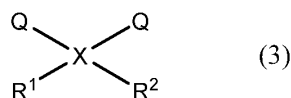


CLAIMS

1. A compound according to formula (3):



where:

R^1 and R^2 are independently selected from a hydrogen atom, $(\text{C}_1\text{--C}_{40})$ 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 $\text{Ar}^1\text{--Y}^1\text{--R}^3\text{--}$ or $\text{Ar}^2\text{--Y}^2\text{--R}^4\text{--}$, where:

R^3 and R^4 are independently selected from $\text{--}(\text{CR}^{\text{C}}_2)_m\text{--}$, where m is 1 or 2, and where each R^{C} is independently selected from the group consisting of $(\text{C}_1\text{--C}_{40})$ hydrocarbyl, $(\text{C}_1\text{--C}_{40})$ heterohydrocarbyl, and --H ;

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

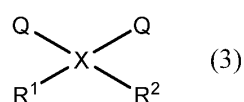
Ar^1 and Ar^2 are independently $(\text{C}_6\text{--C}_{50})$ aryl; and

$\text{Ar}^1\text{--Y}^1\text{--R}^3\text{--}$ and $\text{Ar}^2\text{--Y}^2\text{--R}^4\text{--}$ are not identical.

2. The compound of claim 1, wherein Y^1 and Y^2 are Se.
3. The compound of claim 1, wherein Y^1 and Y^2 are S.
4. The compound of any one of claims 1 to 3, wherein R^3 and R^4 are $\text{--CH}_2\text{--}$.
5. The compound of any one of claims 1 to 3, wherein R^3 and R^4 are $\text{--CH}_2\text{CH}_2\text{--}$.
6. The compound of 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. The compound of any one of the preceding claims, wherein X is Si.

9. The compound of any one of the preceding claims, wherein R^1 and R^2 are independently (C_1-C_{12}) alkyl.
10. The compound of any one of the preceding claims, wherein each Q is $Ar^1-Y^1-R^3-$ and is identical.
11. 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. 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):



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 $Ar^2-Y^2-R^4-$;

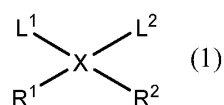
R^3 and R^4 are independently selected from $-(CR^C)_m-$, where m is 1 or 2, and where each R^C is independently selected from (C_1-C_{40}) hydrocarbyl, (C_1-C_{40}) heterohydrocarbyl, or $-H$;

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):



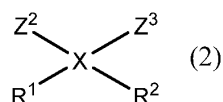
where:

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

L^1 and L^2 are independently $-\text{R}^3-\text{Z}^1$ or $-\text{R}^4-\text{Z}^1$, 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. The method of claim 12, 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)



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

14. The method of claim 13, 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 $-\text{R}^3-\text{Z}^1$ and are identical.

15. The method of claim 14, wherein R^3 in all instances is $-\text{CH}_2-$.

16. The method of claim 14, wherein R^3 in all instances is $-\text{CH}_2\text{CH}_2-$.

17. The method of claim 14, wherein:
- Z^2 and Z^3 of formula (2) are Cl;
- Y^1 in all instances is S;
- R^3 in all instances is $-\text{CH}_2-$; and
- Ar^1 in all instances is 4-methylphenyl.
18. The method of claim 13, 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 $\text{Ar}^1-\text{Y}^1-\text{R}^3-\text{Li}$ and a compound having the formula $\text{Ar}^2-\text{Y}^2-\text{R}^4-\text{Li}$, 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 $(\text{C}_1-\text{C}_{12})\text{alkyl}$.
25. The method of any one of claims 12 to 24, 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 $\text{Ar}^1-\text{Y}^1-\text{R}^3-\text{H}$ 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 $\text{Ar}^1\text{-Y}^1\text{-R}^3\text{-H}$ to provide the first lithium compound $\text{Q}^1\text{-Li}$; and

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

26. The method of any one of claims 12 to 25, wherein:

the at least one alkyl halide comprises $\text{HR}^3\text{-h}$, $\text{HR}^4\text{-h}$, 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 $\text{Z}^1\text{-Li}$, where Z^1 is as defined in formula (1).