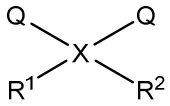
CLAIMS

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 2, wherein R^3 and R^4 are $–CH_2–$, or wherein R^3 and R^4 are $–CH_2CH_2–$.

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

5. The compound of any of claims 1 to 3, wherein X is Si.

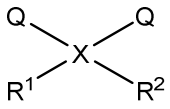
6. The compound of any of claims 1 to 3, wherein R^1 and R^2 are independently $(C_1–C_{12})$alkyl.

7. The compound of any of claims 1 to 3, wherein each Q is $Ar^1–Y^1–R^3–$ and wherein each Q is identical.

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.

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 $Ar^2–Y^2–R^4–$;

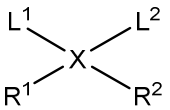
R^3 and R^4 are independently selected from $–(CR^C_2)_m–$, where m is 1 or 2, and where each R^C is independently selected from $(C_1–C_{40})$hydrocarbyl, $(C_1–C_{40})$heterohydrocarbyl, or –H;

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)

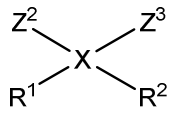
where:

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.

10. The method of claim 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).

11. The method of claim 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.

12. The method of claim 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.

13. The method of claim 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.

14. The method of any one of claims 9 to 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 $Q^2–Li$.

15. The method of any one of claims 9 to 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).