

Table S1

Table S1. Overview of the organization and key contents of this review.

Major topic		Scope and key focus
Basic introduction of ultrasound-induced luminescence		Advantages, development history, and conceptual basis of ultrasound-induced luminescence
Paradigms and mechanisms of ultrasound-induced luminescence		Instant ultrasound-induced luminescence, sonoafterglow luminescence, Off-On switching luminescence and their energy-conversion mechanisms
Molecular design in available materials for ultrasound-induced luminescence		Inorganic, organic, and hybrid systems across instant ultrasound-induced luminescence, sonoafterglow luminescence, and Off-On switching luminescence
Luminescent enhancement (structure–property relationships for energy pathways)	performance strategies for energy	Four key steps in the energy-conversion pathway: (Stage 1) the excitation input stage, (Stage 2) the energy capture stage, (Stage 3) the energy transfer and transformation stage, and (Stage 4) the emission stage where radiative and nonradiative pathways compete
Biological optimization	performance	Biocompatibility, stability, targeting, and metabolism
Biomedical applications in various disease models		Tumor microenvironment, immune system, nervous system, and other biomedical regions
Challenges and perspectives		Fundamental bottlenecks, unresolved controversies, practical limitations, translational barriers and clinical readiness, and future directions for advanced probes and precision theranostics

Table S2

Table S2. Comparative performance matrix of representative system directions relevant to ultrasound-induced luminescence.

Representative system	λ_{em} (nm)	US	Penetration depth		Half-life SN (life/dur R ation)	s.c.	i.v.		Imaging and therapeutic efficacy	Re f.	
			Through tissue	<i>In vivo</i> (model)			Intensity per mass concentratio n	SBR Intensity per dose per mouse			
mSZ-Clr@ePDA NP (SrAl ₂ O ₄ :Eu ²⁺ /ZnGa ₂ O ₄ :Cr ³⁺ nanodots)	700	1M Hz, 2 W cm ⁻²	N.A.	N.A.	N.A. N. (life≈ 4 A. h)	N.A.	N.A	N.A.	N.A.	US-propelled motion & afterglow for precise imaging and efficient eradication of <i>H. pylori</i>	20 22
NCBS/DPAs SNAP	780	1M Hz, 2 W cm ⁻²	4 cm	N.A.	110 s N. A.	2.3×10 ⁵ (p/s/cm ² /sr)/(μg/mL)	225 (Bal b/c mic e)	1.1×10 ⁴ (p/s/cm ² /s r)/μg	114 c [Note]	Modular sonoafterglow for deep-tissue background- free <i>in vivo</i> optical imaging	20 22
NCBS/AMPA SNAP	500	1M Hz, 2 W cm ⁻²	N.A.	N.A.	75 s N. A.	9.5×10 ⁵ (p/s/cm ² /sr)/(μg/mL)	946 (Bal b/c mic e)	N.A.	N.A.		
Q SNAP (NCBS/DPAs)	780	1M Hz, 1.5 W cm ⁻²	4 cm		≈ 1.5 N. min A. (life>5 min)	N.A.	N.A	N.A.	58.3 (Balb/ c mice) [SBR]	Activatable sonoafterglow nanoprobes for T-cell imaging	20 23
PNCL (PpIX/phenoxy-dioxetane precursor containing a dicyanomethyl chromone acceptor scaffold)	710	1M Hz, 1.5 W cm ⁻²	20 mm	4T1	N.A. N. (life>25 A. 0 min) (i.t.)	28 (p/s/cm ² /sr)/ μM (i.t.)	N.A	N.A.	N.A.	US-activated NIR chemiluminesce nce for deep tissue and tumor foci imaging	20 23
Janus mSZ@PDA-NO NPs	696	1M Hz, 2 W cm ⁻²	N.A.	N.A.	N.A. N. (life≈ 4 A. h)	N.A.	N.A	N.A.	N.A.	US-chargeable persistent luminescence for self-	20 23

											propelled photothermal/N O Therapy		
Lipo@IR780/L012	470	FUS (1.5 MH z, puls 100 ms on, 900 ms off, 1 Hz, 2.2 MPa)	10 mm	Motor cortex After i.v.	N.A.	N. A.	N.A.	N.A .	N.A.	N.A.	US-triggered <i>in situ</i> photon emission for noninvasive optogenetics	20 23	
Lipo@IR780/L012/CaO ₂	470	FUS (1.5 MH z, 1.55 MPa , puls e 100 on 900 ms off)	10 mm	Superficial motor cortex and deep ventral tegmental area after intracrania l injection	N.A.	N. A.	N.A.	N.A .	N.A.	N.A.	Minimally invasive deep brain stimulation for behavioral control in animals <i>via</i> a flexible, mechanolumine scent sono- optogenetic system	20 23	
TD NPs	625– 650	1M Hz, 2 W cm ⁻²	2.2 cm	N.A.	180 s (life>7 h)	20 6 <i>in vivo</i>	N.A.	N.A .	N.A.	N.A.	Advance in energy- conversion for sonoafterglow imaging	20 24	
DPA-H ₂ S	710	1M Hz, 1.5 Wc m ⁻²	20 mm	MET- induced liver injury	3.2 min (life 6 min)	N. A.	N.A.	N.A .	N.A.	4.5 (Balb/ c-nude mice) [SBR]	Dual-locked probe with activatable sonoafterglow for precise imaging of liver injury	20 24	

NPs-Ce4-SN	~1100	2.5 W cm ⁻²	2 cm	subcutaneous MC38 tumor model	≈ 10 s	N.A.	N.A.	N.A.	N.A.	N.A.	NIR-II sonoafterglow for precise cancer imaging	20 24
BTB-OC9/BDTSe	727	50 kHz, 5.6 W cm ⁻²	3 mm	N.A.	N.A. (life ≈ 174.83ms)	N.A.	9.15 ± 1.32 × 10 ⁴ p s ⁻¹ cm ⁻² sr ⁻¹	24	N.A.	N.A.	N.A.	20 24
FURIN (Zn ₂ Ga _{2.96} Ge _{0.75} O ₈ :Cr _{0.02} ,Nd _{0.02} /MSN)	694, 883, 1062, 1335	Pre- char ged by (five repetit ions of LED and FUS)	N.A.	Footpad of the right forelimb	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	FUS-responsive persistent mechanoluminescence for spatiotemporal immune activation control in lymph nodes	20 24
FUSION (Zn _{1.2} Ga _{1.6} Sn _{0.2} O ₄ :0.5%Cr ³⁺ /MSN/R848/DPPC)	694	Pre- char ged by 635nm light + pulsed FUS (1 MHz, 34.1 W cm ⁻²)	N.A.	4T1	N.A.	8.5 (first M L) 0.2 (after 20 times FU S) (i.v .)	N.A.	N.A.	N.A.	N.A.	FUS-responsive persistent mechanoluminescence for reporting the effectiveness of macrophage regulation	20 24

CSAPs (HMME/ MACF)	≈ 700	30 kHz, 2 Wc m ⁻² (<i>in vivo</i> after subcuta neous injection)	1.8 cm	Glioblastoma	8 min (life≈ 30 min)	N.A.	N.A.	24.1 1	N.A.	N.A.	Intratumoral bacterial- targeted cascade- responsive sonoafterglow nanoprobes for immune reprogramming and visualization in glioblastoma	20 25
SPNs (SP1) @CoOOH	570- 650	1 MH z, 0.7- 1 W cm ⁻² (<i>in vitro</i>) 2.2 W cm ⁻² (<i>in vivo</i>)	1.2 cm	4T1	N.A. 1 min (imaging) 10 min (therapy)	N.A.	N.A.	N.A. .	N.A.	N.A.	CoOOH universal approach for enhanced SDT efficiency and ultrasound- activated luminescence	20 25
ncRuPA _{APN}	560 640	1 MH z, 2 Wc m ⁻²	N.A.	4T1	5 s	N.A.	N.A.	N.A. .	≈ 1600 (p/s/cm ² /s r)/μM	2.7 (Balb/ c mice) (i.t.)	Sonoafterglow luminophore with a nonconjugated linker for tumor-specific Theranostics	20 26
FZ970 (ZnPc/FZA)	970	1 MH z, 1.6 W cm ⁻²	4 cm	N.A.	≈ 150 s	N.A.	N.A.	N.A. .	N.A.	N.A.	Ultrasound/peroxynitrite- synergized NIR-II afterglow- guided SDT	20 26
TCL NPs (TTQ/ CL-COOCH ₃ /DHF)	N.A.	1 MH z, 1.5 W cm ⁻²	2 cm	CT26	N.A. (life>27 min <i>in vivo</i>)	11 80 (peak at 3	N.A.	N.A. .	N.A.	N.A.	High-Contrast Imaging and Synergistic Gas-SDT of Hypoxic Tumors	20 26

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3SCe-NP	710	20 Hz, 1.5 W cm ⁻²	7 cm	subcutaneo us colon, orthotopic tumor (colon/ breast/pan creatic/ lung/gliom a) tumor, peritoneal metastasis, lymph nodes	≈ 40 min	N. A.	N.A.	330	N.A.	27-39 (perito neal metast asis) (SBR)	A self- activating cyclic amplification NIR sonoafterglow probe for high- contrast imaging <i>in vivo</i>	20 26
PpIX-M (PpIX/TPP ⁺)	600– 700	1 MH z, 1.5 W cm ⁻²	N.A.	N.A.	N.A. (life>20 min <i>in</i> <i>vivo</i>)	N. A.	≈266 (p/s/cm ² /sr)/(μg/mL)	48.6 (nud e mic e)	N.A.	N.A.	Sonofterglow- guided SDT	20 26
FTA NPs	600- 710	1 MH z, 2.2 W cm ⁻²	5 cm	Pancreatic tumor model	N.A. (life>15 min)	N. A.	N.A.	N.A. .	N.A.	N.A.	Fractionated ultra-bright sonofterglow endoperoxide SDT	20 26

Abbreviations: λ_{em}, emission wavelength; s.c., subcutaneous injection; i.v., intravenous injection; CNDs, carbon nanodots; FUS, focused ultrasound; SDT, sonodynamic therapy; NIR-II, near-infrared-II.

[Note] Balb/c mice have higher background (~5×10³ p/s/cm²/sr) than nude mice (~2×10³ p/s/cm²/sr).