted carrier pathway, whereas CuO-$TiO_2$/Si incorporates additional interfaces that can support broadband photovoltaic response. These explanations are consistent with the reported structures, but their relative importance remains conditional on contacts, control devices, energy-level characterization, and operating voltage. It would therefore overstate the evidence to assign one universally dominant mechanism to every CuO-based device (Kumawat *et al*., 2022; Ngo *et al*., 2024; Ghosh *et al*., 2024; Fayad *et al*., 2026).

### 3.8 Why responsivity and detectivity do not establish a universal ranking

Responsivity is defined as the photocurrent increment divided by incident optical power under specified illumination and electrical conditions. A high value can arise from photoconductive gain, longer charge-carrier lifetime, or a voltage-assisted collection regime; it does not independently determine speed, bandwidth, signal-to-noise ratio, or power efficiency. EQE is closely related to responsivity and wavelength, so these two metrics are not independent when one is derived from the other. The inconsistent R-EQE pairs in Costas *et al*. (2020, 2022b) demonstrate the value of applying basic dimensional checks before transferring published maxima into a comparative graphic.

Specific detectivity presents a related problem. A large reported D* may reflect low dark current and an assumed shot-noise-limited estimate, but actual detection limits depend on spectral noise, bandwidth, interface defects, and amplification mechanisms. The disagreement between Giang *et al*. (2023) abstract/body and comparison-table values is a source-level reporting issue, whereas between-study differences in D* may arise even when each author's own calculation is internally coherent. A methodologically meaningful comparison requires the same or explicitly adjusted wavelength, irradiance, bias, effective area, noise model, and measurement bandwidth.

### 3.9 Applied bias, spectral range, and time response

The comparison within Kumawat *et al*. (2022) is especially instructive because the same nominal structure demonstrates substantially different figures of merit at 0 V and −1 V. Fayad *et al*. (2026) likewise document separate architectures and applied-bias regimes. A device should only be described as self-powered in relation to the zero-applied-bias measurement itself; performances obtained with an external power supply must not be presented as if they characterized the unbiased operating mode. "Self-powered" also does not imply zero energy expenditure for the measurement instrumentation.

Spectral boundaries require comparable care. For this review the operational visible window was 400-700 nm. Results at 395 nm, frequently called violet illumination in device papers, are preserved as an explicitly marked boundary condition rather than counted as strictly visible-range evidence. Wavelengths of 720, 808, 850, or 945 nm fall outside that operational window, while a response maximum at 300 nm is ultraviolet. Thus, broad spectral coverage does not necessarily imply uniform performance throughout the visible band (Giang *et al*., 2023; Ngo *et al*., 2024; Ghosh *et al*., 2024; Fayad *et al*., 2026).

Transient response introduces an additional comparability issue. Rise and recovery times can be defined using different thresholds (for example 10-90% or 63% criteria), recording rates, and illumination duty cycles. Because those conventions and measurement settings are not matched across the selected studies, the temporal figures should be treated as conditional characteristics of each experiment rather than used in an aggregate speed ranking (Costas *et al*., 2022b; Giang *et al*., 2023; Fayad *et al*., 2026).

### 3.10 Reporting priorities and implications for future research

A reproducible device report should connect every figure of merit to an identifiable sample composition, crystal phase, fabrication route, architecture, contact design, and device area. The optical record should specify wavelength or spectrum, source bandwidth, irradiance, total incident power, illumination footprint, and the location of the active area. The electrical record should state bias magnitude and polarity, dark and illuminated currents, measurement bandwidth, noise-model assumptions, and whether detectivity was calculated or measured from a noise spectrum. Formulas and units for R, D*, and EQE should be provided beside the values, not only in an unrelated methods paragraph. The minimum set of reporting items proposed from this narrative synthesis is summarized in Table 2.

For dynamics and reliability, studies should report the response-time threshold convention, acquisition rate, repeat cycles, specimen-to-specimen variability, and uncertainty. Material-phase characterization is also essential: monoclinic CuO cannot automatically be inferred from a generic "copper oxide" label, and the possible presence of $Cu_2O$ or interfacial oxides should be evaluated with phase-sensitive measurements. These priorities follow from the measurement dependencies illustrated in the analyzed reports and should be treated as methodological recommendations rather than an empirically validated consensus checklist (Costas *et al*., 2020, 2022b; Giang *et al*., 2023; Ghosh *et al*., 2024).

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**Table 2.** Proposed minimum reporting framework for CuO photodetector studies (author synthesis).

| Reporting domain | Minimum information to report | Why it matters |
|---|---|---|
| Material and device | CuO/$Cu_2O$ phase evidence, geometry, contacts, effective area | Prevents attributing mixed-phase or contact effects solely to CuO |
| Optical excitation | Wavelength or spectrum, bandwidth, irradiance and incident power | Distinguishes visible results from UV/NIR peaks and power effects |
| Electrical conditions | Bias magnitude/polarity, dark current and illuminated current | Separates photovoltaic operation from externally biased gain |
| Calculated figures of merit | Equations, normalization area, units, noise model and bandwidth | Makes R, EQE and D* arithmetically and physically interpretable |
| Dynamics and variability | Rise/decay definitions, sampling conditions, replicate devices and spread | Enables meaningful comparison of speed and repeatability |

Source: Author synthesis based on the reviewed literature. This framework is an interpretive recommendation derived from the present narrative synthesis; it is not an experimentally validated standard.

### 3.11 Scope and limitations of this narrative review

This narrative review draws on seven deliberately selected experimental reports and therefore does not represent the entire CuO photodetector literature. It does not establish the frequency of individual device designs, the rate of publication growth, or a pooled estimate of responsivity or detectivity. Moreover, several quantities were available only as published summaries rather than as original photocurrent curves, calibration records or measured noise spectra. The analytical checks identify numerical relationships that warrant clarification, but they cannot determine the underlying experimental causes or independently replicate device behavior.

The contribution of this synthesis lies in treating device geometry and operating conditions as inseparable from the interpretation of performance metrics, while explicitly distinguishing reported data from calculations and mechanistic inference. Its conclusions should be viewed as a focused assessment of representative architectures rather than a definitive comparison of all CuO-based photodetectors. Future narrative or integrative reviews could broaden material systems and source coverage, provided that each reported metric remains linked to its experimental conditions and measurement definitions.

## 4. CONCLUSION

The available experimental literature demonstrates visible or broadband photoresponse in several CuO-containing photodetector architectures, including radial CuO-ZnO nanowires and arrays, decorated ZnO nanorods, $MoS_2$/CuO junctions, CuO/rGO hybrids, and CuO-$TiO_2$/Si devices. These studies support a physically plausible contribution from interfaces, transport pathways, and external bias; they do not establish one universally superior CuO platform. The review's device-level synthesis further indicates that comparisons based only on the largest responsivity or detectivity values obscure important differences in illumination conditions, electrical regime, device area, and noise assumptions.

A distinct contribution of this review is the identification and explicit reporting of source-internal numerical discrepancies: conventional responsivity-EQE conversions do not reproduce selected published pairs in two Costas studies, and conflicting detectivity values occur within the Giang study. These discrepancies call for documentary or experimental clarification, not retrospective alteration of primary results. The most defensible path to reliable benchmarking is standardized, condition-specific reporting of device structure, spectrum, bias, irradiance, area, noise, and temporal-response definitions, followed by comparisons restricted to compatible operating conditions.

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