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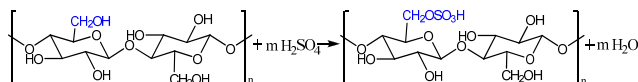
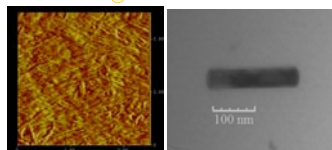
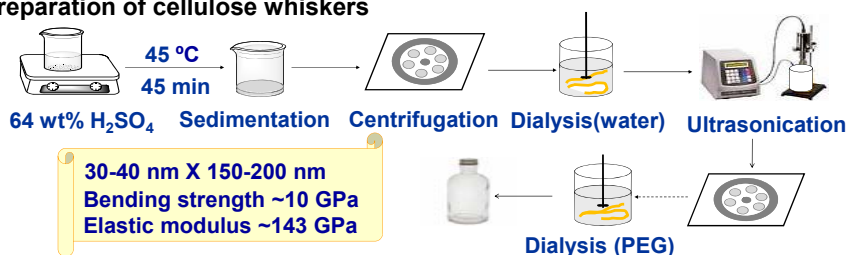
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## Background and Purposes

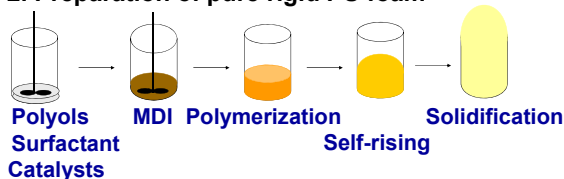
Cellulose whisker, the acid hydrolyzed product mainly from wood fibers, is a promising new generation of nano filler. It not only inherits the merits of cellulose, which are the wide availability, low cost, renewability, and biodegradability, but also provide superior mechanical properties thanks to its high crystallinity and aspect ratio. Several natural and synthetic polymer composites reinforced with cellulose whisker have already been investigated. In the present study, polyurethane (PU) was chosen as the polymer matrix due to its wide applications. Rigid PU foam filled with up to 1 wt% of cellulose whiskers were prepared by a one shot method. The density and cell size of nanocomposites were measured, the chemical structure was characterized by FT IR, and the mechanical and thermal properties were also studied.

## Experimental

### 1. Preparation of cellulose whiskers

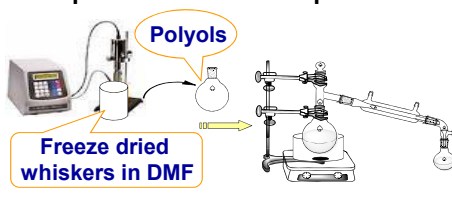


### 2. Preparation of pure rigid PU foam



	M <sub>n</sub>	F	I <sub>OH</sub>	NCO
Sucrose polyol	690	4.4	156	-
Glycerol polyol	1008	3	246	-
MDI	340	2.7	-	31.1%

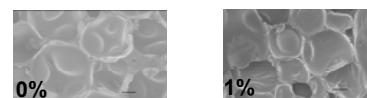
### 3. Preparation of nanocomposite



Sucrose based polyol	27.90
Glycerol based polyol	16.70
Polymeric MDI	40.60
Dimethylcyclohexylamine	1.30
1-methyl-4-(2-dimethylaminoethyl) piperazine	0.90
n-pentane	11.20
Silicone surfactant	1.40

## Results and Discussions

The closed cells had a homogeneous dispersion in nanocomposites and the cell size was around 350 μm and decreased slightly with increasing whiskers content.



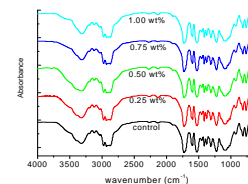
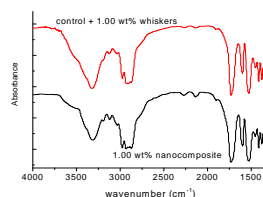
Whiskers	0	0.25	0.50	0.75	1.00
Density (kg/m <sup>3</sup> )	537.6	414.4	461.6	535.9	820.1
	± 5.1	± 5.1	± 5.6	± 3.3	± 5.7

Presence of urethane linkage, ether linkage, and methyl groups

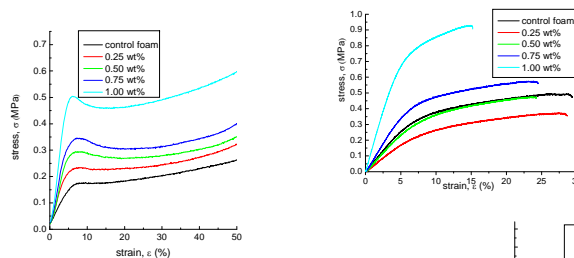
--- The dominant structure of PU has not been changed

Shift of carbonyl stretching from 1732 to 1736 cm<sup>-1</sup>

--- H bonding between NH and C=O has been disturbed

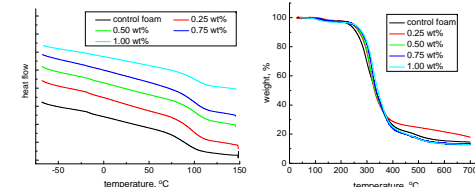


Peak intensity reduction at ~3500 cm<sup>-1</sup> which is due to OH and NH stretch vibrations---crosslinking between cellulose hydroxyl groups and isocyanate groups



Whisker	Modulus	Strength
0.75%	36.8% ↑	13.8% ↑
1.00%	227.2% ↑	99.2% ↑

Whisker	Modulus	Strength
0.25%	66.6% ↑	29.0% ↑
0.50%	118.5% ↑	131.0% ↑
0.75%	179.9% ↑	143.4% ↑
1.00%	210.0% ↑	269.7% ↑



Whisker (%)	0	0.25	0.50	0.75	1.00
T <sub>g</sub> (°C)	88	94	100	97	97
T <sub>d</sub> (°C)	333	329	331	336	343

## Conclusions

Rigid PU foams reinforced with up to 1 wt% of cellulose whiskers were prepared with a homogeneous cell dispersion and uniform cell size. The intrinsic high strength and aspect ratio of whiskers, additional H-bonding and crosslinking between whiskes and PU, and the effect of whiskers acting as nucleation sites resulted in the improved mechanical and thermal properties of the nanocomposites. The reinforcement effect was more significant at higher filler contents.

## Acknowledgments

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