Figure S1: FTIR of SiO2 nanoparticles

**Si-O-Si**

**Si-O-Si**

**Si-O-H**

**O-H**

**O-H**

**Si-O-Si**



| Element | Atomic % | Atomic % Error | Weight % | Weight % Error |
| --- | --- | --- | --- | --- |
| O | 64.2 | 0.4 | 50.5 | 0.3 |
| Si | 35.8 | 0.1 | 49.5 | 0.2 |

 Figure S2: EDX of SiO2 nanoparticles



**Si-O-Si**

**Si-O-Si**

**Si-O-Si**

**-CH2**

**C=C**

**C=O**

**-CH2**

**O-H**

**Si-O-Si**

Figure S3: FTIR of SiO2 MPS nanoparticles



| Element | Atomic % | Atomic % Error | Weight % | Weight % Error |
| --- | --- | --- | --- | --- |
| C | 27.0 | 0.6 | 19.3 | 0.5 |
| O | 50.6 | 0.5 | 48.1 | 0.5 |
| Si | 22.4 | 0.1 | 32.6 | 0.1 |

Figure S4: EDX of MPS nanoparticles

|  |  |
| --- | --- |
|  |  |
|  |  |



**Si-O-Si**

**Si-O-Si**

C=C

C=O

C=O

C-H

exocyclic **O-H**

**Si-O-Si**

Figure S5: FTIR of STEM extract

Figure S5: FTIR of STEM extract



**Si-O-Si**

**Si-O-C**

**C-S**

**C-N**

**C-H**

**Si-O-C**

**C=C**

**C=O**

**C-H**

**O-H**

**Si-O-Si**

Figure S6: FTIR of STEM extract@SiO2 MPS nanoparticles

 Figure S6: FTIR of STEM extract@SiO2 MPS nanoparticles



| Element | Atomic % | Atomic % Error | Weight % | Weight % Error |
| --- | --- | --- | --- | --- |
| C | 26.8 | 0.6 | 19.0 | 0.4 |
| N | 5.1 | 0.9 | 4.2 | 0.7 |
| O | 50.6 | 0.5 | 47.8 | 0.5 |
| Si | 17.5 | 0.1 | 29.0 | 0.1 |

Figure S7: EDX of MPS-stem extract nanoparticles

|  |  |
| --- | --- |
|  |  |
|  |  |



**C-C-O**

**C-O**

**C=H**

**C=C**

**C=C**

**C=O**

**C-H**

**O-H, N-H**

Figure S8: FTIR of FRUIT extract



**Si-O-Si**

**Si-O-Si**

**Si-O-Si**

**Si-O-C**

**Si-O-C**

**C-H**

**C=C**

**C=O**

**C-O**

**C-H**

**O-H**

Figure S9: FTIR of FRUIT extract@SiO2 MPS nanoparticles



| Element | Atomic % | Atomic % Error | Weight % | Weight % Error |
| --- | --- | --- | --- | --- |
| C | 27.4 | 0.4 | 19.5 | 0.3 |
| N | 5.3 | 0.6 | 4.4 | 0.5 |
| O | 50.5 | 0.4 | 48.0 | 0.4 |
| Si | 16.8 | 0.1 | 28.0 | 0.1 |

Figure S10: EDX of MPS-fruit extract nanoparticles

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |



**Si-O-Al**

**Si-O-Ca**

**Zr-O**

**Si-O**

**Zr-OH**

**Si-OH**

**C=C**

**C=O**

**C-H**

**O-H**

Figure S11: FTIR of bioceramic

Figure S12: EDX of bioceramic



**Zr-O**

**Si-O-Al**

**Si-O-Ca**

**Si-O**

**Si-O-Si**

**CH3**

**C-H**

**O-H**

**C=O**

**C=C**

**C=C**

Figure S13: FTIR of ceramic-SiO2-MPS-Fruit extract



Figure S14: EDX of ceramic-SiO2-MPS-Fruit extract



**C-H**

**C=C**

**C=O**

**Si-O-C**

**C-H**

**O-H**

**Si-O-Si**

**Zr-OH**

**Si-O**

**Zr-O**

**Si-O-Si**

**Si-O-Al or Ca**

**Si-O-Si**

Figure S15: FTIR of ceramic-SiO2-MPS-Stem extract



Figure S16: EDX of ceramic-SiO2-MPS-Stem extract

Table S1: FTIR data of silica nanoparticles

| Wavenumber (cm-1) | Functional Group/Vibration |
| --- | --- |
| 3410 | Hydroxyl (–OH) Stretching |
| 1654 | Hydroxyl (–OH) Bending |
| 1095 | Si–O–Si Bond Stretching (Asymmetrical) |
| 956 | Si–O–H Bond Stretching |
| 806 | Si–O–Si Bond Bending (Symmetrical) |
| 470 | Si–O–Si Bond Bending (Asymmetrical) |

Table S2: FTIR information of SiO2-methacryloxypropyltrimethoxysilane

| Wavenumber (cm-1) | Vibrational Mode | Corresponding Functional Group / Bond |
| --- | --- | --- |
| 3433 | Stretching vibration of -OH groups | Surface hydroxyl groups of SiO2 nanoparticles |
| 2954 | Asymmetric stretching vibration of -CH2 groups | Methylene groups in methacryloxypropyltrimethoxysilane |
| 1720 | Stretching vibration of C=O group | Carbonyl group in methacryloxypropyltrimethoxysilane |
| 1630 | Stretching vibration of C=C bond | Carbon-carbon double bond in methacryloxypropyltrimethoxysilane |
| 1459 | Deformation vibration of -CH2 groups | Methylene groups in methacryloxypropyltrimethoxysilane |
| 1435 | Deformation vibration of -CH2 groups | Methylene groups in methacryloxypropyltrimethoxysilane |
| 1099 | Stretching vibration of Si-O-Si bond | Si-O-Si bond in SiO2 nanoparticles |
| 798 | Rocking vibration of Si-O-Si bond | Si-O-Si bond in SiO2 nanoparticles |
| 470 | Bending vibration of Si-O-Si bond | Si-O-Si bond in SiO2 nanoparticles |

Table S3: FTIR data of STEM extract

| Wavenumber (cm-1) | Vibrational Mode | Corresponding Functional Group / Bond |
| --- | --- | --- |
| 3410 | Stretching vibration | exocyclic O-H group |
| 2927 | Stretching vibration | Aliphatic C-H groups |
| 1770 | Stretching vibration | Carbonyl group (C=O) in ester functional group |
| 1639 | Stretching vibration | Carbonyl group (C=O) in ester functional group |
| 1620 | Stretching vibration | Carbonyl group (C=O) in ester functional group |
| 1600 | Stretching vibration | C=C (vinyl group) |
| 1458 | Deformation vibration | Phenyl group |
| 1377 | Bending vibration | Aliphatic C-H groups |
| 1072 | Stretching vibration | C=O bond in ketone functional group |
| 779 | Rocking vibration | Si-O-Si bond in siloxane group |
| 470 | Bending vibration | Si-O-Si bond in siloxane group |

Table S4: FTIR data of SiO2-3-methacryloxypropyltrimethoxysilane-stem extract

| Wavenumber (cm-1) | Vibrational Mode | Corresponding Functional Group / Bond |
| --- | --- | --- |
| 3425 | O-H stretching vibration | Hydroxyl groups in organic molecules |
| 2954 | C-H stretching vibration | Methylene groups in organic molecules |
| 2897 | C-H stretching vibration | Methyl groups in 3-methacryloxypropyltrimethoxysilane |
| 1720 | C=O stretching vibration | Ester group in 3-methacryloxypropyltrimethoxysilane |
| 1635 | C=C stretching vibration | Vinyl group in 3-methacryloxypropyltrimethoxysilane |
| 1465 | Deformation vibration | CH2 group in methylene chain of 3-methacryloxypropyltrimethoxysilane |
| 1435 | Deformation vibration | CH3 group in 3-methacryloxypropyltrimethoxysilane |
| 1408 | Si-O-C stretching vibration | 3-methacryloxypropyltrimethoxysilane |
| 1300 | C-N stretching vibration | Nitrogen-containing organic molecule (1-(N)-hydroxyethyl-9-phenyl-4,5,6,7-tetrahydro[1]benzothieno[2,3-c]pyridine) |
| 1168 | C-O stretching vibration | Ester group in ethyl phthalate |
| 1099 | Si-O stretching vibration | SiO2-3-methacryloxypropyltrimethoxysilane hybrid material |
| 937 | C-H deformation vibration | Methylene groups in organic molecules |
| 813 | C-S stretching vibration | 1-(N)-hydroxyethyl-9-phenyl-4,5,6,7-tetrahydro[1]benzothieno[2,3-c]pyridine |
| 794 | Deformation vibration | Si-O-C bond in SiO2-3-methacryloxypropyltrimethoxysilane hybrid material |
| 690 | Bending vibration | Si-O-Si bond in SiO2-3-methacryloxypropyltrimethoxysilane hybrid material |
| 651 | Bending vibration | Si-O-Si bond in SiO2-3-methacryloxypropyltrimethoxysilane hybrid material |
| 470 | Si-O-Si stretching vibration | SiO2-3-methacryloxypropyltrimethoxysilane hybrid material |

Table S5: FTIR data of fruit extract

| **Compound** | **Vibrational Bands (cm-1)** | **Functional Groups** |
| --- | --- | --- |
| 5,4'-Dimethoxy-2-methylbibenzyl | 2931, 1624, 1404, 1076 | C-H stretching, aromatic ring, C-H bending, C-O |
| 4,7,7-Trimethylbicyclo[3.3.0]octan-2-one | 1728, 2931, 1076 | Carbonyl stretching, C-H stretching, C-O |
| Urea N,N'-dibutyl-N,N'-dimethyl | 3329, 1624, 1404, 2931, 2854, 1728 | N-H stretching, C-N stretching, C-N bending, C-H stretching, C=O |
| Diethyl Phthalate | 1728, 1269, 1145 | Carbonyl stretching, C-O bending, C-C-O bending |
| Linoleic acid | 2921, 1728, 1624, 1404 | C-H stretching, carbonyl stretching, C=C, CH2 bending |
| 2-Propylphenanthro[9,10-d]oxazole | 1624, 1523, 1404 | Aromatic ring, C-H bending |
| Decanedioic acid, bis(2-ethylhexyl) ester | 2931, 1728, 1404 | C-H stretching, carbonyl stretching, C-H bending |
| N-[2-Hydroxyethyl]succinimide | 3329, 1728, 1624, 1404 | N-H/O-H stretching, carbonyl stretching, C-H bending |

Table S6: FTIR data of SiO2-3-methacryloxypropyltrimethoxysilane-fruit extract

| Wavenumber (cm-1) | Vibrational Mode | Corresponding Functional Group / Bond |
| --- | --- | --- |
| 3479 | O-H stretching | Hydrogen-bonded hydroxyl groups |
| 3421 | O-H stretching | Hydroxyl groups |
| 2954 | C-H stretching | Aliphatic C-H bonds |
| 1720 | C=O stretching | Carbonyl groups (esters, ketones, carboxylic acids) |
| 1635 | C=C stretching | Double bonds |
| 1469 | C-H bending | Alkane or alkene groups |
| 1431 | C-H bending | Methylene group |
| 1300 | C-O stretching | Ether groups |
| 1103 | Si-O-C stretching | Siloxane bond |
| 941 | C-H bending | Various organic groups |
| 879 | Si-O-C stretching | Siloxane bond |
| 813 | Si-O-Si stretching | Silicates |
| 794 | Si-O-C stretching | Siloxane bond |
| 690 | Si-O-Si bending | Silicate groups |
| 551 | Si-O-Si stretching | Silicates |
| 466 | Si-O-Si bending | Silicate groups |

Table S7: FTIR data of bioceramic

| **Wavenumber (cm-1)** | **Vibrational Mode** | **Corresponding Functional Group / Bond** |
| --- | --- | --- |
| 3383 | Stretching vibration | O-H (hydroxyl) groups |
| 2924, 2877 | Stretching vibration | C-H (methyl and methylene) groups |
| 1654 | Stretching vibration | Carbonyl group (C=O) |
| 1577 | Stretching vibration | Aromatic C=C bonds |
| 1473 | Deformation vibration | CH3 (methyl) groups |
| 1350 | Bending vibration | C-H bonds in alkane groups |
| 1103 | Stretching vibration | Si-OH (silanol) groups |
| 1064 | Stretching vibration | Zr-OH (zirconium-oxygen-hydrogen) bonds |
| 945 | Stretching vibration | Si-O (silicon-oxygen) bonds |
| 528 | Bending vibration | Si-O-Ca or Si-O-Al bonds |
| 420 | Bending vibration | Zr-O (zirconium-oxygen) bonds |

Table S8: FTIR data of ceramic-SiO2-MPS-Fruit extract

| **Wavenumber (cm-1)** | **Vibrational Mode** | **Corresponding Functional Group / Bond** |
| --- | --- | --- |
| 3394 | O-H stretching | Hydroxyl groups |
| 2904, 2873 | C-H stretching | Methyl and methylene groups |
| 1716 | C=O stretching | Carbonyl groups |
| 1654, 1577 | C=C stretching | Aromatic compounds |
| 1477 | Deformation vibration | CH3 groups (methyl groups) |
| 1350 | Bending vibration | C-H bonds in alkane groups |
| 1099 | Si-OH stretching | Silanol groups and Zirconium hydroxide, possibly Ca-Si-O and Al-Si-O |
| 945 | Si-O stretching | Silicate groups |
| 590 | Bending vibration | Si-O-Ca or Si-O-Al bonds (silicate groups) |

Table S9: FTIR data of ceramic-SiO2-MPS-Stem extract

| **Wavenumber (cm-1)** | **Vibrational Mode** | **Corresponding Functional Group / Bond** |
| --- | --- | --- |
| 3371 | O-H stretching | Hydroxyl groups |
| 2924, 2877 | C-H stretching | Methyl and methylene groups |
| 1716 | C=O stretching | Carbonyl groups |
| 1639 | C=C stretching | Vinyl group in 3-methacryloxypropyltrimethoxysilane |
| 1581 | C=C stretching | Aromatic compounds |
| 1469 | Deformation vibration | CH2 group in 3-methacryloxypropyltrimethoxysilane |
| 1438 | Deformation vibration | CH3 group in 3-methacryloxypropyltrimethoxysilane |
| 1354 | Bending vibration | C-H bonds in alkane groups |
| 1296 | Si-O stretching | Silicon-oxygen bonds (silicate groups) |
| 1246 | Si-O-C stretching | 3-methacryloxypropyltrimethoxysilane |
| 1103 | Si-OH stretching | Silanol groups |
| 1064 | Zr-OH stretching | Zirconium hydroxide, Ca-Si-O, Al-Si-O |
| 941 | Si-O stretching | Silicon-oxygen bonds (silicate groups) |
| 744 | Bending vibration | Si-O-Si bonds in SiO2-3-methacryloxypropyltrimethoxysilane hybrid |
| 528 | Bending vibration | Si-O-Ca or Si-O-Al bonds (silicate groups) |
| 482 | Bending vibration | Si-O-Si bond in SiO2-3-methacryloxypropyltrimethoxysilane hybrid |
| 420 | Bending vibration | Zr-O bending (zirconium-oxygen bonds) |