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Mechanical Properties of Transparent Sodium Phosphosilicate Glass-Ceramics

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1. Background-improve mechanical properties



Mechanical Properties



architectural glass

Hardness



touch-screen devices

Crack initiation resistance

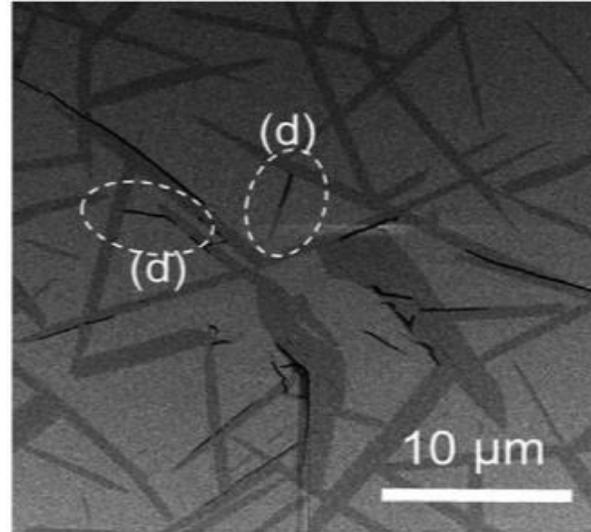
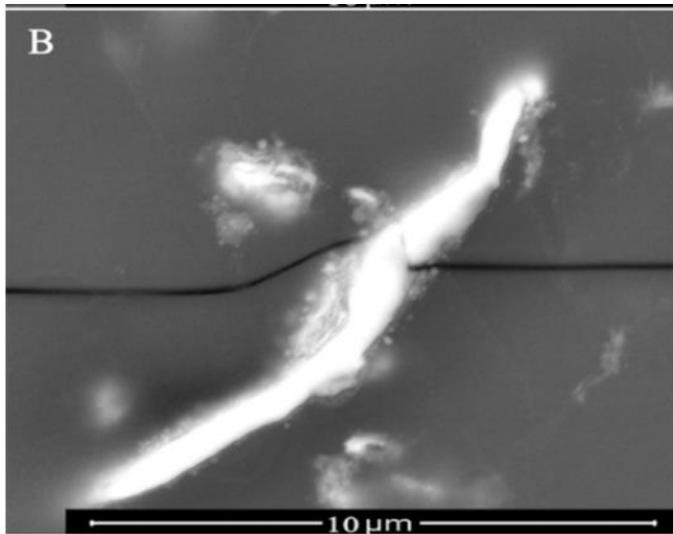
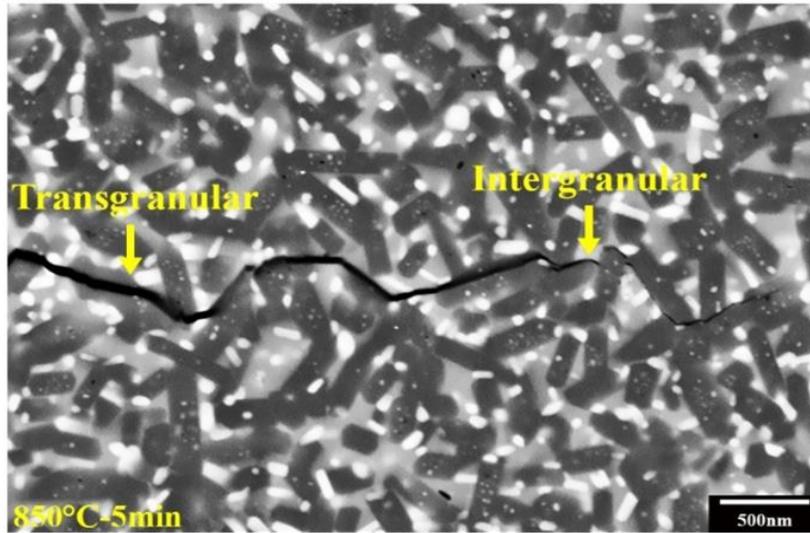


automotive glass

Fracture toughness



1. Background-improve mechanical properties



Crack Bridging



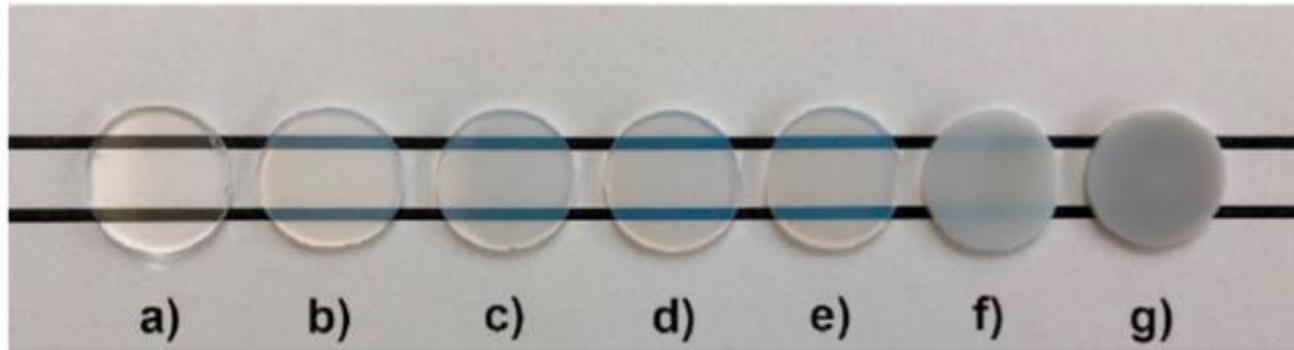
Crack Trapping



Crack Deflection



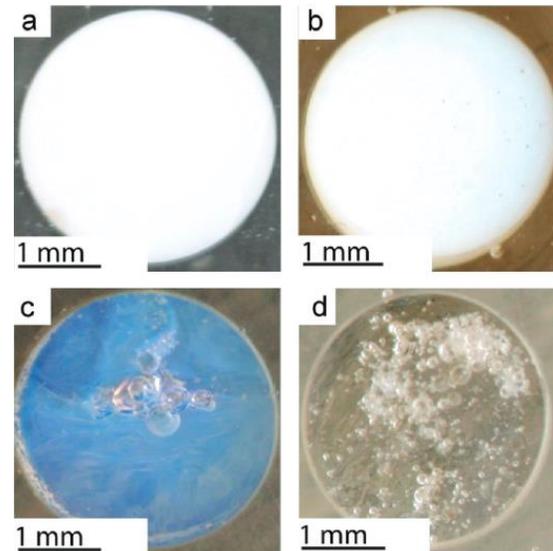
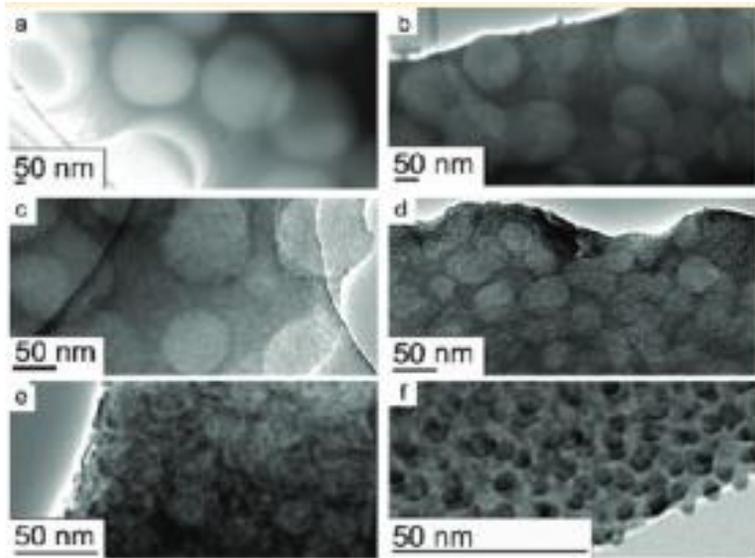
1. Background-improve mechanical properties



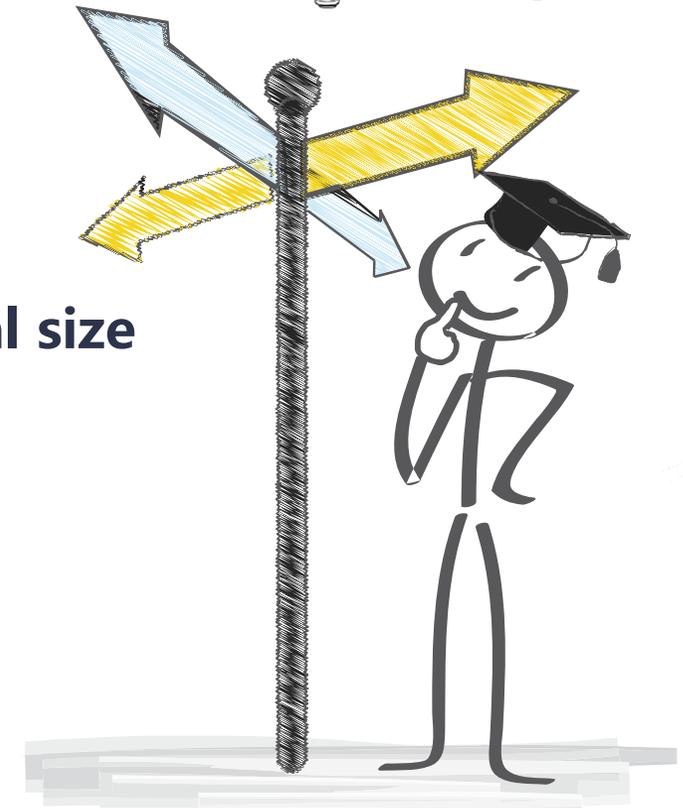
Crystal content



Transparency



Crystal size



Soares V O, Serbena F C, dos Santos Oliveira G, et al. *Ceramics International*, 2021, 47(4): 4707-4714.

Martel L, Allix M, Millot F, et al. *The Journal of Physical Chemistry C*, 2011, 115(39): 18935-18945.



1. Background



Crystal

Content
Size
Shape
Characteristic
.....

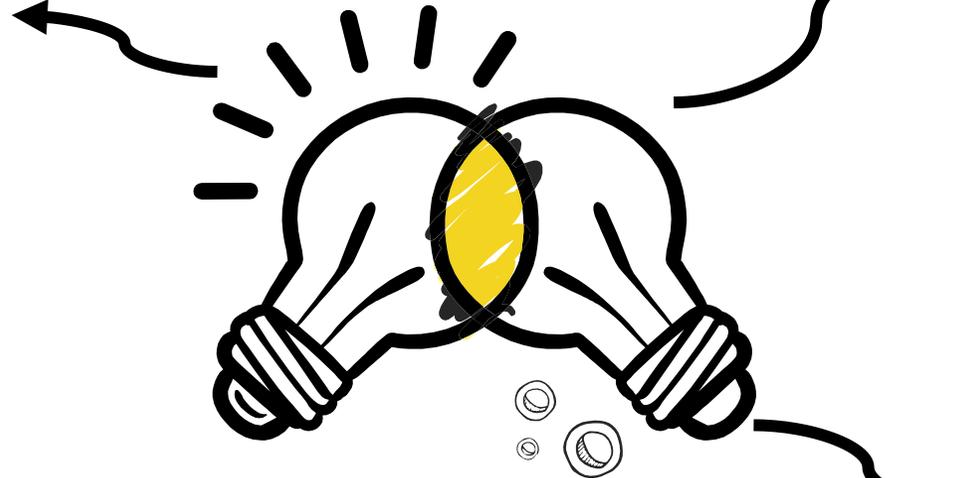


Mechanical Property

Fracture toughness
Crack resistance
Hardness
.....



Transparency



$\text{Na}_2\text{O}-\text{P}_2\text{O}_5-\text{SiO}_2$ ternary system glass



2. Research content

Sample ID	Na ₂ O	SiO ₂	P ₂ O ₅	T _g (K)	Y parameter
NSP-1	45	44	11	537	3.45
NSP-2	50	40	10	492	3.00
NSP-3	50	45	5	705	2.44

Heat treatment

1.05 T_g for 1h

Structure

- ▶ Glass matrix structure → NMR
- ▶ Crystal content → XRD
- ▶ Crystal size → SEM

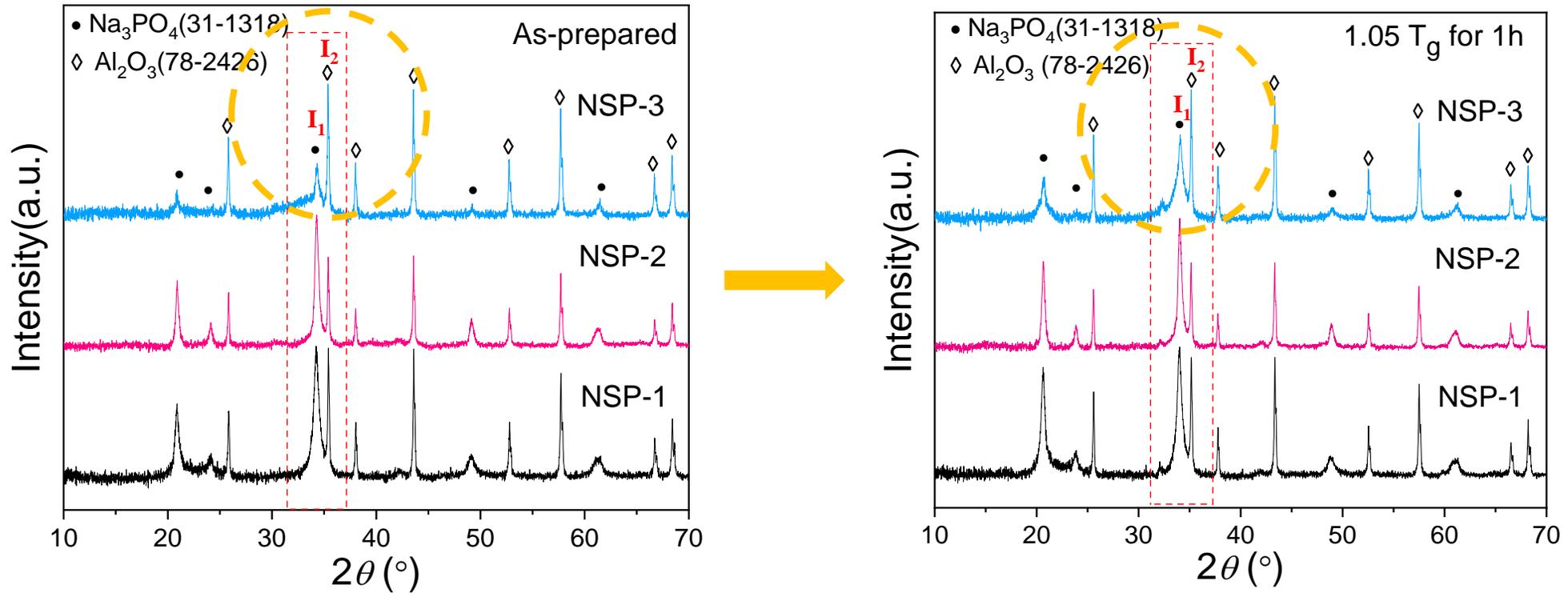
Property

- ▶ Transparency → UV-VIS
- ▶ Fracture toughness → SEPB
- ▶ Crack resistance → Indenter



3. Structure part1: crystal characterization

❖ Al_2O_3 as reference sample

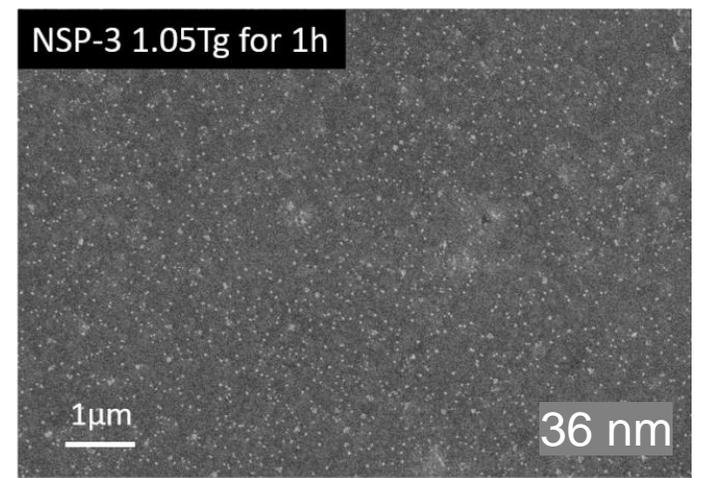
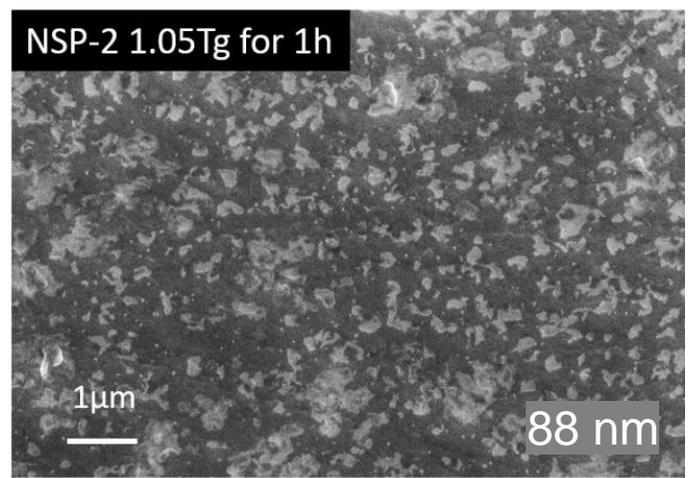
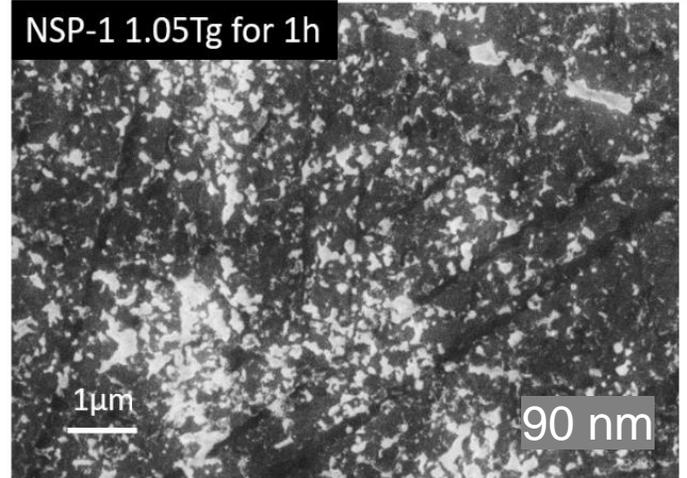
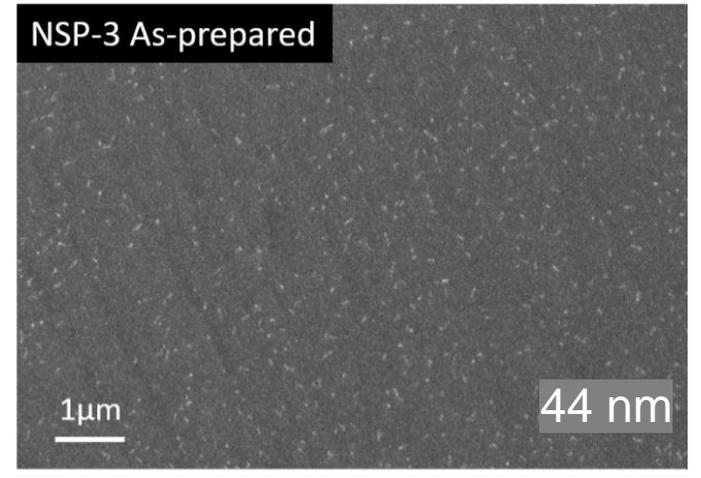
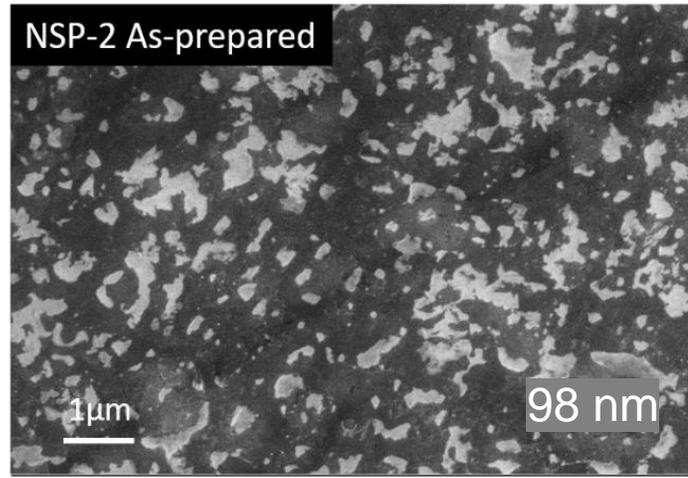
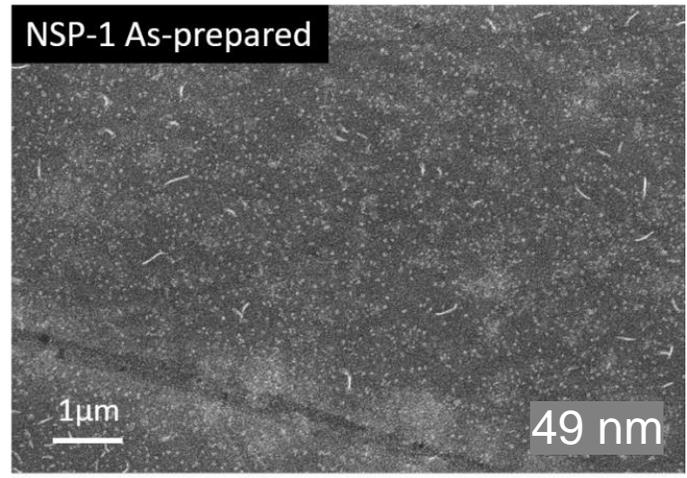


- ▶ The XRD shows there is one kind of crystal: Na_3PO_4 formed after the synthesis procedure.
- ▶ The content of Na_3PO_4 crystal increased in each sample after heat treatment



3. Structure part1: crystal characterization

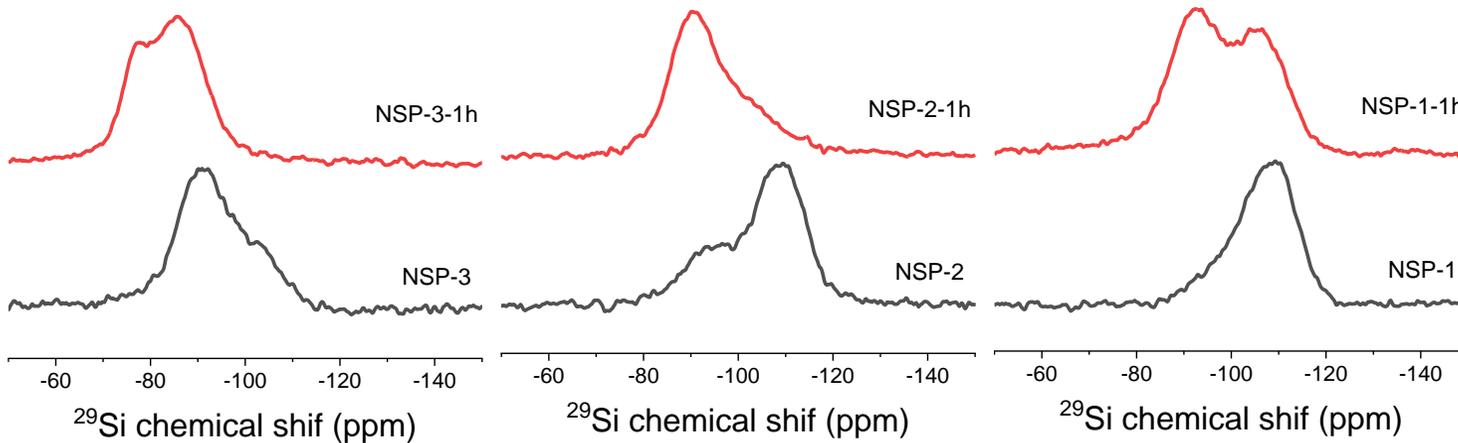
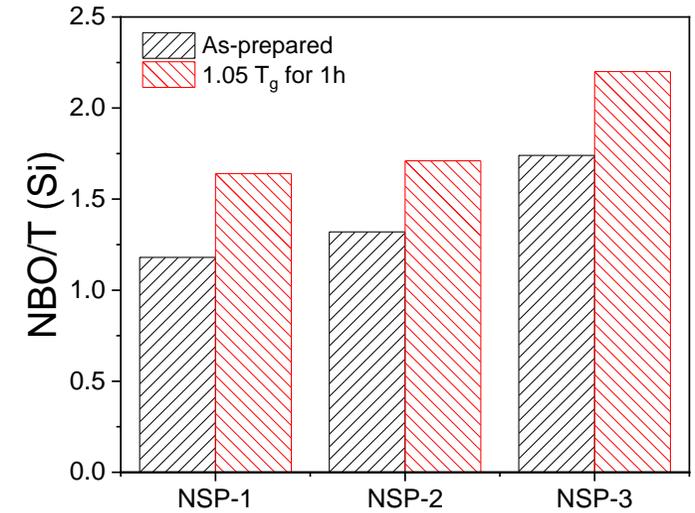
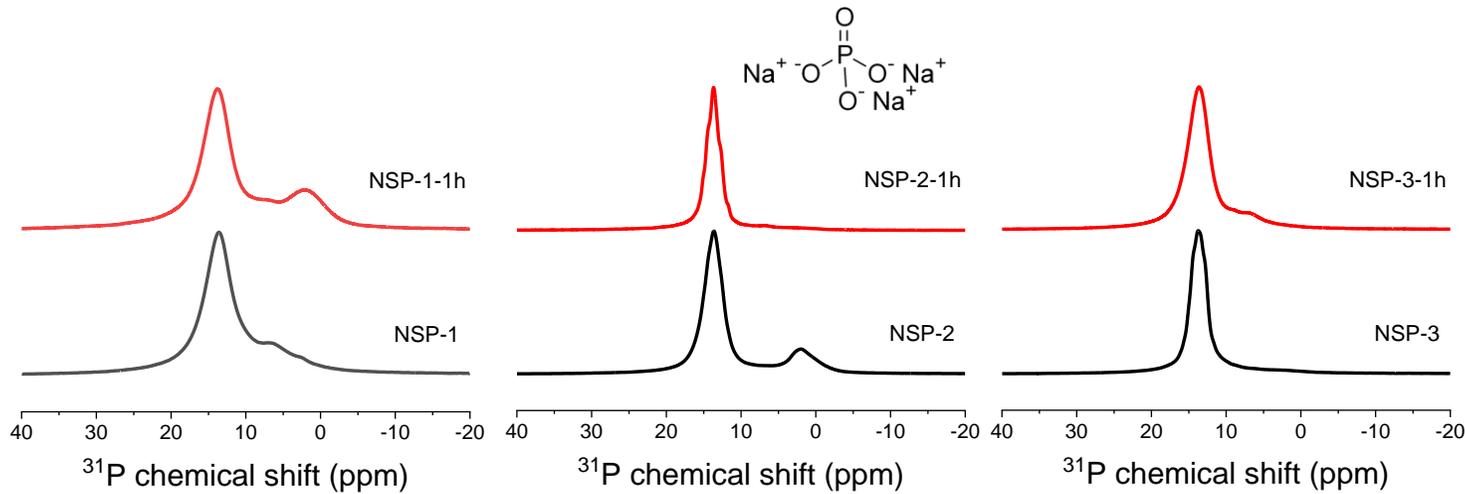
H
E
A
T



• The crystal size in NSP-1 increased significantly after heat treatment.



3. Structure part2: glass matrix network characterization



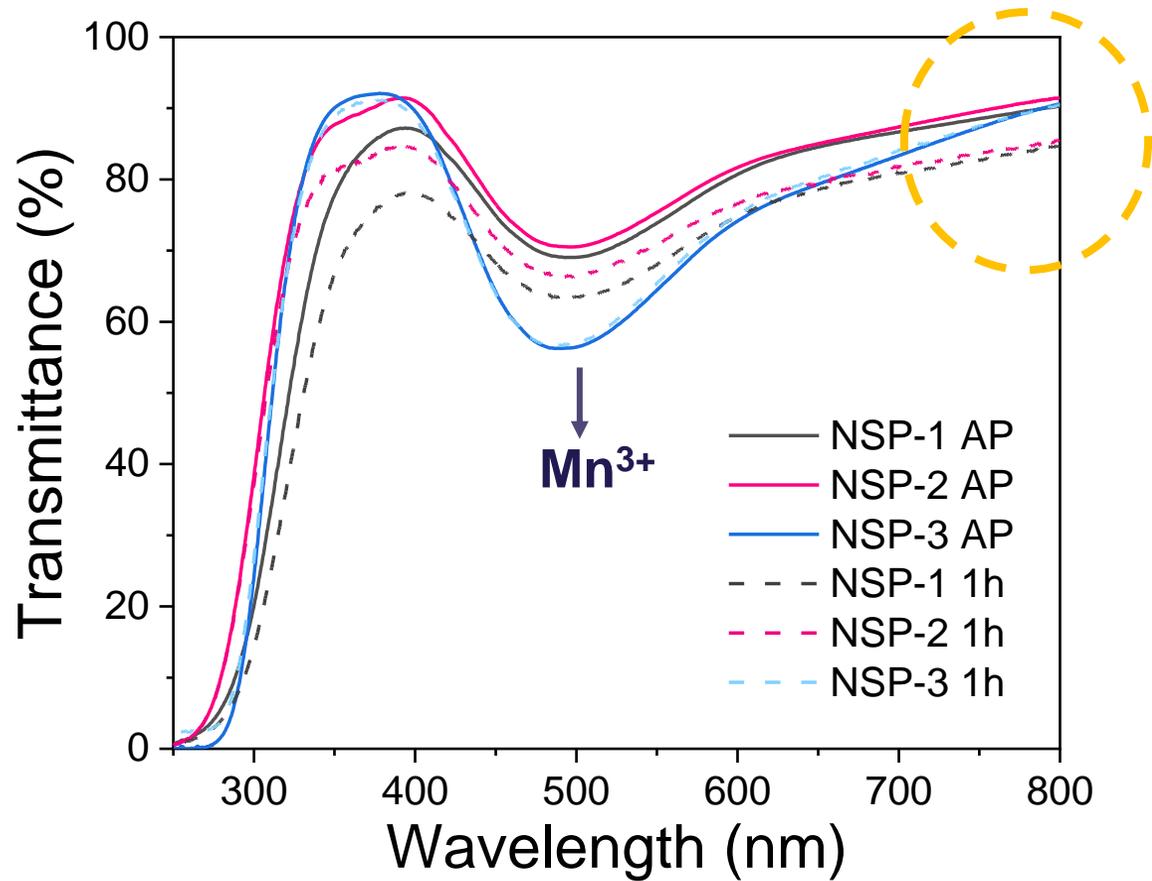
$$NBO/T_{(^{29}\text{SiNMR})} = [\sum(\%Q_{\text{Si}}^n)_{\text{NMR}}(NBO/T)_n]/100$$

- From the ³¹P NMR spectra, the P present mainly as Na₃PO₄ phase or units in all samples
- From the ²⁹Si NMR spectra, NBO/T of heat-treated glass-ceramics increased compared to the as-prepared samples

Glass matrix (Si-rich) network connectivity



3. Property-Transmittance



Sample ID	Crystal content	Crystal size
NSP-1	↑	↑
NSP-2	↑	-
NSP-3	↑	-

● Refractive index:

Na₃PO₄ ~1.59

Phosphosilicate glass ~1.5

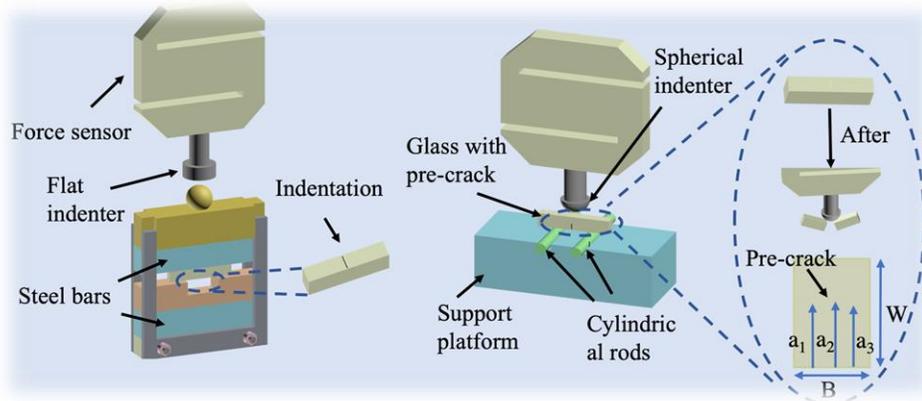


Similar refractive index and nano-scale crystal contribute to the high transmittance

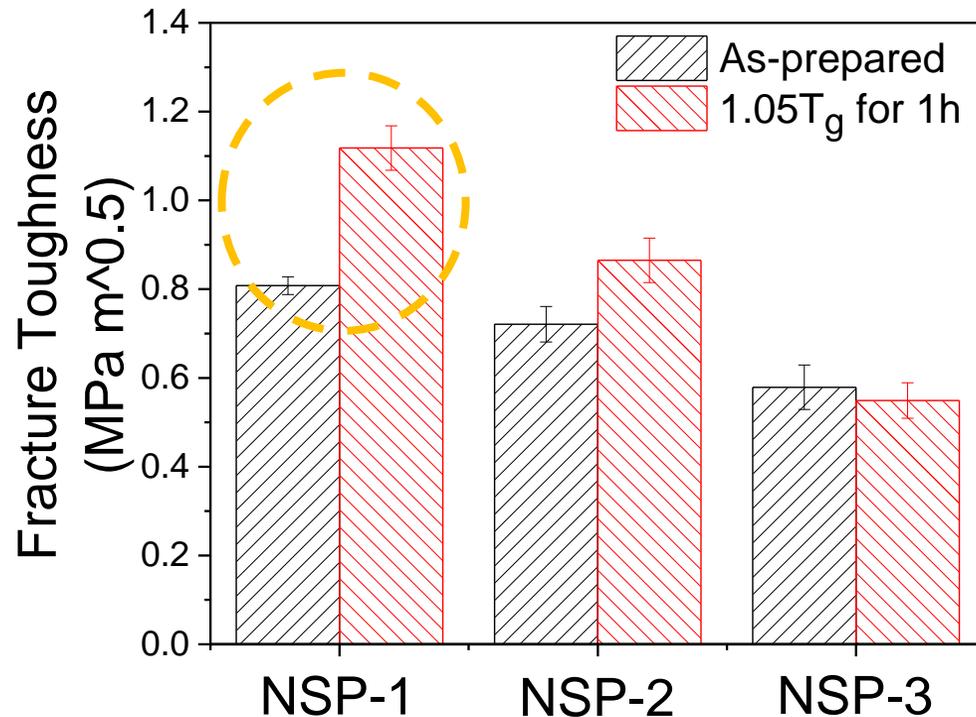
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3. Property- Mechanical properties: fracture toughness P10



Sample ID	Crystal content	Crystal size	Glass matrix connectivity
NSP-1	↑	↑	↓
NSP-2	↑	-	↓
NSP-3	↑	-	↓

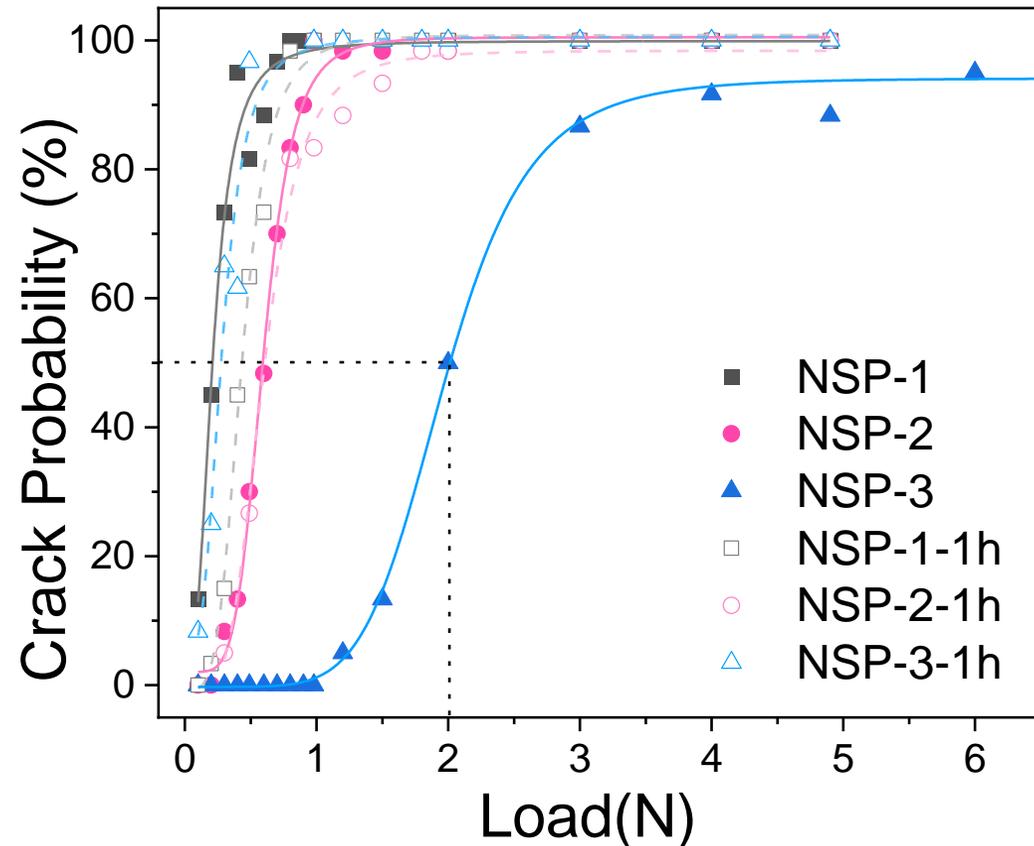


- Crystal content ↑, fracture toughness ↑
- Crystal size ↑, fracture toughness ↑
- Glass network connectivity ↓, fracture toughness ↓

Crystal size has a more significant effect on fracture toughness



3. Property- Mechanical properties: crack resistance



Sample ID	Crystal content	Crystal size	Glass matrix connectivity
NSP-1	↑	↑	↓
NSP-2	↑	-	↓
NSP-3	↑	-	↓

- Crystal content ↑, crack resistance ↓
- Crystal size ↑, crack resistance no change
- Glass network connectivity ↓, crack resistance ↑

Crystal content has a more significant effect on crack resistance





4. Conclusion

- The influence of glass matrix and crystal on mechanical properties before and after heat treatment is a competitive relationship, and the influence of crystal on mechanical properties is more significant.
- The increase in **fracture toughness** is mainly caused by the increase in the content of **large-sized crystals**.
- The decrease of **crack resistance** is mainly determined by the increase of **crystal content**.

Future: A transparent glass-ceramics with high fracture toughness and crack resistance



Thanks

Q&A



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