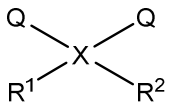
CLAIMS

1. A compound according to formula (3):



(3)

where:

R^1 and R^2 are independently selected from a hydrogen atom, $(C_1–C_{40})$hydrocarbyl and, optionally, R^1 and R^2 are connected to form a ring having from 3 to 50 atoms in the ring, excluding hydrogen atoms;

X is Si, Ge, Sn, or Pb; and

each Q is independently $Ar^1–Y^1–R^3–$ or $Ar^2–Y^2–R^4–$, where:

R^3 and R^4 are independently selected from $–(CR^C_2)_m–$, where m is 1 or 2, and where each R^C is independently selected from the group consisting of $(C_1–C_{40})$hydrocarbyl, $(C_1–C_{40})$heterohydrocarbyl, and –H;

Y^1 and Y^2 are independently S, Se, or Te;

Ar^1 and Ar^2 are independently $(C_6–C_{50})$aryl; and

$Ar^1–Y^1–R^3–$ and $Ar^2–Y^2–R^4–$ are not identical.

2. The compound of claim 1, wherein Y^1 and Y^2 are Se, or wherein Y^1 and Y^2 are S.~~.~~

~~3. The compound of claim 1, wherein Y^1 and Y^2 are S.~~

~~4.~~3. The compound of ~~any one of claims 1 to 3~~claim 2, wherein R^3 and R^4 are $–CH_2–$, or wherein R^3 and R^4 are $–CH_2CH_2–$.~~.~~

~~5. The compound of any one of claims 1 to 3, wherein R^3 and R^4 are $–CH_2CH_2–$.~~

~~6.~~4. The compound of any of claims 1 to 3~~any one of the preceding claims~~, wherein Ar^1 and Ar^2 are independently selected from the group consisting of phenyl, 2-methylphenyl, 3-methylphenyl, and 4-methylphenyl.

~~7. The compound of any one of the preceding claims, wherein Ar^1 and Ar^2 are phenyl.~~

~~8.~~5. The compound of any of claims 1 to 3~~any one of the preceding claims~~, wherein X is Si.

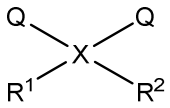
~~9.~~6. The compound of any of claims 1 to 3~~any one of the preceding claims~~, wherein R^1 and R^2 are independently $(C_1–C_{12})$alkyl.

~~10.~~7. The compound of any of claims 1 to 3~~any one of the preceding claims~~, wherein each Q is $Ar^1–Y^1–R^3–$ and~~-~~ wherein each Q is identical.~~is identical.~~

~~11.~~8. The compound of claim 1, wherein each Q is $Ar^1–Y^1–R^3–$, where R^3 is $–CH_2–$, Y^1 is S, and Ar^1 is 4-methylphenyl.

~~12.~~9. A method for providing a heteroatom-bridge precursor from a compound according to formula (3), the method comprising:

reacting, at from 90 °C to 150 °C, at least one alkyl halide, an alkali-metal halide, and a compound according to formula (3):



(3)

where:

R^1 and R^2 are independently selected from a hydrogen atom, $(C_1–C_{40})$hydrocarbyl and, optionally, R^1 and R^2 are connected to form a ring having from 3 to 50 atoms in the ring, excluding hydrogen atoms;

X is Si, Ge, Sn, or Pb;

each Q is independently $Ar^1–Y^1–R^3–$ or $Ar^2–Y^2–R^4–$;

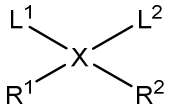
R^3 and R^4 are independently selected from $–(CR^C_2)_m–$, where m is 1 or 2, and where each R^C is independently selected from $(C_1–C_{40})$hydrocarbyl, $(C_1–C_{40})$heterohydrocarbyl, or –H;

Y^1 and Y^2 are independently S, Se, or Te;

Ar^1 and Ar^2 are independently $(C_6–C_{50})$aryl; and

$Ar^1–Y^1–R^3–$ and $Ar^2–Y^2–R^4–$ are not identical,

to provide a heteroatom-bridge precursor having formula (1):



(1)

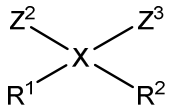
where:

R^1, R^2, and X are as defined in formula (3); and

L^1 and L^2 are independently $-R^3-Z^1$ or $-R^4-Z^1$, where R^3 and R^4 are as defined in formula (3), and where each Z^1 is independently selected from Cl, Br, and I.

~~13.~~10. The method of claim ~~12~~9, further comprising preparing the compound of formula (3), wherein preparing the compound of formula (3) comprises:

reacting, at from 0 °C to 5 °C, a compound having formula (2)



(2)

where:

X, R^1, and R^2 are as defined in formula (3), and

Z^2 and Z^3 are independently selected from Cl, Br, I, and triflate,

with a single lithium compound having the formula Q^1-Li where Q^1 is $Ar^1-Y^1-R^3-$ as defined in formula (3), or with a first lithium compound having the formula Q^1-Li where Q^1 is $Ar^1-Y^1-R^3-$ as defined in formula (3) and a second lithium compound having the formula Q^2-Li where Q^2 is $Ar^2-Y^2-R^4-$ as defined in formula (3), to provide the compound of formula (3).

~~14.~~11. The method of claim ~~13~~10, wherein reacting the compound having formula (2) with the at least lithium compound comprises reacting the compound having formula (2) with the single lithium compound having the formula Q^1-Li, whereby both L^1 and L^2 of the heteroatom-bridge precursor having formula (1) are $-R^3-Z^1$ and are identical.

~~15. The method of claim 14, wherein R^3 in all instances is $-CH_2-$.~~

~~16. The method of claim 14, wherein R^3 in all instances is $-CH_2CH_2-$.~~

12.~~17.~~ The method of claim ~~14~~10, wherein:

Z^2 and Z^3 of formula (2) are Cl;

Y^1 in all instances is S;

R^3 in all instances is $-CH_2-$; and

Ar^1 in all instances is 4-methylphenyl.

~~18.~~13. The method of claim ~~13~~10, wherein reacting the compound having formula (2) with the at least one lithium compound comprises reacting the compound having formula (2) with a compound having the formula $Ar^1-Y^1-R^3-Li$ and a compound having the formula $Ar^2-Y^2-R^4-Li$, whereby L^1 and L^2 of the heteroatom-bridge having formula (1) are not identical.

~~19. The method of any one of claims 12 to 18, wherein Z^2 and Z^3 of formula (2) are Cl.~~

~~20. The method of any one of claims 12 to 19, wherein Y^1 and Y^2 in all instances are S.~~

~~21. The method any one of claims 12 to 20, wherein Ar^1 and Ar^2 are independently selected from the group consisting of phenyl, 2-methylphenyl, 3-methylphenyl, and 4-methylphenyl.~~

~~22. The method of any one of claims 12 to 21, wherein Ar^1 and Ar^2 in all instances are phenyl.~~

~~23. The method of any one of claims 12 to 22, wherein X is Si or Ge.~~

~~24. The method of any one of claims 12 to 23, where R^1 and R^2 are independently (C_1–C_{12})alkyl.~~

~~25.~~14. The method of any one of claims ~~12~~ 9 to ~~24~~13, further comprising either:

preparing the single lithium compound Q^1-Li by:

reacting, at from 0 °C to 25 °C, an alkyl lithium compound with a compound having a formula $Ar^1-Y^1-R^3-H$ to provide the single lithium compound Q^1-Li; or

preparing the first lithium compound Q^1-Li, the second lithium compound Q^2-Li, or both, by performing at least one of:

reacting, at from 0 °C to 25 °C, an alkyl lithium compound with a compound having a formula $Ar^1-Y^1-R^3-H$ to provide the first lithium compound Q^1-Li; and

reacting, at from 0 °C to 25 °C, an alkyl lithium compound with a compound having a formula $Ar^2–Y^2–R^4–H$ to provide the first lithium compound $Q^2–Li$.

~~26.~~15. The method of any one of claims ~~12~~ 9 to ~~25~~13, wherein:

the at least one alkyl halide comprises $HR^3–h$, $HR^4–h$, or a combination thereof, where R^3 and R^4 are as defined in formulas (1) and (3), and where h is a halogen chosen from Cl, Br, or I; and

the alkali-metal halide comprises $Z^1–Li$, where Z^1 is as defined in formula (1).